GCDAMP External Review of FY2021-23 Triennial Plan Draft of May 19, 2020

David P. Braun, Ph.D., and Robert S. Unnasch, Ph.D., Sound Science LLC, June 15, 2020

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Introduction

The Glen Canyon Dam Adaptive Management Program (GCDAMP) Science Advisor has facilitated an external expert review of the Grand Canyon Monitoring and Research Center (GCMRC) projects proposed for the GCDAMP Triennial Budget and Work Plan (TWP) for FY 2021-2023, draft of May 19, 2020. The review also addresses the proposal for Bureau of Reclamation (Reclamation) Projects C.7 and C.8, draft of April 2, 2020.

The external review panel consists of six experts selected based on their well-established, demonstrated expertise and ability to provide independent, neutral-party reviews, with no existing or potential conflicts of interest:

- Professor Ellen Wohl, Department of Geosciences, Colorado State University, reviewed GCMRC Project A, Streamflow, Water Quality, and Sediment Transport and Budgeting, and Project B, Sandbar and Sediment Storage Monitoring and Research.

- Professor Mark Dixon, Department of Biology, University of South Dakota, reviewed GCMRC Project C, Riparian Vegetation Monitoring and Research, Project D, Effects of Dam Operations and Vegetation Management on Archaeological Sites, and Reclamation Projects C.7 and C.8, Experimental Vegetation Treatment. The review of C.7 and C.8 addresses not only the short proposal in the draft Triennial Work Plan but also a separate document prepared by the National Park Service in April 2020, "*Long Term Experimental and Management Plan Experimental Vegetation Project Plan for the Implementation of the Vegetation Environmental Commitments from the LTEMP ROD in Glen Canyon National Recreation Area and Grand Canyon National Park below Glen Canyon Dam*." This separate document presents a detailed plan for the experimental vegetation treatment program.

- Professor Mark Sweeney, Department of Sustainability & Environment, University of South Dakota, also reviewed GCMRC Project D, Effects of Dam Operations and Vegetation Management on Archaeological Sites, from a geological perspective.

- Dr. Emma Rosi, Aquatic Ecologist, Cary Institute of Ecosystem Studies, reviewed GCMRC Project E, Controls on Ecosystem Productivity: Nutrients, Flow, and Temperature, and Project F, Aquatic Invertebrate Ecology.

- Professor Julian Olden, School of Aquatic and Fishery Sciences, University of Washington, reviewed Project G, Humpback Chub Population Dynamics, Project H, Humpback Salmonid Research and Monitoring Project, and Project I, Warm-water Native and Non-Native Fish Monitoring and Research.

- Professor Bonnie Colby, Department of Agricultural and Resource Economics, University of Arizona, reviewed Project J, Socioeconomic Research, and Project N, Economic Impacts of Electrical Production at Glen Canyon Dam.

Additionally, Dr. Robert Unnasch of Sound Science LLC reviewed Project K, Geospatial Science, Data Management and Technology Project, and Project L, Overflight Remote Sensing in Support of Long-Term Monitoring and LTEMP. The review does not address Project M, GCMRC Administration.

The report section on each project, below, consists of a summary prepared by the Science Advisor followed by the full text of the external review itself, with four exceptions: The external reviews for Projects A, B, K, and L are brief and do not receive separate summaries. Each external review is presented verbatim.

This document begins with background information on the purposes of the review and the processes through which the Science Advisor identified and instructed the external reviewers. The individual project reviews follow these two initial sections. Readers can use the Table of Contents to jump straight to the individual reviews. Appendices contain the full set of reviewer instructions and copies of the Curriculum Vitae of the reviewers.

Background

The 2016 Glen Canyon Dam Long-Term Experimental and Management Plan (LTEMP) and the December 2016, Secretary of the Interior Record of Decision (ROD) on the LTEMP Environmental Impact Statement establish goals for eleven priority resources for the GCDAMP. Further, the LTEMP and ROD identify numerous lines of evidence needed to (a) guide decisions on when twelve different types of experimental dam operations and non-flow management actions should take place, (b) guide decisions on where some non-flow management actions should be carried out, and (c) make sense of the data collected during experiments and management actions, particularly concerning their effects on the eleven priority resources.

The LTEMP priority resources are as follows (in the order they appear in the ROD):

1. *Archaeological and Cultural Resources.* Maintain the integrity of potentially affected NRHP (National Register of Historic Places)-eligible or listed historic properties in place, where possible, with preservation methods employed on a site-specific basis.

2. *Natural Processes.* Restore, to the extent practicable, ecological patterns and processes (including aquatic nutrient cycles and food web dynamics) within their range of natural variability, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems.

3. *Humpback Chub.* Meet humpback chub recovery goals, including maintaining a self-sustaining population, spawning habitat, and aggregations in the Colorado River and its tributaries below the Glen Canyon Dam.

4. *Hydropower and Energy.* Maintain or increase Glen Canyon Dam electric energy generation, load following capability, and ramp rate capability, and minimize emissions and costs to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources.

5. *Other Native Fish*. Maintain self-sustaining native fish species populations and their habitats in their natural ranges on the Colorado River and its tributaries.

6. *Recreational Experience*. Maintain and improve the quality of recreational experiences for the users of the Colorado River Ecosystem. Recreation includes, but is not limited to, flatwater and whitewater boating, river corridor camping, and angling in Glen Canyon.

7. *Sediment*. Increase and retain fine sediment volume, area, and distribution in the Glen, Marble, and Grand Canyon reaches above the elevation of the average base flow for ecological, cultural, and recreational purposes.

8. *Tribal Resources*. Maintain the diverse values and resources of traditionally associated Tribes along the Colorado River corridor through Glen, Marble, and Grand Canyons.

9. *Rainbow Trout Fishery*. Achieve a healthy high-quality recreational rainbow trout fishery in Glen Canyon and reduce or eliminate downstream trout migration consistent with NPS fish management and Endangered Species Act compliance.

10. *Nonnative Invasive Species*. Minimize or reduce the presence and expansion of aquatic nonnative invasive species.

11. *Riparian Vegetation*. Maintain native vegetation and wildlife habitat, in various stages of maturity, such that they are diverse, healthy, productive, self-sustaining, and ecologically appropriate.

The LTEMP calls for the adaptive management of these resources through eleven types of experimental and management actions (in alphabetical order)[1]:

- Fall high-flow experiments consisting of dam releases ≤ 45,000 cfs in October or November with > 96-hr duration

- Fall high-flow experiments consisting of dam releases ≤ 45,000 cfs in October or November with < 96-hr duration

- Humpback chub translocation

- Larval humpback chub head-start program

- Macroinvertebrate production flows

- Mechanical removal of invasive fish species (since expanded to a wider array of methods for controlling invasive fish species)

- Mechanical removal of rainbow trout from the Little Colorado River reach (the Colorado River immediately up- and downstream from the Little Colorado River inflow)

[1] The LTEMP also includes provisions for summer low-flow experiments but only during the second decade of implementation.

- Spring high-flow experiments consisting of dam releases ≤ 45,000 cfs in April, May, or June
- Spring high-flow experiments consisting of dam releases ≤ 45,000 cfs in March or April
- Riparian vegetation restoration
- Trout management flows consisting of dam releases designed to control trout spawning success

Monitoring and research carried under the LTEMP and ROD address three broad sets of questions crucial to the adaptive management of the eleven priority resources:

- Status and Trend: How should the condition of each resource be tracked; how does this condition vary over time and space; how closely do conditions approach management objectives; and are there trends toward or away from management objectives?
- LTEMP Experimental and Management Actions: How do the LTEMP experimental and management actions affect resource status and trends; how strong (in magnitude and predictability) are these effects; how well understood are the reasons for these effects; and how do interactions among the experimental and management actions affect their outcomes?
- Drivers and Constraints: What other factors, including environmental factors and antecedent conditions, human actions, and routine dam operations also affect resource status and trends and the outcomes of the experimental and management actions; and how strong are these effects?

Reviewer Selection and Instructions

The GCDAMP Triennial Budget and Work Plan for FY 2021–2023 is the second work plan implemented under the LTEMP, its ROD, and the January, 2017, "Scientific Monitoring Plan in Support of the Selected Alternative of the Glen Canyon Dam Long-Term Experimental and Management Plan," prepared by the GCMRC. Reclamation, in consultation with the GCMRC, arranged for the Science Advisor to carry out an external review of the draft Triennial Work Plan for FY 2021–2023, specifically the second draft, distributed on May 19, 2020.

The review focuses on the proposals for thirteen GCMRC projects, as follows:

- Project A: Streamflow, Water Quality, and Sediment Transport and Budgeting
- Project B: Sandbar and Sediment Storage Monitoring and Research
- Project C: Riparian Vegetation Monitoring and Research
- Project D: Effects of Dam Operations and Vegetation Management on Archaeological Sites

- Project E. Controls on Ecosystem Productivity: Nutrients, Flow, and Temperature
- Project F: Aquatic Invertebrate Ecology
- Project G: Humpback Chub Population Dynamics
- Project H: Salmonid Research and Monitoring Project
- Project I: Warm-water Native and Non-Native Fish Monitoring and Research
- Project J: Socioeconomic Research
- Project K: Geospatial Science, Data Management and Technology Project
- Project L: Overflight Remote Sensing in Support of Long-Term Monitoring and LTEMP
- Project N: Economic Impacts of Electrical Production at Glen Canyon Dam

As noted above, the review does not address Project M, GCMRC Administration. On the other hand, Reclamation arranged for the review to include Reclamation Projects C.7 and C.8, Experimental Vegetation Treatment, which are closely linked to GCMRC Project C.

The Science Advisor prepared a list of potential reviewers for each proposed Project based on professional knowledge, literature searches, a list prepared for the GCDAMP in June 2018, and suggestions from Reclamation and the GCMRC. One reviewer also recommended another individual for consideration. Reclamation and the GCMRC reviewed the list of all potential reviewers to identify any with existing or potential conflicts of interest. The Science Advisor then ranked the final, approved master list and recruited reviewers for all projects. The criteria for identifying and ranking the potential reviewers included well-established, demonstrated expertise in one or a combination of the topics addressed by the proposed projects, and an ability to provide an independent, neutral-party review with no existing or potential conflicts of interest.

The Science Advisor provided each reviewer with instructions in the form of a "Prospectus," a copy of which is included as Appendix I to this document. In addition to reviewing the technical details of each proposal, each reviewer was asked to look at (a) the clarity and scientific quality of the proposal consistent with the goals established by the 2016 LTEMP Record of Decision and the need to assess resource status and trends, the effects of experimental and management actions, and potential other drivers and constraints; (b) integration with other projects proposed under the Triennial Work Plan; (c) the feasibility of accomplishing the stated three-year goals and elements of each project; and (d) contributions to the adaptive management of the resources and the experimental and management actions prioritized in the 2016 ROD and in subsequent evolving plans for controlling invasive species in the Colorado River ecosystem. Each reviewer also signed a form declaring that they have no conflicts of interest that might affect their review. This form follows standard declaration language used by the U.S. Geological Survey.

Project A: Streamflow, Water Quality, and Sediment Transport and Budgeting

Science Advisor Summary: (none needed)

External Review (Dr. Ellen Wohl):

This project builds on existing work to understand the sources, transport, and deposition of sediment within the Colorado River ecosystem (CRe). The investigation of basic sediment dynamics, and the application of the resulting knowledge, within the CRe represent an internationally recognized effort to quantify a large-scale river sediment budget. I have been following this work for nearly two decades and the quantitative rigor, attention to detail, and conceptual framework developed in the course of the research are very impressive. The work plan outlined for FY 2021-23 represents a logical extension of existing work. The work plan carefully lays out what has been learned from past investigations, articulates the key management questions that remain, and develops a framework for answering these remaining questions. I see no sources of weakness or grounds for criticism in this work plan. On the contrary, it is remarkably well conceived and thorough and is very likely to address the relevant questions. The team undertaking this work has a stellar record of accomplishment, as detailed in the peer-reviewed scientific journal articles summarizing their work and in the application of their understanding of sediment dynamics to the design of high-flow experiments.

In summary, the science questions posed in this project are appropriate and relevant to assessing resource status and trends and the effects of experimental and management actions. The project is well integrated with other project proposed under the Triennial Work Plan. The stated 3-year goals and elements are highly feasible and the contributions of the project are central to the adaptive management of the resources and the experimental and management actions prioritized in the 2016 LTEMP Record of Decision.

Project B: Sandbar and Sediment Storage Monitoring and Research

Science Advisor Summary: (none needed)

External Review (Dr. Ellen Wohl):

As in the case of Project A, this project builds on decades of prior work to continue to enhance understanding of sediment dynamics and hydraulics at the smaller spatial scales that influence the size and persistence of individual sandbars in the CRe. The team undertaking this work pioneered some of the basic methods of investigation that have been used to monitor sandbars, including repeat photography and repeat surveys. Sandbars are the physical features that reflect interactions among sediment supply (Project A) and stream flow through time. Sandbars also create the habitat for diverse riparian and aquatic organisms and thus represent the physical manifestation of whether high-flow experiments have the desired effects on river-corridor morphology. Previous work indicates that the response of sandbars to fluctuations in water and sediment through time are remarkably difficult to predict, which means that continued monitoring of sandbar responses to high-flow experiments is necessary.

In summary, the science questions posed in this project are appropriate and relevant to assessing resource status and trends and the effects of experimental and management actions. The project is well integrated with other project proposed under the Triennial Work Plan. The stated 3-year goals and elements are highly feasible and the contributions of the project are central to the adaptive management of the resources and the experimental and management actions prioritized in the 2016 LTEMP Record of Decision.

Project C: Riparian Vegetation Monitoring and Research

Science Advisor Summary:

> Dr. Dixon finds the proposal overall very well thought out, with a strong conceptual foundation and excellent integration of its parts. He applauds the hierarchical Bayesian modeling framework to integrate monitoring data, mechanistic experiments, studies of other regional rivers, and broad-scale hydro-climatic and species distributional data. He expects that these will help attain the goal of predicting vegetation responses to flows and management under a wider range of conditions than have been sampled recently in the CRe. In addition, he expects that the multiple data sources and predictive models will help inform the non-flow vegetation plans and actions, the results of which can be integrated into the knowledge base as well.
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> At the same time, he notes that the proposal makes little mention of historical, current, or future remote sensing methods or products that could help support the modeling and guide monitoring. He also notes that the proposal makes little mention of plant species age structure and demography (e.g., recruitment niches): considerations of recruitment niches and plant demography should be included in analyses of monitoring data, the meta-analysis of regional data, and construction of the hierarchical Bayesian models. He notes a lack of discussion of groundwater dynamics being an important influence on riparian vegetation, even though this has been documented in many studies in the Southwest. Finally, he notes that the proposal makes little mention of how the proposed vegetation work relates to the LTEMP experimental flows. His review then provides detailed comments on each section of the proposal, including each Project Element and the Budget. These detailed comments include several specific questions about (a) information that should be included or might be helpful to include in the proposal, and (b) underlying assumptions and methods.

External Review (Dr. Mark Dixon):

This work plan is very well thought out, with a strong conceptual foundation and excellent integration of its parts. I like the use of a hierarchical Bayesian modeling framework to integrate monitoring data, mechanistic experiments, studies of other regional rivers, and broad-scale hydro-climatic and species distributional data. Together, these will help attain the goal of predicting vegetation responses to flows and management under a wider range of conditions than have been sampled recently in the CRe. In addition, the multiple data sources and predictive models should be useful for informing the non-flow vegetation plans and actions, the results of which can be integrated into the knowledge base as well.

A few possible data sources received little mention in the proposed TWP. For instance, there was little mention of historical, current, or future remote sensing methods or products. In chapter L of the report, it indicates that a fine-resolution mapping mission has been proposed for May 2021. Will data generated from this be incorporated into the Bayesian models? How is data collection from the remote sensing project being linked with the semi-annual vegetation monitoring? Also, in terms of extending the range of conditions under which CRe riparian vegetation has been studied, could historical mapping, repeat photography or other historical data (e.g., flow and climate data) from before or soon after dam construction be used to see how vegetation responds to a wider range of flow conditions? I suspect, though, that these sorts of data were used extensively in past work plans, in construction of the State-and-Transition models, and in development of the original LTEMP program. For the current TWP, however, it may be worth considering how remote sensing products could be used to complement field monitoring (and vice versa) and inform construction of the models, particularly since a new mission is planned for May 2021.

I also noticed that there was not much mention of plant species age structure and demography (e.g., recruitment niches). The LTEMP talks about maintaining native vegetation "in various stages of maturity" and that is "self-sustaining." Plant physiological performance will be very important for influencing future vegetation change, but vegetation response must also be mediated by population and community processes, including propagule dispersal, establishment, growth, and successional dynamics. Considerations of recruitment niches and plant demography should be included in analysis of monitoring data, the meta-analysis of regional data, and in construction of the hierarchical Bayesian models. I can see why this might be deemphasized in terms of vegetation restoration (C4), as the methods are explicitly referred to as "non-flow" alternatives, involving vegetation removal and planting, vs. natural regeneration. But again, I suspect that plant demographic responses have already been considered in past work, particularly in the State-and-Transition models.

Perhaps this is beyond the thematic and geographic scope of this project, but the Glen Canyon AMP might also want to consider the effects of reservoir dynamics and sedimentation at the river-reservoir interface on riparian vegetation response and associated wildlife habitat. On the Missouri River (Johnson 2002, Volke et al. 2015, 2019) and perhaps in portions of the Colorado River-reservoir system (C. Lott, personal communication) sedimentation at the river-reservoir interface can lead to creation of deltaic landforms that are colonized by wetland or riparian vegetation. These effects can be even greater during dry periods when reservoir levels decline, allowing spread of riparian vegetation along the lake shore. Riparian habitat formed at these interfaces may help to mitigate some of the losses of riparian habitat that may occur elsewhere in a regulated river system and perhaps may be valuable for riparian wildlife species (e.g., Southwestern Willow Flycatcher, Yuma Ridgway's Rail). Both field work (vegetation, fish, birds, etc.) and remote sensing could be useful for mapping and evaluating the potential ecological value of these novel ecosystems. With prospects of climate change and increasing demands on the reservoirs, a more integrated understanding of reservoir dynamics and its influence on riparian habitats could be useful for conservation.

Finally, I did not see much linkage of the proposed vegetation work with the LTEMP experimental flows. The chapter mentions high flows and states that they are mostly responsible

for changing depth to water table due to sand deposition, rather than more direct effects on plants. However, the descriptions in the modeling section (C3) suggests that models will be used to help predict plant responses to experimental flows. Perhaps more formal linkage has occurred in past work and is not a priority area for new studies right now.

Below are some comments and questions about sections of chapter C:

3. Hypotheses and Science Questions

For C4, can we also gain understanding about riparian vegetation constraints from the outcomes of management? Can management actions be treated as experiments that help generate new knowledge?

4. Background

It is surprising that the influence of daily flow fluctuations and base flows on riparian vegetation has not been previously evaluated (p. 64), given their demonstrated importance in other systems and likely influence in the CRe. The proposed experiments (C2) will provide very valuable findings in this regard. I like the conceptual framework and use of physiological and morphological measures of plant performance in these experiments. These sorts of experiments also have great promise for informing non-flow vegetation management actions.

I am not clear on what the macroinvertebrate production flows are (p. 64) and why they would be particularly harmful for obligate riparian species.

I did not see much discussion of groundwater dynamics being an important influence on riparian vegetation, even though this has been documented in many studies in the Southwest. In the CRe is this moot because groundwater levels are mostly a function of daily river flows?

5. Proposed Work

Project Element C.1. Ground-based Riparian Vegetation Monitoring

This section is solid, but without much detail on specifics of sampling. For example, geomorphic features are being used to stratify sampling and how is sampling being stratified across a hydrologic gradient? Details are provided, however, in the published protocol by Palmquist et al. (2018b) that is provided via a link on p. 67. However, given that these protocols are probably well-known to LTEMP participants, and this component of the FY21-23 work plan is mostly a continuation of past monitoring, I can understand why some details of the sampling have been left out. The main new products are the proposed analyses of the individual and joint influences of flows and climatic conditions on species cover and distributions.

Minor point: it would be good to italicize and capitalize the titles of the LTEMP goals when they are mentioned (as was done earlier in the chapter).

The authors mention that stakeholders have suggested reducing the frequency of vegetation monitoring efforts. If it is necessary for budgetary considerations, I think that shifting to a sampling schedule of alternate years would be acceptable, although it could make it more difficult to assess impacts of flows or other events in a particular year. I suppose it depends in

part whether the annual time scale was important for informing management actions or other components of the AMP. For the sandbar monitoring, does this imply that the geomorphic surveys (B1) will also be moved to an every-other-year basis and coordinated with the vegetation sampling? Otherwise, valuable information for sandbar-campsite management and for understanding vegetation-geomorphology interactions could be lost if the vegetation monitoring is temporally decoupled from the topographic surveys. Could the remote cameras in project B also be used to look at short-term vegetation responses?

On p. 67, it mentions that the monitoring is meant to be complementary to the remote sensing work (project L) that takes place over longer time scales and focuses on common species. I raised this point above, but is there any formal integration between the two? Could some things accomplished by the vegetation sampling could be accomplished by remote sensing or at least complemented by it?

p. 67, line 10 – insert "the" before river

p. 68, end of second paragraph – data "are"? Personal preference perhaps, but I always refer to data as plural.

Does the monitoring occur at the non-flow vegetation management sites? Or, is this accomplished by other personnel (e.g., NPS)? It would be good for those two projects to be linked, so that sampling can inform management and management can produce data useful for other things. Some of this is mentioned in C4, but it was not clear to me if there was ongoing coordination of the widespread monitoring and the site-based vegetation treatments.

Project Element C.2. Determining Hydrological Tolerances and Management Tools for Plant Species of Interest.

The hypotheses and conceptual framework for this section are interesting and could lead to greater fundamental understanding of species responses to environmental stress. The first experiment will improve understanding of species-specific constraints on riparian vegetation across many of the most important species in the CRe. The second experiment focuses on three species of concern for vegetation management: Goodding's willow, arrowweed, and Emory's baccharis/seepwillow. The focus on these three species seems appropriate and the design of the experiment to try to disentangle the otherwise confounded effects of daily flow fluctuations and baseflow levels on plant physiological performance could yield important new information for CRe management and for more basic understanding of plant responses to power-peaking flows on other rivers.

Minor note: "Goodding's" is misspelled as "Gooding's on second paragraph p. 71.

Very minor point: *Baccharis emoryi* is called several different names throughout the chapter: Emory's baccharis, seepwillow, Emory's seepwillow, etc. It might be best to use a consistent common name.

Are the substrates in the field like the pure sand being used in the experiments?

On p. 72, it refers to 13 species, while elsewhere in the proposal and in the table on p. 71 it only refers to 12. Is there a 13th species? I do not know much about its role in the CRe, but *Phragmites australis*, a clonal species with potentially important geomorphic effects, could be an interesting species to consider as well.

Although it is fine if this has not been determined yet, I did not see any information on how long the experiments will be run (i.e., when will the plants be harvested) or how quickly water tables will be raised or lowered.

In the top paragraph on p. 73, it was unclear to me what "observed gradient length" means. I found the description of the ordination analysis, and particularly its outcomes, as a little vague. Also, I do not believe that the authors described how the results of experiment 2 would be analyzed. Will this be with GLMMs?

p. 77, last line – Perhaps not critical, but how will the authors assess which models have greater support? Through comparison of AIC values?

Project Element C3: Predictive Models and Synthesis

It sounds like a great idea to integrate the monitoring data, experimental results, and other existing data sources to build predictive models (of LTEMP veg objectives). Findings from the experiments could help to develop models with a solid mechanistic basis, in terms of hydrology and plant physiological performance. Including data from other regional rivers will help to expand the range of hydrologic and climatic conditions considered, providing a better understanding of the hydroclimatic niches of various riparian plant species and perhaps enabling projections under flow and climatic conditions beyond the historical and environmental/flow limits of the field data (e.g., beyond the last 5-6 years). Overall, model results that are based on plant functional responses to flow variation, hydrologic and climatic constraints on species distribution, and a range of flow conditions should provide more reliable projections.

I did have some questions, though, about how well plant hydro-climatic niches can be determined from the broad-scale hydrology and species distribution data. However, given all of the past fine-scale work in the CRe and other regional rivers, I imagine that these data in the "informatics" approach are being used to provide a coarse-scale filter of plant-environment relationships that will complement the previous fine-scale studies. As the authors say, these broad-scale data will help to show where the CRe occurs in this regional hydro-climatic space and may help in considering the effects of climate change on plant performance. In any event, it will be important to consider both coarse and fine scale relationships (and their interactions or nestedness) when projecting vegetation responses.

Philosophically, the hierarchical Bayesian modeling framework sounds great, but relatively few specifics are provided in the proposed TWP. For instance, what will be some of the specific model outputs from the Bayesian model and how will these be linked to the LTEMP objectives? I am sure that these will be developed as the research goes on, but some examples would make the quantitative review and Bayesian modeling less mysterious to a novice. Perhaps a more explicit link to the State-and-Transition modeling rules would be helpful.

On p. 77, the phrase "conditions that could lead to these conditions" is awkward and vague.

Project Element C4: Vegetation Management Decision Support

It is a great idea to use these models to determine site potential (perhaps part of the site prioritization approach) and to otherwise inform the non-flow vegetation management actions. I did not see this mentioned in the LTEMP Experimental Vegetation Project Plan (although I could have missed it). It is important that modeling, monitoring, and implementation efforts be coordinated/integrated between these two projects.

Outcomes and Products:

I found this section, particularly the lists of planned publications, to be very helpful for understanding specifics of the other parts.

References: Capitalize "Merritt" in Diehl et al. citation.

Budget (p.85): "Cooperative Agreements" for part C3, the Bayesian modeling, is a large part of the budget (nearly $290K in direct costs, more than a quarter of each year's budget). This is fine, but I am wondering who is doing this work. Is the Cooperative Agreement with NAU, USGS, or other? Is an outside entity doing the modeling work?

Projects C.7 and C.8 (Reclamation): Experimental Vegetation Treatment

Science Advisor Summary:

> The review of these two projects addresses not only the short proposal in the draft Triennial Work Plan but also a separate document prepared by the National Park Service in April 2020, "***Long Term Experimental and Management Plan Experimental Vegetation Project Plan for the Implementation of the Vegetation Environmental Commitments from the LTEMP ROD in Glen Canyon National Recreation Area and Grand Canyon National Park below Glen Canyon Dam***." This separate document presents a detailed plan for the experimental vegetation treatment program.
>
> Dr. Dixon finds the project plan to be "… solid and well thought-out. The basic vegetation management objectives are clearly described, and the program has made an excellent start developing metrics to prioritize reaches and sites for management." He also commends "… the choice of an adaptive management framework to iteratively inform restoration actions across the life of the program. Finally, close collaboration and annual coordination with the Tribes and GCMRC will help to make the projects relevant to stakeholder concerns (including protection of cultural resources), and well supported scientifically."
>
> At the same time, the review recommends improvements in several elements of the project proposal:
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> - "First, use of an adaptive management framework suggests that research hypotheses will be formed to address key unknowns related to management, these will be tested with experimental treatments (and controls), and these results will be used to inform future management… However, given that vegetation

management has gone on for several years, including FY18-20, there should be some specific hypotheses that can be stated and used to guide the next round of management experiments. So, I think that the proposal could be strengthened by explicitly listing some of these hypotheses/questions and indicating how they will be addressed in upcoming work."

- Second, the review recommends that the proposal describe "… how elements of ongoing or proposed work (e.g., in the FY21-23 work plans for GCMRC projects B, C, D, or L) by GCMRC would link with restoration actions or monitoring under C.7 and C.8."

- Third, while commending the criteria for identifying Priority Treatment Areas, the review recommends that the organization and usage of these criteria be clarified. Specifically, the review states that "… it would be good to clearly differentiate reach-based vs. site-based criteria in Table 3, to make the hierarchical nature of the system (coarse and fine-scale) more evident." Further, the reviewer states, "… I would not expect the same set of prioritization criteria to be relevant to different vegetation management objectives."

- Finally, the reviewer "… found the organization of the budgetary material at the end of the proposal to be confusing. The authors provide a very rough annual budget of $150,000 to $350,000, but then indicate that this is only an order of magnitude estimate. It would seem to me that an approximate budget could be based on the values in the separate proposed FY21-23 TWP document, which ran between $235,000 and $260,000."

The review concludes with specific suggestions for individual items in the proposal.

External Review (Dr. Mark Dixon):

Main Suggestions:

Overall, I think the LTEMP Experimental Vegetation Treatment project plan is solid and well thought-out. The basic vegetation management objectives are clearly described, and the program has made an excellent start developing metrics to prioritize reaches and sites for management. I also appreciate the choice of an adaptive management framework to iteratively inform restoration actions across the life of the program. Finally, close collaboration and annual coordination with the Tribes and GCMRC will help to make the projects relevant to stakeholder concerns (including protection of cultural resources), and well supported scientifically.

There are elements of the proposed project plan that could be improved, however. **First, use of an adaptive management framework suggests that research hypotheses will be formed** to address key unknowns related to management, these will be tested with experimental treatments (and controls), and these results will be used to inform future management. As this is meant to be a cyclical, iterative process, the specific research questions will change over time. However, given that vegetation management has gone on for several years, including FY18-20, there should be some specific hypotheses that can be stated and used to guide the next round of

management experiments. So, I think that **the proposal could be strengthened by explicitly listing some of these hypotheses/questions and indicating how they will be addressed in upcoming work.** A conceptual diagram showing the adaptive management process in general or showing the iterative process for testing questions for a specific vegetation objective (e.g., cultural site protection or campsite restoration), might also be useful in this regard.

Although I know that this project is collaborating closely with GCMRC, **I also did not find much description of how elements of ongoing or proposed work (e.g., in the FY21-23 work plans for GCMRC projects B, C, D, or L) by GCMRC would link with restoration actions or monitoring under C.7 and C.8**. For instance, how will the data generated by the annual vegetation monitoring (Project C, Element C.1) or sandbar topography monitoring (Projects B and C) by the GCMRC inform the Experimental Vegetation Treatment project? Parts of GCMRC Project C for the FY21-23 TWP (Elements C.3 and C.4) will involve development of a hierarchical Bayesian model – which may subsume the State and Transition model - that is meant to help inform vegetation management actions. How will data from ongoing remote sensing (GCMRC Project L) or the ground-based LiDAR surveys of dune stability and aeolian transport (GCMRC Project D) be integrated with vegetation management activities. I know that those projects have not been approved yet and that the time scale of the Experimental Vegetation Treatment project is much longer (20 years), but more explicit integration for at least the early stages of this project would be helpful.

I like the criteria for the Priority Treatment Areas but wonder if their organization and usage could be clarified. **First, it would be good to clearly differentiate reach-based vs. site-based criteria** in Table 3, to make the hierarchical nature of the system (coarse and fine-scale) more evident. **Second, I would not expect the same set of prioritization criteria to be relevant to different vegetation management objectives**. For instance, one might want to use a different set of criteria for judging sites to be treated for invasive species vs. choosing campsites overgrown with arrowweed or sites where vegetation management could improve aeolian transport. So, perhaps the different treatment objectives could be prioritized separately.

Finally, I found the organization of the budgetary material at the end of the proposal to be confusing. The authors provide a very rough annual budget of $150,000 to $350,000, but then indicate that this is only an order of magnitude estimate. It would seem to me that an approximate budget could be based on the values in the separate proposed FY21-23 TWP document, which ran between $235,000 and $260,000. The authors do indicate that the project would run in phases, with lower budgets needed in the first few years of pilot projects and greater funding needed as time goes on to cover more sophisticated and larger scale work. What seemed a little out of place was an unlabeled (no heading) budget justification section with lists of costs per acre from different restoration activities (non-native plant monitoring and control, Granite Camp pilot project, and Hidden Slough pilot project) and a total of $50,000 to $100,000. If this section is included, there should be a heading or a sentence or two introducing it and providing context or it could have been structured as table with a table heading. It is not clear if these are all of the projects being proposed, nor what the timeline is for doing the projects (FY21?), and the total has nothing to do with either the rough budget totals suggested on the previous page ($150-350K) or the proposed budget for FY21-23. So, I am somewhat puzzled by

why this section is included (or, if included, not explained and included with a full budget). Should it have been included as supporting materials for Attachment B?

Other, more detailed, comments/questions by section:

Background (pp. 2-4):

p. 2, 3rd line: replace "called out" with "designated" or other choice?

p. 3, 2nd paragraph: GCMRC pilot project and Granite Camp restoration project will help inform suitable locations and strategies.

- How will the GCMRC and Granite Camp pilot projects help inform suitable locations and strategies? What questions or techniques are being explicitly tested?

p. 3: "Funding levels would increase with successive phases" – This sounds good, but what if funds are needed more at early or intermediate stages? Is the plan to start with fewer sites, which are treated more experimentally, and then increase to larger implementation based on learning?

p. 3: What is the Minimum Requirements Analysis process for evaluating mechanical treatment methods? No reference or explanation is provided?

p. 3, bottom: Should have a subheading or sentence indicating that these are the goals and priorities for implementation.

Objectives:

- **Control non-native species**
    - How will they determine/predict which areas will be most effective for tamarisk removal?
    - Why is clearing dead tamarisk a priority? Is this mostly for scenic /aesthetic concerns, or are there functional reasons (e.g., aeolian sediment transport, fire risk)?
    - Tamarisk defoliation by biocontrol agents appears to have a big impact on vegetation. Is NPS considering management that more directly involves the biocontrol agents, e.g., increasing or limiting their spread and effectiveness?
    - If the biocontrol agents are effective, could efforts be shifted from manual control of tamarisk to other vegetation objectives or control of other invasive plant species?
    - It will be important to have annual updates of defoliation status across the area.
    - Follow-up steps (including monitoring) should be taken to prevent increases in other invasive species after tamarisk removal or defoliation.
    - In "b", change "Oher" to "Other"
- **Develop native plant materials**
    - What has been accomplished in this regard so far? What constitutes appropriate source areas?

- **Replant native species to high priority sites**
    - Is habitat for Ridgway's Rail an issue in the GRCA/GLCA? Are habitat modifications (e.g., management of marsh habitat?) being considered for this or other species besides Yellow-billed Cuckoo and SW Willow Flycatcher?
    - Sandbar/bank stabilization: This conflicts with the goal of keeping sites open and facilitating aeolian transport, but emphasizes the need for site-specific criteria
- **Remove vegetation encroaching on campsites**
- **Manage vegetation to assist with cultural site protection**
    - It is good to have this strong tie-in with ongoing GCMRC work on aeolian transport and vegetation management. This suggests that development of predictive models and perhaps expansion of monitored sites should be priorities for GCMRC.
    - How would vegetation removal enhance river deposition?
    - I have not seen any explicit consideration of the role of native xeric vegetation in cultural site protection/rehabilitation (increasing deposition, reducing erosion) in GCMRC's project D work plan. Perhaps this should be a priority research area and could be posed as a hypothesis for experimental vegetation treatments.

Conceptual Framework of the Project (pp. 4-6):

- p. 5: Non-flow vegetation treatments to mitigate for effects of Glen Canyon Dam
    - If these are "experimental" restoration projects, are there specific hypotheses being tested? How are these being implemented as experiments? Being explicit about this could help to ensure learning in the adaptive management process. The only implicit hypotheses I have seen are those related to managing vegetation for aeolian transport.
        - A schematic indicating the iterative/adaptive process of restoration experiments, monitoring, learning and feedback, etc., might be useful.
- "Improvement" of vegetation is subjective. Some actions "improve" vegetation only in the context of other objectives, as some involve removing native vegetation (e.g., arrowweed).
- p. 6, top paragraph: Should say "where conflicts" and "ways to encourage."
- Yes, it is critical for coordination/monitoring with GCMRC to continue, if this work is to be experimental and adaptive. Specific research hypotheses should accompany management experiments and should be incorporated into GCMRC work plans.

NPS Vegetation Planning and Specifics (pp. 6-9)

- Focus on species that pose a high threat to park resources
    - What sorts of ecosystem functions are invasive species disrupting?
- Methods included chemical, mechanical, manual, cultural, etc. under an IPM approach
    - Are any of these methods being tested experimentally? Is there learning here?
- Why has tamarisk control focused on side canyons vs. other invasives on mainstem?
- Pilot projects to test riparian rehabilitation treatments at Soap Creek and Granite Camp

    - What treatments were tested? What were the questions? What lessons have been learned?
- p. 7: Seems like a big question in the future might be how to work with the biocontrols. Is this something that NPS may want to more actively engage in (rather than just passively observe)? Should it be part of management questions? Seems like this should be an important area of research.
- Is it likely that Fremont cottonwood or Goodding's willow can be self-sustaining anywhere in the GRCA, given the alteration of flows? What determines where they will be planted? The native species that are self-sustaining are the problem ones (seepwillow, arrowweed)!
- p. 7-8: Table 1 – Priority non-natives for control – why are these species chosen?
    - *Phragmites australis* not included. Is it a concern? Is it considered native?
    - No *Kochia* (*Bassia*) *scoparia*?

Project Treatment Areas (pp. 9-10)

- p. 10, first line: Should read "non-flow" action instead of "flow"?
- Using the State and Transition model to help guide finer-scale decisions seems like a good approach. Would this change at all with development of hierarchical Bayesian models in GCMRC's FY21-23 workplan (project B3, with decision support provided by project B4… if funded)?
- "Different outcomes will be generated depending on the model time-step chosen and associated outputs"
    - How would you determine what time step to use?
    - Is the relative acreage based on the site acres vs. the projected amount of undesirable states through the whole reach or study area, or just the proportion of the site that is treated? This seems like a good prioritization criterion… choosing areas where you can make the biggest difference.
        - Why not treat an entire site?
- Will PTA scheme be applied to GLCA too? Would seem best to do so.
- "actual work… would be guided by the results from future… monitoring in relation to LTEMP resource goals, performance outputs, and associated action thresholds… and not the model outputs generated for the EIS analysis."
- What model outputs? Why wouldn't they be used to guide restoration?
- How would action thresholds be determined?

Table 3 – Criteria for PTAs (pp. 11-14): This is a good framework, but some adjustments may be useful. See my earlier suggestion to more clearly differentiate reach vs. site scale variables. Also consider whether might use different formulas or combinations of criteria to address different objectives (e.g., focused cultural site protection vs. widespread control of invasives). Are there criteria that can be used for determining appropriate species for planting as well?

- Are these criteria values binary or do some have different levels or potential weightings? Are there cutoff values for defining some of these (wide, high defoliation, suitable, high richness, etc.)?
- Need up-to-date tamarisk defoliation data. What is cutoff for "high"?
- Is there a SWFL habitat model being used to determine potential habitat?
- How will vegetation classification maps be updated and how often? Will this be done via remote sensing with field confirmation?
- It will be important to coordinate closely with GCMRC monitoring programs (e.g., B, C, D and L), as well as proposed hierarchical Bayesian modeling work in project C3 and proposed decision support in project C4 (GCMRC FY21-23 TWP).
- For the dune stability criterion, seems like could use predictive models of aeolian transport potential… also the level of threat to cultural resources?

Riparian – Subject to Glen Canyon Dam Influence (p. 15)

Desired Condition

- Is this a section under "Project Treatment Areas"? It is introduced rather abruptly without any text providing context for it. Should this be in the Background section?

Table 4. defines desired condition

- Does "reference" refer to the current (at least based on most recent data) condition?
- At what scale are these criteria to be applied? Are some of these goals at the site level (e.g., native cover, richness)?
- Should there be goals/indicators about campsites, cultural resources, Tribal preferences, etc. here?
- Will there be monitoring for the bird indicators? Is there habitat for Ridgway's Rail or other sensitive species in the GRCA and GLCA?

Figure 1. What defines the different priority levels in the map? What are the cutoffs between categories?

Funding and Budget (pp. 17-18)

p. 17: FYxxx… should this be for FY21-23 or was it approved during FY18-20?

I agree that dependable annual base funding is important for this work. Should certain tasks (e.g., restoration of beaches, protection of cultural sites) should receive the higher priority over more *ad hoc* invasive control?

p. 18: As I note earlier, this section is introduced rather abruptly with no headings or other context provided. It is not clear what these cost estimates are connected to. Is this a budget request for a specific Triennial Work Plan? Or, is it simply to give estimates of possible per-acre costs for restoration work? If there is an important reason for including this section, then greater context should be provided. Otherwise, perhaps it should be cut out.

The minimum costs per acre for the Granite Camp project are 6x higher than the Hidden Slough. Why is this? The range of estimated costs per acre is so large that it is not very useful. If the range is this wide, perhaps estimates should be split out into specific components to show why.

Text starting with "Use of NPS Invasive…" is not a sentence.

Other…

Is there a major guiding 20-year goal for treatments and restoration for each objective?

Will this plan/framework apply equally to GRCA and GLCA?

Attachment A: GCD AMP FY18-FY20 Workplan… project C.7. Experimental Vegetation Treatment (pp. 20-22)

This links up with GCMRC project C.4 from FY18-20, although this sounds like GCMRC's proposed work in the FY21-23 TWP (science support) too. It is good that NPS is working with GCMRC to develop these protocols, but it is not clear what the product was of this work.

The native plant materials theme did not get much treatment in the proposal. I'm not sure what has been done in the past in this regard, although GCMRC's project C in the FY21-23 TWP did talk about past genetic work on cottonwood and Goodding's willow.

Not clear what mean by "GCMRC vegetation 16 data processing" – does this mean data collected in 2016?

Based on the table, it sounds as if considerable work was done in FY18-20, including delineation of preliminary Priority Treatment Areas. It mentions considering whether the PTAs should be revised based on each vegetation management objective. As I mentioned earlier, I think that might be worth doing.

In year 2, it suggests that the decision was made to "focus on campsite encroachment as the highest priority for the initial phases." Given that considerable work was already done, are there research questions that can be developed for the next phase of treatment experiments?

Attachment B: Planning Notes for 2021-23 TWP (p. 23)

Goals for each objective seem reasonable. Are the GCMRC and GRCA joint vegetation removal sites the ones being done to enhance aeolian transport and are being monitored using ground-based LiDAR (project element D1 in GCMRC TWP for FY21-23)?

Greenhouse experiments: the hydrologic part of this is being accomplished in the proposed FY21-23 TWP for project C (Riparian Vegetation). I don't think that sediment burial was part of it though. Or, is this a separate effort by NPS?

Attachment C: GRCA Project Sites for 2020-2021 (p. 25)

The first blank table looks like an error. Should delete for final version. The table that follows provides a nice detailed listing of projects.

Project D: Effects of Dam Operations and Vegetation Management on Archaeological Sites

Science Advisor Summary:

The Science Advisor elected to have Project D reviewed by two experts because it addresses such a wide range of topics. Dr. Sweeney (Review #1) reviewed the project from the perspective of a specialist in the study of eolian dynamics. Dr. Dixon (Review #2) reviewed the project from the perspective of a specialist in riparian vegetation dynamics.

Dr. Sweeney finds that the proposal "… is well written and contains reasonable hypotheses informed by previous research, and identifiable goals. The scientific quality is high, using proven methods (such as lidar) to measure and assess geomorphic change, which will help them address their primary research questions of whether HFEs and resultant sandbar building will increase eolian sand transport to dune areas, resulting in higher preservation potential for archaeological sites and cultural artifacts. Using new and previously collected repeat photos will help the team assess vegetation change in these environments over time. Some additional clarity is needed regarding the different dune types and sites representing pre- and post-dam river flows and altered eolian sediment connectivity."

Dr. Sweeney specifically asks for greater clarity for Element D.1 concerning whether the project addresses (1) dunes associated with modern fluvial sources (MFS), which are adjacent to the river and associated with flows <45,000 cfs., (2) dunes associated with pre-dam Colorado River flows, or relict fluvial sources (RFS), which are higher in elevation and associated with flows >45,000 cfs that no longer occur, or (3) both. He suggests an alternative hypothesis concerning the importance of the vegetation on these dunes from a management standpoint. He also recommends (for D.1) continuing use of LiDAR and poses several specific questions. For Element D.2, he lauds the use of repeat photography and suggests other ways in which this could be useful to the project. He praises Element D.3. And he is confused by the lack of a budget for Element D.4.

Dr. Dixon characterizes Element D.1 as "… a valuable project that directly investigates the role of Glen Canyon Dam flow releases (especially High-Flow Experiments) and vegetation management on eolian transport to protect eroding cultural sites. He commends the use of LiDAR but poses some questions about its application and linkages to other projects. He characterizes Elements D.2 and D.3 and their specific methods as "valuable" but again poses some questions about methods and linkages and suggests needs for more information in the exposition of D.3. Finally, he sees Element D.4 as providing "… important baseline data on stratigraphy, sedimentary context, prehistoric climatic conditions, etc. that would complement the archaeological work for the site" and "… a model for future cross-cultural communication and collaboration between physical scientists, NPS, and tribal members." However, he questions the budgeting arrangements for D.4 and suggests that at least some funds be formally dedicated to it.

External Review 1:

The impacts of Glen Canyon Dam have been wide-reaching and influence not only river discharge, sediment transport, geomorphology, ecology, but also archaeological sites, including sites and artifacts that are culturally important to Native American tribes. Uniform flows from the dam facilitates the erosion of sandbars, and the lack of annual floods on the river has resulted in vegetation encroachment on exposed bars. Project D involves geomorphic processes, changes in riparian vegetation, and their impacts on the preservation of cultural resources.

The overarching goal of Project D is to assess the effectiveness of planned High Flow Events (HFEs) to rebuild sandbars and regenerate the sand supply for eolian redistribution into adjacent sand dunes. Sand dunes contain archaeological sites and cultural artifacts, and burial by eolian sand helps to preserve them. Due to dam operations and the modification of Colorado River flows and sediment loads, these sites and artifacts are threatened by erosion. I am familiar with some of the previous research on this issue by Joel Sankey and Amy East (Draut). In this review, I will consider each of the four project elements in the context of previous research, the LTEMP, and other projects in the Adaptive Management Work Plan, to the best of my knowledge.

Project Element 1: Dam Operations, Vegetation Management, Archaeological Sites

This element focuses on HFEs, their frequency, and the role of eolian sand in the preservation of archaeological sites and cultural artifacts. Dam management has impacted the growth and encroachment of riparian vegetation on sandbars. This encroachment of vegetation may impede eolian transport of sand from the sandbars to the dunes, so vegetation removal is necessary in some cases.

Some additional context associated with previous research helped me to better understand the situation. In two USGS reports, Draut and Rubin (2008) and Draut et al. (2010) documented that dunes containing artifacts are found at different elevations: 1) dunes associated with modern fluvial sources (MFS) are adjacent to the river and are associated with flows <45,000 cfs. 2) dunes associated with pre-dam Colorado River flows, or relict fluvial sources (RFS), are higher in elevation and associated with flows >45,000 cfs, which no longer occur. It is my understanding that this project focuses primarily on sites adjacent to modern sandbars, but this is not entirely clear to me.

Draut and Rubin (2008) noted that RFS dunes have biological crust and vegetative cover because they no longer receive sand from deflating sandbars and are essentially stabilized. This is a potential problem because gullies can erode through these stabilized dunes, exposing sites and artifacts. Previous to the dam, high flows would build sandbars that provide a source of dune sand that would blow into the gullies and promote deposition rather than erosion, resulting in continued preservation of the artifacts. While these are reasonable observations and interpretations, I would like to pose an alternative hypothesis: the vegetation and biological crust cover, while stabilizing the dunes, also helps to maintain burial of sites and cultural artifacts in the present management situation. If these dunes were reactivated by vegetation removal, continued wind erosion of sand and migration by dunes is likely to expose artifacts, reducing their preservation potential. For me, and perhaps others, the challenge is determining which scenario results in longer term preservation of sites and artifacts. Some additional clarification is

needed to know if Project Element 1 plans to deal with archaeologic sites associated with "MFS dunes", "RFS dunes", or both.

For the MFS dunes, vegetation has grown and is spreading on sandbars, prohibiting the wind transport of sand to the dunes, thus decreasing preservation potential of archaeological sites and cultural artifacts. The reason for this is that vegetation baffles the wind, reducing wind velocity, resulting in deposition of sand. If the dunes are still active but not receiving new sand from adjacent bars, wind erosion in the dunes can expose artifacts, which will remain exposed because the sand supply has been reduced. This element plans to remove vegetation so that sand can blow into adjacent dune areas. The justification behind this is reasonable and consistent with other projects, especially Project C and the control of invasive vegetation. It appears that only the vegetation blocking sand transport by wind to the dunes would be removed, and not vegetation on the dunes themselves (Fig. 1). Natural vegetation on dunes themselves could be left alone (unless it is invasive) because the vegetation facilitates deposition of eolian sediment (as it presently does at the bar-dune interface), thus increasing preservation potential of artifacts.

At what rate does eolian sand rebury sites and artifacts? If sandbars are regenerated by HFEs at the right time of year (prior to sand transporting winds in the right direction), does burial begin the same year, or does it take 2-3 years (or more) for this process to be effective? Having successive HFEs each year (rather than a one-time HFE) seems to be key in helping answer that questions. Are sites being monitored beyond measurement with lidar?

LiDAR has been previously used (Sankey et al., 2018a, 2018b) and shown to be an effective and accurate method of measuring geomorphic change including areas of erosion and deposition on sandbars and sand dunes. Continued use of lidar as proposed may help to answer some of the questions I ask above, as well as lead to a broader understanding of erosion and deposition of sand in these areas.

Project Element 2: Monitoring Landscape-scale Ecosystem Change with Repeat Photography

The goal of this element is to document changes in vegetation of the sandbars and dunes via repeat photography. This includes recent photography (in the last few decades) as well as historic photography going back to 1940. Part of this element seeks to work through the backlog of several years of photo analysis that had not been completed due to a lack of funding. This seems entirely justifiable in this project because perhaps one of the only ways scientists can understand how vegetation has changed pre- and post-dam is through repeat photography. The more data/photo sets that can be incorporated, the better, in my opinion. Otherwise, you are left with only a few snapshots that do not allow you to assess rates of change, or changes that may have occurred in intervening years (i.e., flood deposition or erosion). The use of repeat photography has been previously used to help understand geomorphic and vegetative changes to sandbars and dunes over time (Sankey et al., 2018a). The historic photos also provide an opportunity to better understand pre-dam vegetation type and structure, also potentially in support of Project C. Repeat photography may also aid in determining the frequency by which vegetation management will need to be maintained (yearly, every two years, or more).

Project Element 3: Cultural Program History

The goal of this element is to retrieve old reports and interview key personnel who have knowledge of past research. Unfortunately, "lost knowledge" seems to be a common problem, but we do not always have the time or resources to retrieve it before it is gone forever. The South Dakota Geological Survey, for example, is working hard to digitize all reports so that they are freely available to anyone, and other information including historical photographs that have been sitting in storage boxes for decades, of use to no-one. In Project D, this is critical in identifying gaps in knowledge and in maintaining tribal relations. I do not normally see budget items for this type of work in proposals, but I recognize the importance of this information and applaud you for your proposed efforts here.

Project Element 4: Geomorphic Research in Support of NHPA Compliance Activities

The goal of this element is to excavate an archaeological site threatened by erosion. This collaborative effort by scientists and tribal members seeks to preserve artifacts as well as learn more about the sedimentology and geomorphology of the area. The information learned in this element could potentially be applied to other culturally significant areas along the river, provide insight to rates of geomorphic change pre-dam, and inform future management decisions. There is no budget listed for this element.

I was also asked to review the Project based on four specific criteria, summarized as follows:

a) Clarity, scientific quality; consistent with LTEMP goals: Project D is well written and contains reasonable hypotheses informed by previous research, and identifiable goals. The scientific quality is high, using proven methods (such as lidar) to measure and assess geomorphic change, which will help them address their primary research questions of whether HFEs and resultant sandbar building will increase eolian sand transport to dune areas, resulting in higher preservation potential for archaeological sites and cultural artifacts. Using new and previously collected repeat photos will help the team assess vegetation change in these environments over time. Some additional clarity is needed regarding the different dune types and sites representing pre- and post-dam river flows and altered eolian sediment connectivity.

The goals of Project D are consistent with the LTEMP, which seeks to build sandbars and increase protection of cultural artifacts and sites in support of the National Historic Preservation Act.

b) Integration with other projects: Project D has clear connections to other projects. Project D depends on Project A which monitors stream flows and sediment loads and assesses the sources of sand for bar building. Project D depends on the success of Project B which assesses effects of HFEs on sandbar generation and maintenance over time. HFEs are necessary to generate high flows that build sandbars. The HFEs deliver sand from the redistribution of channel bed sand, some of which is derived from tributaries. Do proposed dams and water retention projects in the Little Colorado River threaten the sand supply, and thus the effectiveness of the HFEs? (Perhaps only minimally based on information provided in Project A?). Project C considers riparian vegetation, some of which may serve as a barrier to eolian transport. Vegetation removal also improves recreational opportunities at some sandbar campsite locations.

c) Feasibility of accomplishing 3-year goals: Time frames seem reasonable on all counts. Research associated with Elements 1 and 2 will occur over three years, which seems entirely reasonable considering the field-intensive nature of element 1, and the backlog of assessment for element 2. Element 3 is occurring over two years, which also seems reasonable.

d) Contributions to adaptive management or resources and experimental and management actions: The number of different projects of the Work Plan are well-integrated and work toward the common goal of Alternative D presented in the LTEMP, which works to make progress on all management aspects including improving sandbar building potential, improving preservation of cultural resources, among others. Project D aims to return and maintain some of the natural geomorphic processes that occurred along the river pre-dam with high flows via HFEs and eolian transport of sand from sandbars to adjacent dunes. This in turn results in the increased preservation potential of culturally important sites and artifacts. The research summarized here will document the effectiveness of HFEs and vegetation removal on resource preservation. This report, and previous published research associated with Project D, emphasize that there are risks involved with HFEs in that they may build sandbars, but erosion may also occur, countering preservation goals. I also recognize that this research pertains to a particular selection of sites where wind direction and strength facilitate the transportation of sand from sandbars to cultural sites; previous work (Sankey et al., 2018 a, b) makes it clear that not all sandbar sites are susceptible to wind erosion or the protection of cultural sites. In my view, the risks of the research are necessary if sites and artifacts are to be preserved, and the ecological diversity of the river is to be maintained.

<u>External Review 2:</u>

This proposal describes an important, albeit diverse, set of project elements to support cultural resources through geomorphic science. The largest part of the work (project element D.1) focuses on the linkages between fine sediment availability in the riparian zone, erosional and depositional processes related to degradation or preservation of cultural sites on the terraces, and impacts of flows and vegetation management on eolian transport of these sediments to the imperiled cultural sites. Other project elements deal more broadly with historical changes in riparian vegetation and sediment availability (D.2), the history of cultural research in the CRe (D.3), and collaborative work between geomorphologists, archaeologists, and tribal members for a proposed archaeological excavation site (D.4). A central motivation for the overall project is that Glen Canyon Dam operations have contributed directly to losses of sediment sources because of increased baseflows and lowered peak flows, and indirectly due to expansion of riparian vegetation, with a 45% decrease in bare sand area since 1963. Hence, this general project theme, especially D.1, is in support of increasing and retaining fine sediment above elevation of average baseflow for “ecological, cultural, and recreational purposes.”

In summary, the project elements of the proposed work include:

- D1: Quantifying effects of flow (High-Flow Experiments) and non-flow (vegetation removal) on eolian sediment transport using ground-based LiDAR.
- D2: Documenting historical riparian vegetation and geomorphic change in the old high-water zone using repeat photography.

- D3: Synthesis of cultural resources research and monitoring in the CRe since 1995.
- D4: Science support and collection of geomorphological information for a proposed archaeological excavation.

Project Element D.1. Dam Operations, Vegetation Management, Archaeological Sites

D.1 is a valuable project that directly investigates the role of Glen Canyon Dam flow releases (especially High-Flow Experiments) and vegetation management on eolian transport to protect eroding cultural sites. Using ground-based LiDAR is a good approach for the work (which appears to be a continuation from past TWPs), although few details is given on how the LiDAR will be deployed, its precision, and how data will be analyzed. Although the LiDAR mapping is an appropriate approach, are there complementary methods that could be employed to directly measure eolian transport? No direct field sampling of vegetation is planned, aside from use of remote cameras on some sites. Given that the investigators are looking both at geomorphology and vegetation (both on the control sites and on the vegetation removal sites), I am wondering if the project could benefit from coordination with the vegetation monitoring (project C), the sandbar topographic monitoring (project B), or the experimental vegetation management projects. Perhaps the ground-based LiDAR work here could also link with (or inform) the remote sensing work of project L.

Project Element D.2. Monitoring Landscape-scale Ecosystem Change with Repeat Photography

The repeat photography work seems particularly valuable to overall goals of the Glen Canyon Dam AMP. Given its low cost and great potential scientific value, it surprises me that it was not funded (at least not fully) during the FY2018-20 TWP. Very useful information can be gained about vegetation and geomorphology from various periods in the past (back to the 1880s) and about more recent changes. I am curious as to whether any of these sites coincide with archaeological sites that are being degraded by erosion and that are being studied in D.1.

The ongoing work to match and analyze recent photos with those derived from the 1923 Birdsey and 1889-1890 Stanton expeditions seems valuable and has been useful for detecting significant changes in vegetation and open sand since the initiation of the "modified low fluctuating flow regime in the mid-1990s." The new sources of historical photos that have been proposed for acquisition, matching, and analysis also seem very valuable and will provide different insights than previously analyzed photo-pairs. For instance, the photo series from Goldwater in 1940 occurred during a pre-dam period with lower flows than some of the other historical sources and is closer to the beginning of the flow regulation period. The Borden series from 1973 focuses on recreational campsites. This source should be valuable for assessing changes in campsite beaches, which are of major interest for recreation and cultural preservation and shows conditions only a decade after dam completion.

Project Element D.3. Cultural Program History

Project element D.3 is thematically quite different from the others, in that it proposes "to assemble a comprehensive history of the GCDAMP cultural resources monitoring and research programs… since 1995." Although this project does not involve any collection of new data, it is

valuable for preserving insights about cultural resources that have been gained from various projects, grey literature, and personal recollections over several decades. It is also timely, as important institutional knowledge may be lost due to retirements, etc. if the work is not done soon. Compiling and making this information available to the public and to the next generation of managers will provide an important history of past cultural resources work and a foundation for future work. I assume that the compiled materials will also include both transcripts and recordings of oral histories, scanned photographs, videos, and other digital resources that will be hosted on a website or provided via other media.

The authors describe this work as being different from a project being conducted by Arizona State University, which they say contains "little information relating to the cultural aspects." However, they never specifically indicate the nature of the ASU work. Does it deal more with the history of natural resources and scientific research?

Project Element D.4. Geomorphic Research in Support of NHPA Compliance Activities

Project Element D.4 is meant to provide geomorphological scientific support (LiDAR topographic mapping, stratigraphy, etc.) for a proposed excavation of an eroding archaeological site by NPS staff and the Pueblo of Zuni. This project element would provide important baseline data on stratigraphy, sedimentary context, prehistoric climatic conditions, etc. that would complement the archaeological work for the site. Besides the actual data collected for the project, it is hoped that this can provide a model for future cross-cultural communication and collaboration between physical scientists, NPS, and tribal members.

The project appears to be mostly in the framing phase at this point (pending discussions about scope and timing with NPS and tribal members), as the proposed archaeological project has not yet been confirmed. The authors indicate that they have identified several research questions, but do not list them in the proposal (perhaps they should?). They also indicate that they can do the work, with minor modifications, even if the proposed excavation project does not occur. Then it would essentially be baseline or background geomorphic/stratigraphic information that would be of use when archaeological work is done at the site later.

No budget has been identified for project element D.4, as the scope and timing will be determined through discussions with NPS and tribal members, but the authors indicate that the work could be completed without additional funding. This would be accomplished under the current Project D budget by repurposing some time and salary for the PIs out of elements D1 and D2. This would likely not require a large amount, but I am wondering if it would be better to formally dedicate at least some of the funding for this project element.

Budget: D.2 and D.3 are inexpensive (together make up about 20% of the budget) but valuable projects. I would suggest a high priority on funding both (along with D.1), particularly the repeat photography work in D.2. As I suggest above, perhaps they should include at least a minimal budget for D.4 or explicitly reprogram some of D.1 to cover it.

Project E: Controls on Ecosystem Productivity: Nutrients, Flow, and Temperature

Science Advisor Summary:

> Dr. Rosi finds that "… both Projects E and F are grounded in previously collected data and understanding of the system. Moreover, both projects seek to maintain existing datasets and advance understanding of the Colorado River, Grand Canyon by conducting new research. The knowledge gaps [are] clearly identified and the research proposed to fill these data gaps [are] well conceived and are doable. I believe that these two projects will lead to advancing out understanding of food webs in the Colorado River, Grand Canyon and that these findings will shed light on our general understanding of food webs in regulated rivers." She also finds that the proposed outcomes and budget for Project E "… seem appropriate and are well justified in the plan." She commends several aspects of the project, including the proposed work and budget to examine aquatic vegetation [macrophyte] responses to experimental flows. She states that "This work should be supported if the experimental flows are adopted as this will likely provides an understanding of how these flows influence the habitats supporting organisms at the base of these food webs." At the same time, Dr. Rosi poses further questions for the investigators to consider in the design of each project element.

External Review (Dr. Emma Rosi):

Overview

Overall, both Projects E and F are grounded in previously collected data and understanding of the system. Moreover, both projects seek to maintain existing datasets and advance understanding of the Colorado River, Grand Canyon by conducting new research. The knowledge gaps were clearly identified, and the research proposed to fill these data gaps were well conceived and are doable. I believe that these two projects will lead to advancing out understanding of food webs in the Colorado River, Grand Canyon and that these findings will shed light on our general understanding of food webs in regulated rivers.

The purpose of Project E is to measure the influence of the various factors that influence ecosystem productivity in the Colorado River, Grand Canyon. The proposed work is well justified by past research and the plan for the research is takes advantage of the latest techniques possible for these types of questions. Some highlights of the research that are strong include the focus on P (Phosphorus) dynamics and interactions of P and silt and clay in the river system. The investigation of P availability in this system will provide insights on its limitation on primary production. The second research goal to explore the interactions among light availability, temperature and nutrients is useful, as it is known that in rivers like the Colorado that various factors can strongly interact to influence ecosystem productivity. The third research element on Humpback chub metabolic demands is somewhat different than the first two elements and may seem tangential. However, I agree with the researchers that a research gap of great concern in the Colorado Basin and the Grand Canyon in particular needs to be filled concerning the energetic demands of this fish species. Understanding the metabolic demands of these fishes is crucial for

exploring how their populations may respond to changes in the river system, especially the overall productivity.

Element E.1.

The P budget approach and especially the work on the P dynamics in riverine sediments is very important work if you want to understand the P budget of a system. I was happy to see that the proposed work includes extractions of sediment bound P and P sorption assays. I was a little less clear on the methods described in the bottom of page 119. Will the water samples you collect be measured for SRP, TDP and TP (Soluble Reactive, Total Dissolved, and Total Phosphorus), in addition to exploration of the suspended sediment collected in the sample? More detail on these methods would be helpful, but the fact that the sorption assays are described on page 120, indicates that these dynamics are of concern to the PIs. If not already planned, I suggest that the PIs work to understand the sorption dynamics in the water samples they collect and how preservation of the samples influences P dynamics.

Element E.2.

The continued measurement of dissolved oxygen for metabolism modeling is an important component to maintain. This is a crucial way of taking the "pulse" of the river. Additional work to constrain estimates of gas exchange are a useful addition and the efforts to develop a mechanistic model of GPP (Gross Primary Production) in the Grand Canyon is valuable. A mechanistic model of GPP will be useful for multiple purposes and is a useful endeavor. The work proposed to disentangle the primary production of macrophytes versus diatoms in the Glen Canyon reach of the river is also ambitious and is very important for understanding the river. Because the whole-river measurements of GPP provide an estimate of the photosynthesis of both macrophytes and diatoms, but the diatoms have been shown to support the food web, there is a great need to be able to separate the productivity of these two contributors to primary production. The light:dark bottle incubations in the field is a very good first step in disentangling the production of these two contributions to primary production. The plans for these experiments are solid. The plans to continue analysis of the images from the underwater imagery also seems to be a useful extension of previous work. It is very wise of the team to focus energy on analyzing existing imagery rather than simply continuing to collect more. I look forward to reading the results of these surveys and how they conduct the spatial analyses in the peer reviewed literature.

Element E.3.

The focus of this element is on refining measures of the metabolic rate of humpback chub and flannel mouth suckers in the Grand Canyon. This work is fundamental in the effort to build models of the effects of management operations on these species. The research proposed is relatively straightforward and the experiments are well designed. The results of this work are essential for understanding and model dynamics of these populations.

Final Comments

The outcomes and budgets for Project E seem appropriate and are well justified in the plan.

The Experimental Project Budget focuses on mapping aquatic vegetation [macrophyte] responses to experimental flows. This work is ideally suited to investigate proposed alteration in flows (e.g. the 2021 steady flows, etc.). This work should be supported if the experimental flows are adopted as this will likely provides an understanding of how these flows influence the habitats supporting organisms at the base of these food webs. I wondered if these flows are implemented if some additional effort to understand the effects of the experimental flows on diatoms versus macrophytes were considered. This would also be a useful research element.

Project F: Aquatic Invertebrate Ecology

Science Advisor Summary:

> Dr. Rosi finds the argument compelling that "… the data collected from Project F [are] crucial for Project E to be successful. These projects seem well linked and in combination they can provide new insights into how the base of the food web responds to dam operations and long-term changes in the river." Dr. Rosi commends the proposed efforts to make maximal use of previously collected data, the continuing important role of citizen science, the continuing study of "bug flow" impacts, and the careful alignment of project elements with other needs of the AMP. At the same time, she poses further questions for the investigators to consider in the project design. Finally, she characterizes the budget for Project F as "… reasonable given the scope of the work proposed [and] adequate to accomplish the goals of the project."

External Review (Dr. Emma Rosi):

Overview

As noted above, overall both Projects E and F are grounded in previously collected data and understanding of the system. Moreover, both projects seek to maintain existing datasets and advance understanding of the Colorado River, Grand Canyon by conducting new research. The knowledge gaps were clearly identified, and the research proposed to fill these data gaps were well conceived and are doable. I believe that these two projects will lead to advancing out understanding of food webs in the Colorado River, Grand Canyon and that these findings will shed light on our general understanding of food webs in regulated rivers.

Project F focuses on continued efforts to track macroinvertebrates that form the base of the food web, especially in response to past or proposed management changes. In order to understand higher trophic levels in the Colorado River, tracking changes in the base of the food web is crucial. The work proposed is strong, with hypotheses about the ecology of these organisms and response to dam operations driving the proposed research and monitoring efforts. The multiple methods of tracking the invertebrates is also useful; this is especially crucial to maintain with the approval of the bugs flows for FY2020. The additional complication of the COVID pandemic disrupting sampling makes efforts in the next few years crucial for understanding the responses to the bug flow experiments.

The work in project F is well grounded in an understanding of the lifecycles of animals at the base of the food web. This is essential as there are varied life history strategies and understanding how different animals respond to changing dam operations.

Element F.1

The creative use of citizen scientists to help collect data on invertebrate emergence is quite strong. It both provides a way for folks to engage in science while visiting Grand Canyon and allows for much more data to explore patterns of emergence than would otherwise be possible in a relatively inaccessible river like the Colorado in the Grand Canyon. This work is very important to the efforts to understand patterns of invertebrate populations. The additional plan to measure drift is useful in the investigation of the long-term effects of the bug flows on invertebrate communities.

Element F.2.

The data set on invertebrates in Marble has been collected since 2007 and represents a manageable long-term dataset for this river. The work has been published in peer reviewed journals and provides a useful way to track long-term dynamics in the food base. Moreover, the focus on Marble Canyon is crucial given what we know of how dynamics in Marble Canyon influence downstream food webs.

Element F.3.

The proposal to translocate HBC to the Bright Angel Creek in 2020 makes continued effort to monitor invertebrates at this site particularly important to continue. The data that have been collected will provide and baseline against which to compare the influence of these translocated fish on the food web and vice versa.

Element F.4.

This element revisits data collected on fish diets that were collected in 2006-2009. Considering that work that has been led by GCMRC scientists suggests alterations in the food web, with introductions, changes in the food base, and expansion of HBC populations, it seems that the proposed work to re-examine fish diets is warranted. The element proposes to examine fish diets now compared to the past. This work will leverage the past investments in research on the food base and I envision that the work will shed light on how flexible fish diets are and how much the changes that have been observed in the base of the food web translates to higher trophic levels. This work is very strong. I was curious if the findings that come out of this work might motivate a second research effort similar to what was published in Cross et al. 2013. It might be useful for GCMRC scientist to think through what evidence might be suggest that enough change has occurred in the food web to trigger another thorough investigation of the energetics and demands in the food web.

Element F.5.

This element includes conducting research if the Springtime HFEs are implemented. This work seems reasonable to add if these flows are conducted so that the team can learn how the response of the food base compares to other previous HFEs.

Final Comments

The plan for producing publications based on this work seems very good and the PIs plan to publish their findings in high profile outlets. Moreover, as pointed out by the plan, the data collected from Project F is crucial for Project E to be successful. These projects seem well linked and in combination they can provide new insights into how the base of the food web responds to dam operations and long-term changes in the river. The budget for this work is reasonable given the scope of the work proposed. It is adequate to accomplish the goals of the project.

Project G: Humpback Chub Population Dynamics

Science Advisor Summary:

> Dr. Olden states, "This project will continue monitoring activities mandated by the 2016 Biological Opinion associated with the LTEMP EIS by focusing on research that improves understanding of the abundance and drivers of humpback chub population dynamics in the Little Colorado River, the western Grand Canyon, and beyond. Overall, the scientific questions are clearly articulated, methods are robust, and findings will be relevant to address BiOp Conservation Measures." The reviewer has no concerns for any elements of the proposal except Element G.2, for which the reviewer suggests that, "Beyond Asian tapeworm, future investigations of parasite composition and burden (according to fish size, condition, location, etc.) might be warranted."

External Review (Dr. Julian Olden):

Overview

This project will continue monitoring activities mandated by the 2016 Biological Opinion associated with the LTEMP EIS by focusing on research that improves understanding of the abundance and drivers of humpback chub population dynamics in the Little Colorado River, the western Grand Canyon, and beyond. Overall, the scientific questions are clearly articulated, methods are robust, and findings will be relevant to address BiOp Conservation Measures.

Project Element G.1. Humpback Chub Population Modeling

The objective of this element is to support a better understanding of the current adult population size of humpback chub and to predict future population states in response to management decisions. This project provides a clear rationale and details appropriate methods to collect data and inform/develop a multistate population model to predict life-stage specific abundance estimates of humpback chub in the LCR. No concerns.

Project Element G.2. Annual Spring/Fall Humpback Chub Abundance Estimates in the Lower 13.6 km of the LCR

The objective of this element is to estimate humpback chub abundance in the lower 13.6 km of the LCR during spring and fall months. Specific goals of this project are well stated and the goal to continue to collect data on other fish species, as well as external parasites, is a welcome. Beyond Asian tapeworm, future investigations of parasite composition and burden (according to fish size, condition, location, etc.) might be warranted.

Project Element G.3. Juvenile Chub Monitoring near the LCR Confluence (JCM-East)

The objective of this element is to gather data to estimate survival, growth and abundance of multiple size classes of humpback chub in the mainstem Colorado River just downstream of the LCR confluence. This appears to also include monitoring rainbow trout and brown trout abundance with the goal of tracking relationships with humpback chub. Monitoring juvenile humpback chub dynamics is fundamental to the LTEMP and the GCDAMP. The methodology approach is well reasoned. No concerns.

Project Element G.4. Remote PIT-tag Array Monitoring in the LCR

The objective of this element is to continue the maintenance of the MUX and NET antenna systems in the LCR to allow tracking the movement of humpback chub in support of population models. No concerns regarding methodology, and this knowledge will clearly inform more accurate estimates of population size.

Project Element G.5. Monitoring Humpback Chub Aggregation Relative Abundance and Distribution

The objective of this element is to monitor the status and trends of humpback chub aggregations and conduct periodic surveys in between aggregations. The proposed monitoring program of chub aggregations is essential to move beyond current understanding of humpback chub populations in a limited set of locations. No concerns.

Project Element G.6. Juvenile Chub Monitoring – West

The objective of this element is to understand the drivers of humpback chub populations in the western Grand Canyon; a goal identified in the Conservation Measures of the BiOp. Similar to Project Element G.3., this data is fundamental to support LTEMP and GCDAMP. Rationale and approach clearly articulated.

Project Element G.7. Chute Falls Translocations

The objective of this element is to continue translocating juvenile humpback chub to upstream of Chute Falls on an annual basis and continue monitoring efforts. Although no details were provided regarding the number of planned translocated individuals and subsequent monitoring, the history of translocations since 2002 have proven beneficial from a restoration perspective that support continuation. No concerns.

Outcomes and Products

Proposed outcomes and products are acceptable.

Elements and Activities not Funded

Although funding restrictions are reality, it was nevertheless disappointing to see backwater monitoring of age-0 humpback chub (Project Element G.8.) no longer being proposed. Knowledge regarding age-0 fish is critical to obtain more robust predictions of production and population size and is a key metric to infer the effects of predation by nonnative fishes and Glen Canyon dam operations. Similarly, assessments of stock-piled otoliths appear to be an excellent opportunity to understand variability in hatch dates as related to environmental conditions, including changes in flow and temperature (Project Element G.9.); funding to support this project is no longer requested.

Project H: Salmonid Research and Monitoring Project

Science Advisor Summary:

> Dr. Olden commends the way the project "… uses a combination of field, modeling, and laboratory techniques to evaluate the response of rainbow trout and brown trout to experimental flows including TMFs, HFEs, equalization flows, and Bug Flows, as well as other management actions (i.e., proposed incentivized take harvest)." The reviewer raises no concerns for Project Elements H.1, H.3, and H.4. However, the reviewer reiterates the concerns expressed in the proposal for Element H.2 regarding the reduction in inference caused by the loss of replication from reducing the number of reaches to be sampled (mark-recapture sampling) from three reaches down to only one starting in FY2022.

External Review (Dr. Julian Olden):

Overview

This project uses a combination of field, modeling, and laboratory techniques to evaluate the response of rainbow trout and brown trout to experimental flows including TMFs, HFEs, equalization flows, and Bug Flows, as well as other management actions (i.e., proposed incentivized take harvest).

Project Element H.1. Rainbow Trout Monitoring in Glen Canyon

The objective of this element is to track the status and trends of rainbow trout in the Lees Ferry reach of the Colorado River and to continue gathering long-term trend data on trout relative abundance, size composition, distribution, and recruitment as well as angler satisfaction and catch quality. Approaches to the long-term monitoring of rainbow trout remain robust. The incorporation of citizen science (fishing guides) to collect data on fish length is a great addition and will help address data gaps.

Project Element H.2. Experimental Flow Assessment of Trout Recruitment

The objective of this element is to determine the effects of LTEMP ROD flows on the recruitment of YOY rainbow trout and brown trout in Glen Canyon, the growth rates of juvenile and adult trout, and dispersal of YOY trout from Glen Canyon to Marble Canyon. A multi-reach mark-recapture sampling design was established in the FY2018-20 TWP, which is proposed to continue with the exception that due to budget constraints only one sub-reach (rather than 3) will be sampled starting in FY2022. The reduction in inference caused by the loss of replication is acknowledged and is a point of concern. The addition of directly examining gonadal structures via ultrasound, dissection, and histology working provides a more accurate estimation of reproductive state. Additional efforts are described to monitor downstream trout dispersal and abundance at the LCR, particularly in years corresponding to Trout Management Flows versus not. This will allow for testing the assumption underlying the LTEMP model that trout recruitment and downstream dispersal correspond with YOY recruit densities.

Project Element H.3. Brown Trout Early Life Stage Survey in Glen Canyon

The objective of this element is to address critical information needs pertaining to brown trout early life-history stages to inform management options for the expanding brown trout population in Glen Canyon. This includes understanding early life stage vital rates for YOY brown trout, assessing hatch and swim-up dates to identify when brown trout are likely to be emerging from gravel redds, and identifying habitat preferences to estimate stranding vulnerability to experimental flows, including Trout Management Flows. The BTELSS study design is proposed to resemble the previous RTELSS work, with the exception of the timing of surveys and locations to match those investigated in Project Element H.2. A small number of fish will be sacrificed and brought back to the laboratory for otolith removal and microstructural analysis to assess hatch and emergence dates; an important piece of knowledge. No concerns regarding methodology is noted.

Project Element H.4. Salmonid Modeling

The objective of this element is to analyze data on rainbow and brown trout populations collected in Elements H.1-H.3 in order to estimate the efficacy of ongoing management actions and improve capacity to predict impacts of future management actions. Such synthesis and re-evaluation work are critical to the management of the Grand Canyon section of the Colorado River. In this case, estimating the impact of incentivized harvest on the population growth rate and overall abundance of brown trout will be possible. Furthermore, this element calls to continue the development a rainbow trout recruitment and outmigration model that integrates data collected over the last two decades.

Outcomes and Products

Proposed outcomes and products are acceptable.

Project I: Warm-water Native and Non-Native Fish Monitoring and Research

Science Advisor Summary:

Dr. Olden commends the priority, overall design, and proposed products of the project but expresses concerns with the proposal overall and with individual project elements. Overall, the reviewer notes a "… complete lack of recognition of the negative impacts of invasive species via competition… [W]hile I appreciate the focus on predation, it is puzzling to me that potential competition continues to receive little attention, at least in this Project." The review suggests "Alternative approaches [that] may provide opportunities to remedy this omission." The reviewer also finds that "… the Background section contains some very outdated citations on invasive species management and control" and advises that the GCDAMP should "… embark on a comprehensive literature review and formal topic modeling analysis to identify gaps in knowledge."

The reviews of the individual project elements include the following expressions of concern and/or recommendations:

- Project I.1: "It is proposed to continue with standardized monitoring that has been occurring annually since 2000, with the exception that no spring downstream monitoring trips will occur in FY22, and no monitoring from Diamond Creek downstream to Pierce Ferry will occur in FY23 because of budget constraints. Long-term, continuous, time series, are fundamental to management, so it is disappointing to see that gaps will be introduced by lack of surveys. I would much rather see budget reductions in the other project elements in order to ensure all monitoring trips are conducted."

- Project I.2: The review notes (with citations) that "… detection of rare species using eDNA is extremely challenging, including inflated false absences and inaccurate estimates of abundance." The review then identifies several questions or issues that the reviewer suggests need to be addressed in the design of the investigations.

- Project I.3: The review expresses concerns about the proposed use of gut content analysis using gastric lavage techniques and suggests alternatives (with citations): "While such techniques are valid, the many challenges of this approach (i.e., many empty stomachs, unidentifiable prey, etc.) could promote the use of stable isotope analysis or fatty acids analysis to determine diet composition… Given Project F (Aquatic Invertebrate Ecology) and other planned food web projects, it would seem that stable isotopes in particular could be beneficial. This would also allow for identifying potential competition, in addition to predation, between native and invasive fishes."

External Review (Dr. Julian Olden):

Overview

This project proposes a combination of monitoring and population models to provide information to support effective integration of monitoring, research, and invasive species management. Additional questions include: (1) what is the incidence of infestation of Asian fish tapeworm in humpback chub in the mainstem Colorado River and what risks does this parasite pose? and (2) what are the current impacts of the existing population of introduced channel catfish on juvenile humpback chub in the LCR?

Predation by invasive species is undoubtedly a major determinant of native fish health in the Colorado River, however, I'm concerned about the complete lack of recognition of the negative impacts of invasive species via competition. So, while I appreciate the focus on predation, it is puzzling to me that potential competition continues to receive little attention, at least in this Project. Alternative approaches described below may provide opportunities to remedy this omission.

I must also say that the Background section contains some very outdated citations on invasive species management and control. For example, Moyle et al. (1986), Dawson and Kolar (2003), Simberloff (2003), etc.… I would advise that Glen Canyon Dam Adaptive Management Program embark on a comprehensive literature review and formal topic modeling analysis to identify gaps in knowledge (e.g., Luiz et al. 2019, Fish and Fisheries).

Project Element I.1. System-wide Native Fish and Invasive Aquatic Species Monitoring

The objective of this element is to monitor the longitudinal distribution of the fish community (both native and nonnative) in the mainstem Colorado River from Lees Ferry to Pierce Ferry. System-wide monitoring is necessary to assess populations of native fish and to track the status of nonnative fish to ensure that LTEMP goals are being met. It is proposed to continue with standardized monitoring that has been occurring annually since 2000, with the exception that no spring downstream monitoring trips will occur in FY22, and no monitoring from Diamond Creek downstream to Pierce Ferry will occur in FY23 because of budget constraints. Long-term, continuous, time series, are fundamental to management, so it is disappointing to see that gaps will be introduced by lack of surveys. I would much rather see budget reductions in the other project elements in order to ensure all monitoring trips are conducted.

Project Element I.2. Invasion and Colonization Dynamics of Warm-water Invasive Fish

This project element proposes to improve detection of warm-water invasive fish that are passing through Glen Canyon Dam so that management agencies can better evaluate risks and deploy resources rapidly when needed to contain or eradicate aquatic invaders. In addition to conventional modeling, the project seeks to used eDNA surveys to estimate the occurrence and abundance of rare nonnative species. It states: "Using information on the spatial distribution and relative abundance of rare non-native species in Grand Canyon gained from the June 2020 or May 2021 eDNA sampling trip, we propose to resample a subset of sites approximately two years later to: 1) determine whether problematic non-native species are detected in the same geographic area or if expansion (or contraction) is occurring; and 2) determine whether non-

native species relative abundance is increasing (or decreasing) based on the amount of DNA in the water column." What is not acknowledged is that detection of rare species using eDNA is extremely challenging, including inflated false absences and inaccurate estimates of abundance (e.g., Jerde et al. 2011, Larson et al. 2020). Past research also demonstrates the difficulties of using eDNA approaches to estimate relative abundance vs. absolute abundance (LaCoursiere-Roussel et al. 2016, Carraro et al. 2018). Furthermore, what is the expectation that species occurrence and/or abundance is going to change over a short 2-year period? Rather than splitting sampling into two time periods, I would much rather see a broad spatial distribution of sampling done in a single year. Finally, just how will the eDNA data be compared to existing fish data collected via electrofishing and hoop netting and evaluated using species occupancy models? No details were provided.

Project Element I.3. Impacts of Channel Catfish on Native Fish in the Little Colorado River

The objective of this element is to quantify the potential impacts channel catfish may have on native fish populations in the LCR, specifically continuing to catch and mark (PIT tag) channel catfish to obtain estimates of population size, distribution and size structure. Traditional gut content analysis using gastric lavage techniques are proposed. While such techniques are valid, the many challenges of this approach (i.e., many empty stomachs, unidentifiable prey, etc …) could promote the use of stable isotope analysis or fatty acids analysis to determine diet composition (e.g., Rubenson et al. 2020). Given Project F (Aquatic Invertebrate Ecology) and other planned food web projects, it would seem that stable isotopes in particular could be beneficial. This would also allow for identifying potential competition, in addition to predation, between native and invasive fishes.

Outcomes and Products

Proposed outcomes and products are acceptable.

Project J: Socioeconomic Research

Science Advisor Summary:

> Dr. Colby notes that "The 2021-23 Work Plan provides a valuable opportunity to build on existing GCDAMP socio-economic approaches and models, to be programmatically well-poised to evaluate socio-economic effects of future proposed long-term operational changes" and finds that "Project J is an essential component of the GCDAMP 2021-23 Work Plan… Improved understanding of socio-economic implications of flow experiments undertaken to support native fish recovery and sediment management is essential to good working relationships between participating federal agencies, stakeholders, and elected officials."
>
> Looking at the individual project elements, the review finds:
>
> - "Element J.1 is clear in its objectives and appropriately chooses cost-effectiveness analysis over cost benefit analysis, sparing the extra effort and

expense to conduct valuation studies as would be entailed in cost benefit analysis."

- For Element J.2, the review states, "Suitable statistical models for data analysis are available in the literature and will allow estimation of the effects of price incentives on number of trips, catch rates, and retention rates of different types of anglers. The work plan proposes a mail survey method, after initial on-site contact and standard follow-up protocols for non-responders." At the same time, the review of this element notes "The Work Plan would benefit from being more explicit about the integration of economic findings in Element J.1 and Element J.2. Both involve assessment of cost-effectiveness in strategies to support native fish. These two elements need to be analyzed in a comparable manner and integrated to identify optimal combinations of actions."

- The review characterizes Element J.3 as "… the weakest of the three elements in Project J" and poses several questions concerning metrics and alternative survey approaches "… along the lines of contingent valuation instruments." The review notes that "Earlier eras of GCD socio-economic research included state of the art valuation research."

Finally, the review notes that "…the Work Plan does not appear to include any work related to regional economic impacts. Such impacts include changes in employment and business activity as linked to GCD operations and flow experiments. Changes in recreation activity linked to themes explored in Project J would generate regional economic impacts through 'ripple effects' in the regional economy. Regional economic impact studies were an important feature of socio-economic work in earlier phases of Reclamation assessments related to GCD operations. Such studies deserve emphasis given the understandable interest of regional stakeholders in economic impacts in their communities… Regional economic impact analyses are essential to evaluating any long term GCD operational changes. It is important to continue to build capacity for these types of studies. Regional economic studies provide a direct link between federal resource managing agencies, resources users, elected officials, community leaders and the public." The review suggests ways in which the proposal might address these matters in the short term, and how the GCDAMP might address them over the longer term.

External Review (Dr. Bonnie Colby):

Overview

This review assesses Project J in context of general goals for priority resources established in LTEMP and Record of Decision (ROD), and on four criteria provided to reviewers [see Appendix I].

The reviewer identified the following LTEMP ROD general goals for priority resources as particularly applicable to Project J:

- ***Natural Processes.*** Restore, to the extent practicable, ecological patterns and processes (including aquatic nutrient cycles and food web dynamics) within their range of natural variability, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems.

- ***Recreational Experience*.** Maintain and improve the quality of recreational experiences for the users of the Colorado River Ecosystem. Recreation includes, but is not limited to, flatwater and whitewater boating, river corridor camping, and angling in Glen Canyon.

The four criteria provided to reviewers are used to structure comments on Project J.

Criteria a) clarity and scientific quality of the proposal consistent with need to assess resource status and trends, effects of experimental and management actions, and other potential drivers and constraints.

Project J socio-economic evaluation of flow experiments likely will need to consider changes in ramp rates, daily flow range, fluctuating flow factors, and monthly volume patterns. Any of these can affect priority resources and can have various socio-economic effects. Tight coordination will be necessary to anticipate effects of flow experiments and develop monitoring to assess socio-economic effects.

For many public officials and stakeholders, socio-economic implications are the top priority arena on which they focus in supporting or opposing proposed GCD operational experiments and long-term changes. Economic effects often are the top concern in stakeholder interactions with resource managing agencies. The 2021-23 Work Plan provides a valuable opportunity to build on existing GCDAMP socio-economic approaches and models, to be programmatically well-poised to evaluate socio-economic effects of future proposed long-term operational changes.

Project J, by design, is highly adaptive in nature. Many details of the work are still to be identified through collaborative consultation. This is understandable as Project J involves evaluating operational experiments still to be designed and implemented.

Project J focuses upon several socioeconomic research elements: integrating economic metrics into predictive biological and physical models; designing and assessing an incentivized harvest program to reduce brown trout abundance in Lees Ferry; and surveying recreational anglers and whitewater boaters regarding their preferences for flow attributes. The focal areas for Project J address socio-economic aspects of goals related to humpback chub, sediment, invasive fish, and hydropower (with hydropower explicitly addressed in Project N).

Element J.1

Project J Element 1 considers cost-effectiveness in achieving humpback chub recovery goals through managing rainbow trout. Element 1 also considers improved sediment management and ensuing ecological, cultural, and recreational benefits, all in the context of economic tradeoffs involving hydropower.

Element 1 is poised to investigate whether mitigation of rainbow trout effects on humpback chub can more cost-effectively be mitigated through altering flow as compared to non-native removal

in target river reaches. This same effort aims to examine whether flow actions that support sediment management also can improve the value of hydropower generation. This initiative uses cost-effectiveness analysis to identify least cost options to achieve humpback chub recovery and sediment goals.

Element 1 is clear in its objectives and appropriately chooses cost-effectiveness analysis over cost benefit analysis, sparing the extra effort and expense to conduct valuation studies as would be entailed in cost benefit analysis.

Element J.2

Element 2 develops socioeconomic monitoring and research in support of a brown trout incentivized harvest program, designed to control brown trout through angler removal as part of non-native invasive species resource goals. Data from a pilot program will yield preliminary information on angler participation, harvest, and retention rates for the Lees Ferry brown trout fishery, along with geographic and demographic characteristics of participants. Data should allow improved modeling of temporal variability of angler's catch rates as abundance brown trout population varies.

Suitable statistical models for data analysis are available in the literature and will allow estimation of the effects of price incentives on number of trips, catch rates, and retention rates of different types of anglers. The work plan proposes a mail survey method, after initial on-site contact and standard follow-up protocols for non-responders.

The researchers working on Element J.2 have a rich research literature to draw upon in survey design and statistical analysis. On-site angler contact, good follow-up, and the uniqueness of the Lees Ferry brown trout fishing experience should motivate adequate response rates.

The Work Plan would benefit from being more explicit about the integration of economic findings in Element J.1 and Element J.2. Both involve assessment of cost-effectiveness in strategies to support native fish. These two elements need to be analyzed in a comparable manner and integrated to identify optimal combinations of actions.

Element J.3

Element J.3 will identify recreational preferences for flow attributes to support GCDAMP in maintaining and improving quality of recreational experiences. Element J.3 focuses on event-triggered surveys of anglers and whitewater boaters, conducted following respondent experiences with specific flow events. Recreationists exposed to the event may be interviewed on-site or followed with a mail survey. The ambitious goal is to survey the entire population of recreational anglers or whitewater boaters that experience the event.

Element J.3 reads as the weakest of the three elements in Project J. What metrics will become available as a result of this work that can usefully be integrated into operational decisions?

Given the effort and expense of administering surveys to a selected population of recreationists, why not design and administer a survey designed to elicit values along the lines of contingent

valuation instruments? That would allow comparison of dollar values embedded in different flow regimes. Earlier eras of GCD socio-economic research included state of the art valuation research.

As an overall comment related to Project J, the GCDAMP 2021-23 Work Plan does not appear to include any work related to regional economic impacts. Such impacts include changes in employment and business activity as linked to GCD operations and flow experiments. Changes in recreation activity linked to themes explored in Project J would generate regional economic impacts through "ripple effects" in the regional economy.

Regional economic impact studies were an important feature of socio-economic work in earlier phases of Reclamation assessments related to GCD operations. Such studies deserve emphasis given the understandable interest of regional stakeholders in economic impacts in their communities.

Assuming that such studies are currently precluded, it is important to include statements in 2021-23 Work Plan socio-economic products noting why regional economic impacts are not addressed. Arguments readily can be made that regional economic impacts will be trivial in the context of brief experiments with GCD operations. Nevertheless, it is useful to keep regional economic impact considerations active in the GCD dialogue.

Regional economic impact analyses are essential to evaluating any long term GCD operational changes. It is important to continue to build capacity for these types of studies. Regional economic studies provide a direct link between federal resource managing agencies, resources users, elected officials, community leaders and the public.

Criteria b) integration with other projects proposed under Triennial Work Plan

The Project J Work Plan reads as well-integrated with native and non-native fish research and sediment modeling and appears integrated in planning for experiments.

Criteria c) feasibility of accomplishing stated three-year goals and elements of project

The description of Personnel and Collaborations appears consistent with the work planned. The Outcomes and Products are compatible with the work plan description, and include submission of manuscripts for peer-reviewed publications

The list of references is impressive and up to date.

The Budget for Project J seems modest in light of the work to be performed. Budget notes do indicate that recreational surveys will be funded from a separate budget, the Experimental Fund related to implementation of experimental flows.

Criteria d) contributions to adaptive management of resources and experimental and management actions prioritized in the 2016 LTEMP Record of Decision

Project J is an essential component of the GCDAMP 2021-23 Work Plan. Native fish recovery

and sediment management are key goals of the GCDAMP. Angling and whitewater boating are central elements in the regional economy, tied to GCD operations.

Improved understanding of socio-economic implications of flow experiments undertaken to support native fish recovery and sediment management is essential to good working relationships between participating federal agencies, stakeholders, and elected officials.

Project K: Geospatial Science, Data Management and Technology Project

Science Advisor Summary: (none needed)

External Review (Dr. Robert Unnasch, Sound Science LLC):

The challenges of information management in adaptive management programs are far too often overlooked because information management is not glamorous nor compelling. However, it is really the foundation of any functioning adaptive management program. Long-term programs, like the GCDAMP, need to access old data, often years or decades old, in order to understand the long-term consequences of their actions. Without effective information management these old data are lost, corrupted, or left in formats that become unreadable over time.

Project K is all about this foundational need of the GCDAMP: the management and sharing of the data crucial for adaptive management. As the Project's Summary and Purpose state, "The primary purpose of this project is to provide high-level support to GCDAMP-funded science efforts in the disciplines of geospatial science, data management, database administration, and emerging information technologies." It is clear from the description of past work and the vision of future activities, this team is fully cognizant of the need to maintain existing information while providing guidance and support to implement new technologies for data acquisition on long-term projects. I found it encouraging that this team has taken the lead within USGS in using current cloud-based resources to manage, archive, and share the GCMRC's data. I have visited a number of the resources identified in this proposal and found them some of the best organized and easiest to navigate examples of webpages set up to share data.

It is clear that this team is very collaborative and is effectively working with a diversity of researchers within the GCMRC and its partners to make their data collection, QA/AC, and management as effective and streamlined as possible. This is always a challenge given the diversity of information collected – ranging from water quality data, to vegetation community data, to remotely sensed imagery. It appears that the team is managing these challenges effectively.

Project L: Overflight Remote Sensing in Support of Long-Term Monitoring and LTEMP

Science Advisor Summary: (none needed)

External Review (Dr. Robert Unnasch, Sound Science LLC):

Project L contains a single deliverable, a mosaiced, geo-rectified image of the entire area affected by the GCDAMP from the Glen Canyon Dam to Lake Mead. This will be the fourth iteration of this work, repeating flights made in 2002, 2009 and 2013. The resulting imagery is foundational to much of the research and monitoring done in the canyon and there is every reason for this work to be repeated in the next 2-3 years. The team has great experience with this work and has developed a well thought-out plan for accomplishing the work.

The National Geodetic Survey is expecting to complete the revision of both the horizontal and vertical datums in 2022. I expect that this change will likely change both the horizontal and vertical positioning in this new imagery relative to earlier maps. While these differences will be small, they may be significant for some research dependent on very accurate spatial positioning. Will the new imagery be re-projected to NAD 83, or will the historical imagery be re-projected using the new standards? It is not clear from the Project's description how the team will deal with these differences and so I am not sure if this additional work is built into the budget.

This may be the last time an aerial based platform is required to get high resolution imagery for this mapping work; I expect that within the next several years satellite imagery will have the same 20 cm. resolution as that expected from the 2021 flights. For example, SkySat data from Planet are now 0.72m multispectral and they expect to improve that to 50cm resolution in the next year or two. They have plans to provide even finer resolution over the next several years. Other commercial suppliers are on the hunt for similar quality data. It may be far less expensive to purchase commercial imagery in the future than pay for overflights. Is there work to be done during the next 3 years that would best position GCMRC to make that assessment and allow for a transition (if appropriate) in anticipation of a 2028 refresh of this map?

As noted in the Project's Summary and Purpose section, the ROD calls for an assessment of the impact of dam operation on sandbar resources. However, there does not seem to be a conceptual linkage between the work of the Project B team and that of the Project L remote sensing team. Remotely sensed data (e.g., structure from motion or LiDAR) collected on a unmanned aerial vehicle (UAV) platform could provide an enormous amount of information on sand erosion and deposition on key sandbars (e.g., see Gillan et al., 2017)[2] and might be more efficient than the 10-year-old survey methods currently being used. Again, it seems that the next 3 years would be an appropriate window to explore updating the sandbar survey methodology.

[2]Gillan, Jeffrey & Karl, Jason & Elaksher, Ahmed & Duniway, Michael. (2017). Fine-Resolution Repeat Topographic Surveying of Dryland Landscapes Using UAS-Based Structure-from-Motion Photogrammetry: Assessing Accuracy and Precision against Traditional Ground-Based Erosion Measurements. Remote Sensing. 9. 437. 10.3390/rs9050437.

Project N: Economic Impacts of Electrical Production at Glen Canyon Dam

Science Advisor Summary:

> Dr. Colby notes that "Project N is an essential component of the GCDAMP 2021-23 Work Plan. Hydropower and Energy Resources are central elements in the regional economy… Improved understanding of socio-economic implications of experiments in GCD operations is essential to good working relationships between participating federal agencies, stakeholders and elected officials." The review further notes that "The 2021-23 Work Plan provides ongoing opportunities to further refine existing socio-economic approaches and models to estimate economic effects of operational changes at GCD… The operational parameters described in the work plan are well-suited to assessing effects of operational changes on the economic value of hydropower."
>
> At the same time, the review notes that the financial metrics described in the proposal, while "…central, and commonly used in decision frameworks related to hydropower production and dam operations," "… are not a complete measure of the economic value to society of changes in cost and availability of hydropower and energy resources." "A complete measure would include changes in consumer and producer surplus, measured in $/MW and $/MWh, associated with changes in GCD operations. A complete economic evaluation would examine changes in regional energy costs attributed to changes in GCD operations, and the associated changes in consumer and producer surplus." Further, the review notes that the proposal "… does not include work related to regional economic impacts" such as "… changes in employment and business activity as linked to Work Plan activities" "… through 'ripple effects' in the regional economy. Studies of this type were an important feature of the socio-economic work in earlier phases of Reclamation assessments related to GCD operations, given the understandable interest of regional stakeholders in this type of economic impacts." The review suggests ways in which the proposal might address these matters in the short term, and how the GCDAMP might address them over the longer term.

External Review (Dr. Bonnie Colby):

Overview

This review assesses Project N in the context of general goals for priority resources established in LTEMP and ROD, and on four criteria provided to reviewers [see Appendix I].

The reviewer identified the following general goals for priority resources as particularly applicable to Project N:

- ***Hydropower and Energy.*** Maintain or increase Glen Canyon Dam electric energy generation, load following capability, and ramp rate capability, and minimize emissions and costs to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources.

- ***Natural Processes.*** Restore, to the extent practicable, ecological patterns and processes (including aquatic nutrient cycles and food web dynamics) within their range of natural variability, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems.

The four criteria provided to reviewers are used to structure comments on Project N.

Criteria a) clarity and scientific quality of the proposal consistent with need to assess resource status and trends, effects of experimental and management actions, and other potential drivers and constraints.

Project N is written to be highly adaptive in nature, with many details of the work plan still to be identified. This is understandable as Project N considers effects on Hydropower and Energy Resources of operational experiments (yet to be fully designed) to improve hydropower and energy resources; as well as experiments to be undertaken to assess effects on other resources and which may also affect Hydropower and Energy Resources.

Experiments to improve hydropower and energy resources may involve changes in ramp rates, daily flow range, fluctuating flow factors, and monthly volume patterns; all of which can affect other priority resources, and all of which can have various socio-economic effects.

Tight coordination will be necessary to anticipate and assess downstream resource effects of experiments to improve hydropower and energy resources; and to provide adequate and timely monitoring in order to evaluate validity of predictive models to assess downstream resource effects.

The 2021-23 Work Plan provides ongoing opportunities to further refine existing socio-economic approaches and models to estimate economic effects of operational changes at GCD.

The operational parameters described in the work plan are well-suited to assessing effects of operational changes on the economic value of hydropower. Standard metrics to be reported include: generating capacity (MW); generating energy (MWh); weekly range of MWh generated; range of changes in ramp rate; and daily flow variation.

The financial metrics described in Work Plan ($/MW and $/MWh) are central, and commonly used in decision frameworks related to hydropower production and dam operations. However, it is important to note in all GCDAMP reports utilizing these metrics that they are not a complete measure of the economic value to society of changes in cost and availability of hydropower and energy resources.

A complete measure would include changes in consumer and producer surplus, measured in $/MW and $/MWh, associated with changes in GCD operations. A complete economic evaluation would examine changes in regional energy costs attributed to changes in GCD operations, and the associated changes in consumer and producer surplus.

Arguments can be made that this more complete modeling approach is not warranted to examine effects of brief experiments that affect hydropower and energy resources. However, the consumer surplus and producer surplus measures are essential when long-term GCD operational

changes are contemplated. In fact, analyzing changes in regional energy costs attributed to changes in GCD operations, with associated changes in consumer and producer surplus, would be a centerpiece of evaluating longer term operational change to optimize hydropower and energy resources. Project N, to the degree possible, should continue the long-term effort to refine this more comprehensive modeling capacity.

Along similar lines, the GCDAMP 2021-23 Work Plan does not include work related to regional economic impacts. Regional economic impacts include changes in employment and business activity as linked to Work Plan activities.

Changes in the financial metrics of $/MW and $/MWh would be associated with regional economic impacts through "ripple effects" in the regional economy. Studies of this type were an important feature of the socio-economic work in earlier phases of Reclamation assessments related to GCD operations, given the understandable interest of regional stakeholders in this type of economic impacts.

It is valuable to include a statement in 2021-23 Work Plan socio-economic products noting why regional economic impacts are not addressed or estimated. An argument can be made that they will be trivial in the context of brief experiments in GCD operations and effects on hydropower and energy.

Nevertheless, it is useful to keep regional economic impact considerations active in the GCD dialogue. Regional economic impact analyses are essential to evaluating any long term GCD operational changes and it is important to continue to build capacity for these types of studies. Regional economic studies provide a direct link between federal resource managing agencies, resources users, elected officials, community leaders and the public.

Criteria b) integration with other projects proposed under Triennial Work Plan

The Project N Work Plan is not specific in regard to integration, given its adaptive nature.

The Work Plan indicates that Project N work related to Hydropower and Energy Resources will be consistent with improvement and long-term sustainability of downstream resources.

Criteria c) feasibility of accomplishing stated three-year goals and elements of project

The description of Personnel and Collaborations appears consistent with the work planned. The Outcomes and Products are compatible with the work plan description.

The list of references goes back to the 1990s. However, it is not clear that the reference list is up-to-date on the latest work relevant to Project N themes and GCDAMP.

The Budget for Project N is modest in light of the work to be performed.

Criteria d) contributions to adaptive management of resources and experimental and management actions prioritized in the 2016 LTEMP Record of Decision

Project N is an essential component of the GCDAMP 2021-23 Work Plan. Hydropower and Energy Resources are central elements in the regional economy.

Improved understanding of socio-economic implications of experiments in GCD operations is essential to good working relationships between participating federal agencies, stakeholders and elected officials.

Appendix I: Glen Canyon Dam Adaptive Management Program, Independent Review Panel Prospectus, Review of Draft FY 2021-23 Triennial Work Plan

Introduction

Glen Canyon Dam, operated by the Bureau of Reclamation, is located on the Colorado River above Glen Canyon, Marble Canyon, and the Grand Canyon. The dam generates substantial hydroelectric power for Wyoming, Utah, Colorado, New Mexico, Arizona, Nevada, and Nebraska. The dam also controls water levels in Lake Powell, a key component of the Colorado River Storage Project, which distributes river water to Wyoming, Utah, Colorado, New Mexico, Arizona, Nevada, California, and Mexico.

The Secretary of the Interior established the Glen Canyon Dam Adaptive Management Program (GCDAMP) in 1996 to provide an organization and process for adaptive management of dam operations, including monitoring and research, to sustain and improve the values for which Congress established Grand Canyon National Park and the Glen Canyon National Recreation Area. Dam operations and related actions affect river hydrology, sediment dynamics, temperature and chemistry, food web dynamics, and aquatic and riparian species and communities, compounded by the impacts of introduced species. These complex interactions in turn affect recreation and its role in the local economy, and Native American cultural resources and associated values in the canyons. Experimental and management actions for the GCDAMP also can affect the timing and magnitude of hydropower generation and associated revenues.

The current activities of the GCDAMP are governed by the twenty-year "Glen Canyon Dam Long-Term Experimental and Management Plan" [LTEMP], approved in a Record of Decision by the Secretary of the Interior (http://ltempeis.anl.gov/documents/docs/LTEMP_ROD.pdf) in December 2016. On a finer timescale, the GCDAMP plans its activities on a three-year cycle in the form of a Triennial Work Plan and is currently developing its Triennial Work Plan for FY 2021-2023.

The Independent Review Panel covered by this Prospectus will review the research and monitoring projects proposed for this next Triennial Work Plan for the Bureau of Reclamation, which manages the GCDAMP, and the U.S. Geological Survey Grand Canyon Monitoring and Research Center (GCMRC), the science provider for the program. The review will also provide guidance to the GCDAMP Adaptive Management Working Group (AMWG) and its Technical Work Group (TWG) for their own reviews of the draft proposal. Additional, comprehensive information on the GCDAMP is available at http://gcdamp.com.

This review is being conducted by the GCDAMP Science Advisor for the Bureau of Reclamation. The Science Advisor, a contractor to the Bureau, conducts external peer reviews and other advisory tasks for the program concerning monitoring and research methods, priorities, integration, and management of natural, cultural, and recreational resources affected by dam operations and related actions.

Key Expectations of the Long-Term Experimental and Management Plan

Every project in the Triennial Work Plan aims to address the goals and schedule of the 2016 LTEMP. *Your review of each proposed project will help evaluate whether it meets this overarching need.*

The following paragraphs summarize the goals of the 2016 LTEMP, as crucial background information for understanding and reviewing the individual proposals. Reviewers are encouraged to read (at least selectively) the LTEMP Record of Decision (see link on page 1, above); and an associated "Scientific Monitoring Plan in Support of the Selected Alternative of the Glen Canyon Dam Long-Term Experimental and Management Plan" (USGS Open-File Report 2017–1006), a copy of which accompanies this prospectus.

The LTEMP and Record of Decision establish general goals for eleven priority resources, as follows (in the order they are listed in the Record of Decision):

12. *Archaeological and Cultural Resources.* Maintain the integrity of potentially affected NRHP (National Register of Historic Places)-eligible or listed historic properties in place, where possible, with preservation methods employed on a site-specific basis.
13. *Natural Processes.* Restore, to the extent practicable, ecological patterns and processes (including aquatic nutrient cycles and food web dynamics) within their range of natural variability, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems.
14. *Humpback Chub.* Meet humpback chub recovery goals, including maintaining a self-sustaining population, spawning habitat, and aggregations in the Colorado River and its tributaries below the Glen Canyon Dam.
15. *Hydropower and Energy.* Maintain or increase Glen Canyon Dam electric energy generation, load following capability, and ramp rate capability, and minimize emissions and costs to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources.
16. *Other Native Fish*. Maintain self-sustaining native fish species populations and their habitats in their natural ranges on the Colorado River and its tributaries.
17. *Recreational Experience*. Maintain and improve the quality of recreational experiences for the users of the Colorado River Ecosystem. Recreation includes, but is not limited to, flatwater and whitewater boating, river corridor camping, and angling in Glen Canyon.
18. *Sediment*. Increase and retain fine sediment volume, area, and distribution in the Glen, Marble, and Grand Canyon reaches above the elevation of the average base flow for ecological, cultural, and recreational purposes.
19. *Tribal Resources*. Maintain the diverse values and resources of traditionally associated Tribes along the Colorado River corridor through Glen, Marble, and Grand Canyons.
20. *Rainbow Trout Fishery*. Achieve a healthy high-quality recreational rainbow trout fishery in Glen Canyon and reduce or eliminate downstream trout migration consistent with NPS fish management and Endangered Species Act compliance.
21. *Nonnative Invasive Species*. Minimize or reduce the presence and expansion of aquatic nonnative invasive species.

22. *Riparian Vegetation*. Maintain native vegetation and wildlife habitat, in various stages of maturity, such that they are diverse, healthy, productive, self-sustaining, and ecologically appropriate.

The LTEMP calls for the adaptive management of these resources through eleven types of experimental and management actions (in alphabetical order)[3]:

- Fall high-flow experiments consisting of dam releases ≤ 45,000 cfs in October or November with > 96-hr duration
- Fall high-flow experiments consisting of dam releases ≤ 45,000 cfs in October or November with < 96-hr duration
- Humpback chub translocation
- Larval humpback chub head-start program
- Macroinvertebrate production flows
- Mechanical removal of invasive fish species (since expanded to a wider array of methods for controlling invasive fish species)
- Mechanical removal of rainbow trout from the Little Colorado River reach (the Colorado River immediately up- and downstream from the Little Colorado River inflow)
- Spring high-flow experiments consisting of dam releases ≤ 45,000 cfs in April, May, or June
- Spring high-flow experiments consisting of dam releases ≤ 45,000 cfs in March or April
- Riparian vegetation restoration
- Trout management flows consisting of dam releases designed to control trout spawning success

The LTEMP and its Record of Decision call for the Bureau of Reclamation, the National Park Service, and the GCMRC to conduct monitoring and research to develop information to address three broad spheres of knowledge for each of the eleven priority resources:

- Status and Trend: How should the condition of each resource be tracked; how does this condition vary over time and space; how closely do conditions approach management objectives; and are there trends toward or away from management objectives?
- LTEMP Experimental and Management Actions: How do the LTEMP experimental and management actions affect resource status and trends; how strong (in magnitude and predictability) are these effects; how well understood are the reasons for these effects; and how do interactions among the experimental and management actions affect their outcomes?
- Drivers and Constraints: What other factors, including environmental factors and antecedent conditions, human actions, and routine dam operations also affect resource status and trends and the outcomes of the experimental and management actions; and how strong are these effects?

[3] The LTEMP also includes provisions for summer low-flow experiments but only during the second decade of implementation.

Review Specifics

The present review addresses thirteen proposed research and monitoring projects in the Triennial Work Plan (the review does not cover Project M, GCMRC Administration):

- Project A: Streamflow, Water Quality, and Sediment Transport and Budgeting
- Project B: Sandbar and Sediment Storage Monitoring and Research
- Project C: Riparian Vegetation Monitoring and Research
- Project D: Effects of Dam Operations and Vegetation Management on Archaeological Sites
- Project E. Controls on Ecosystem Productivity: Nutrients, Flow, and Temperature
- Project F: Aquatic Invertebrate Ecology
- Project G: Humpback Chub Population Dynamics
- Project H: Humpback Salmonid Research and Monitoring Project
- Project I: Warm-water Native and Non-Native Fish Monitoring and Research
- Project J: Socioeconomic Research
- Project K: Geospatial Science, Data Management and Technology Project
- Project L: Overflight Remote Sensing in Support of Long-Term Monitoring and LTEMP
- Project N: Economic Impacts of Electrical Production at Glen Canyon Dam

Each project consists of one or more project "elements." Abstracts for these thirteen projects are provided in the accompanying document, "U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Glen Canyon Dam Adaptive Management Triennial Budget & Work Plan, Fiscal Years 2021-2023, Preliminary Draft" (April 1, 2020). However, as of April 22, 2020, the plans for Project N are presently undergoing significant revision and will look more like the plans for the project in the last Triennial Work Plan, which can be found here: https://www.usbr.gov/uc/progact/amp/amwg/2017-09-20-amwg-meeting/Attach_04a.pdf.

Each reviewer is asked to review one or more of these projects in their respective areas of expertise, looking at (a) the clarity and scientific quality of the proposal consistent with the goals established by the 2016 LTEMP Record of Decision and the need to assess resource status and trends, the effects of experimental and management actions, and potential other drivers and constraints; (b) integration with other projects proposed under the Triennial Work Plan; (c) the feasibility of accomplishing the stated three-year goals and elements of each project; (d) contributions to the adaptive management of the resources and the experimental and management actions prioritized in the 2016 LTEMP Record of Decision (as subsequently expanded to include other methods for controlling invasive species.

Review Schedule and Format

The GCMRC and Bureau of Reclamation presently (as of April 22, 2020) plan to deliver the draft project proposals to the Science Advisor – and through him to you – on or by Friday, May 18, with your review returned to the Science Advisor on or by Monday, June 8. The draft proposal for each project will be approximately 20 pages long or less (plus references).

There is no standard format for your review. However, we would prefer to receive it in the form of a Microsoft Word document with minimal formatting. Sound Science staff will provide basic technical editing, and the Science Advisor may send a marked-up copy back with questions for clarification (if any) for quick turnaround. The Science Advisor is also responsible for preparing a summary of the key points of every review and will share a draft of this summary with every reviewer to make sure it accurately captures these key points.

Appendix II: Curriculum Vitae of Colby, Bonnie G., Ph.D.

Bonnie G. Colby, Ph.D.
Professor of Agricultural & Resource Economics
The University of Arizona

AREAS OF PROFESSIONAL EXPERTISE

Water, Energy, Agricultural and Natural Resource Economics
Economics of Water Policy, Water Transactions, Litigation and Negotiations
Resource Economics Trainings for Attorneys, Engineers, Public Officials, Stakeholders

EDUCATION AND EMPLOYMENT

B.S. Agricultural Economics, University of California-Davis, 1978 Ph.D. Agricultural Economics, University of Wisconsin-Madison, 1983
Major Field: Natural Resource Economics

1983 - present Professor, Department of Agricultural Economics, The University of Arizona. Teaching and research in agricultural and natural resource economics.

HONORS, AWARDS AND DISTINGUISHED OUTREACH (selected examples)

Warren Hall Medal awarded for distinguished water research, public service and enduring contribution to knowledge and the public good. Universities Council on Water Resources, 2015

Appointed to blue ribbon panel of experts, Colorado River Research Group, 2015 -21

Invited testimony on water banking before the State of Colorado Legislature, Water Resources Committee, October, 2013; August, 2014

Invited testimony on policies to govern water trading, Western Governors Association, November, 2011, on Colorado Water Plan, 2015-16

Distinguished Scholar Award, Western Agricultural Economics Association, 2007 Lead Economist, Kinship Conservation Leadership Training Program, 2007-10
Faculty, Kennedy School of Government, Executive Training Program in Environmental Economics, Harvard University, 2000-01

Faculty for Dividing the Waters; program providing specialized resource economics training for federal and state judges and water masters, 1999- 2002.

Invited testimony on water trading before the U.S. Senate Energy and Natural Resources Committee on water policy, June 1994

Outstanding Research Scientist Award, University of Arizona College of Agriculture, 1990

ECONOMICS TRAININGS PROVIDED FOR PROFESSIONAL GROUPS (examples):

Regional Economies & How They Work, workshops for public officials & agency staff, Colorado.

Water and Energy Economics, foundation-supported workshops for high school and community college economics teachers

Water Banking and Regional Economies, workshops for public officials & stakeholders, Lower Rio Grande Valley, New Mexico, sponsored by NM Office State Engineer

Kinship Conservation Fellows, month-long training for international conservation professionals Kennedy School of Government, *Executive Training Program in Environmental Economics Environmental Economics for Public Land Managers,* BLM National Training Center

Dividing the Waters, resource economics training for federal and state judges and water masters

PUBLICATIONS (selected examples, peer-reviewed publications)

Isaaks R. and B. Colby, "Empirical Application of Rubinstein Bargaining Model in Western Water Transactions", *Water Economics and Policy,* forthcoming, 2020.

Colby, B. and R. Isaaks Water Trading: Adaptation, Innovations and Modeling, *Journal of Contemporary Water Research and Education*, January, 2019.

E. Kendy, B. Aylward, L. Ziemer, B. Richter, B Colby, T. Grantham, L Sanchez, W Dicharry, E. Powell, S. Martin, P. Culp, L. Szeptycki, and C. Kappel. "Water Transactions for Streamflow Restoration, Water Supply Reliability, and Rural Economic Vitality in the Western United States" *Journal of the American Water Resources Association,* February, 2018 https://doi.org/10.1111/1752-1688.12619.

Colby, B. and R. Young, Tribal Innovations in Western Water Management, *Western Economics Forum,* May, 2018

Deol, S. and B.G. Colby, Economies of Tribal Nations: Water Rights, Agriculture and Gaming**,** *Journal of Contemporary Water Research and Education*, April, 2018.

Andrew Clarke, Bonnie Colby and Gary Thompson, Seasonal Elasticities of Household Water Demand: Application of the Stone-Geary Model Under an Increasing Block Rate Structure, *Land Economics*, Vol 93: 603-630, November, 2017.

Bonnie Colby, Water Linkages beyond the Farm Gate: Implications for Agriculture, *Federal Reserve Bank Economic Review,* November, 2016.

Bonnie Colby, "Water Trading Innovations: Reducing Agricultural Consumptive Use to Improve Adaptation to Scarcity," chapter in *Competition for Water Resources: Experiences and Management Approaches in the US and Europe*, edited by Jadwiga Ziolkowska and Jeffrey Peterson, Elsevier Publishing, 2016

Dari Duval and Bonnie Colby, "Colorado River Flows and the Fisheries Economy of the Upper Gulf of California", *Ecological Engineering*, 2016.

Ashley Kerna, Bonnie Colby, and Francisco Zamora, Valuing Environmental Flows in Mexico's Colorado River Delta, *Water Economics and Policy, December, 2016*.

Bonnie Colby, George Frisvold and Matthew Mealy, "Reallocating Climate Risks Through Water Trading", Chapter 16 in *Handbook of Water Economics*, James Roumasset, editor, Springer-Verlag Co 2015.

Bonnie Colby, "Innovative Water Transactions to Meet Urban and Environmental Demands in the Face of Climate Change" Chapter 10 in *Innovations in Water Markets*, William Easter, editor, Springer book series on Global Issues in Water Policy, 2014.

Elizabeth Schuster and Bonnie Colby, "Farm & Ecological Resilience to Water Supply Variability," *Journal of Contemporary Water Research and Education*, Issue 151, August, 2013 pages 70-83.

Bhagyam Chandrasekharan and Bonnie Colby, "Electricity Load Forecasting Improvements as a Climate Change Adaptation", *Journal of Natural Resources Policy Research,* 2013.

Rosalind H. Bark, Daniel E. Osgood, Bonnie G. Colby, and Eve B. Halper, "How Do Homebuyers Value Different Types of Green Space?"*Journal of Agricultural and Resource Economics* 36(2):395–415, 2011

Colby, B.and G. Frisvold, *Risk and Resilience: The Economics Of Climate-Water-Energy Challenges In The Arid Southwest*, Resources for the Future Press, 2011.

Jones L & BG Colby. Farmer Participation in Temporary Irrigation Forbearance: Portfolio Risk Management. *Rural Connections*: 43-48, 2010.
Basta, E and B Colby, "Water Market Trends: Transactions, Quantities, and Prices," *The Appraisal Journal*, Winter 2010, volume 78, number 1, p 50-66.

Bark R.H., Colby B.G. and Dominguez F. Snow Days? Snowmaking adaptation and the future of low latitude, high elevation skiing in Arizona, USA. *Climatic Change,* 2009.

Colby, Bonnie, "Water Management in Urbanizing, Arid Regions: Innovative Voluntary Transactions As a Response to Competing Water Claims ", Chapter 4 in *Policy and Strategic Behaviour in Water Resource Management*, Arial Dinar and Jose Albiac, editors, Ashgate Publishing, 2009.

Bark-Hodgins, D Osgood, b. Colby et al. "Habitat Preservation and Restoration: Preferences for Habitat Quality", *Ecological Economics,* 2008.

Colby, Bonnie and J Pullen, "Influence of Climate Variability on the Market Price of Water in the Gila-San Francisco Basin." *Journal of Agricultural and Resource Economics*, December, 2008.

Colby, B.G. and Kathy Jacobs, *Water Policy for Urbanizing Arid Regions*, Resources for the Future Press, 2006.

Thorson, J., S. Britton and B. Colby, *Tribal Water Conflicts: Essays in Law, Economics and Policy*, University of Arizona Press, 2006.

Colby, B.G., John Thorson and Sarah Britton. *Negotiations Over Tribal Water Rights*. University of Arizona Press, 2005.

Colby, B.G. and P. Orr, "Economic Tradeoffs in Preserving Riparian Habitat", *Natural Resources Journal*, 2005.

Colby, B.G. and E. Smith-Incer, "Visitors Values of Local Economic Impacts of Riparian Habitat Preservation", *Journal of American Water Resources Assoc.,* 41:709-717, 2005.

McCann, L. and Colby, B.G "Transaction Cost Measurement Related to Environmental and Natural Resource Policies", *Ecological Economics,* 2005.

Colby, B.G. “Cap-and-Trade Policy Challenges: A Tale of Three Markets”, Source: *Land Economics*, Vol. 76, No. 4 (Nov., 2000), pp. 638-658

Appendix III: Curriculum Vitae of Dixon, Mark D., Ph.D.

Mark D. Dixon, Ph.D.
Professor
Department of Biology
University of South Dakota

EDUCATION

Institution	Area of Specialization	Degree	Year Earned
University of Wisconsin-Madison	Zoology (Landscape Ecology)	Ph.D.	2001
South Dakota State University	Wildlife Biology	M.S.	1994
Virginia Tech University	Zoology	--	--
Iowa State University	Animal Ecology	B.S.	1987

PREVIOUS PROFESSIONAL EXPERIENCE

Institution	Position/Title	Dates
University of South Dakota	Professor	2018-present
University of South Dakota	Associate Professor	2012-2018
University of South Dakota	Assistant Professor	2006-2012
Phoenix College	Residential Faculty (full time)	F 2005-Sp 2006
Arizona State University	Postdoctoral Researcher	2001-2006
Mesa Community College	Adjunct Faculty (Instructor)	F 2004
University of Wisconsin - Madison	Graduate Research Assistant	Su 2001
	Graduate Teaching Assistant	1997-1998
South Dakota State University	Research Assistant (full time)	1990-1992 & 1994-1996

I. SPECIAL HONORS AND RECOGNITIONS

Faculty

President's Award for Research Excellence: Early-Mid Career Faculty, USD (Nov. 2012)
Arts and Sciences Travel Grant, College of Arts and Sciences, USD (Feb. 2015)
USD Research Catalyst Award (Fiscal Year 2007, $4000)

Graduate

NASA-MSU Professional Enhancement Award (student travel award for 2001 IALE national meeting)
John T. Emlen Research Award, Dept. Zoology, University of Wisconsin (2001)
EPA Science to Achieve Results Graduate Fellow (1998-2001)
Wisconsin Alumni Foundation (WARF) Graduate Fellow (1996-97)
National Science Foundation Graduate Fellow (1988-89, 1992-93)

Undergraduate

Iowa State University Scholarship for Excellence ($10,000)
Rice Estate Advanced Curriculum Scholarship ($1000)
Outdoor Writers of America Scholarship ($1400)

"Ding" Darling Scholarship (Animal Ecology Dept., Iowa State University) ($500)
W.H. Brown Scholarship (Iowa Ornithologists Union) ($2000)
Highest ranking graduate in Animal Ecology Dept., Iowa State University
Dean's List all semesters
Iowa State University Honors Program, graduated with Honors

II. TEACHING AND ADVISING

A. Courses taught

A1. General Course Schedule at USD (Current)

BIOL 311 & 311L	Principles of Ecology (and Lab)	Every fall semester
BIOL/ESCI 442/542	Introduction to River Studies	Fall semesters, odd years
BIOL 408/508, 408L/508L	Landscape Ecology	Spring semesters, even yea
BIOL 720/720L	Biostatistics (Graduate)	Spring semesters, odd years
BIOL 490	Senior Seminar	As needed
BIOL 498	Undergraduate Research	As needed
BIOL 792	Topics	As needed

Past Courses at USD

BIOL 420/520, 420L/520L	Intro. Biostatistics (and Lab)	10 times
BIOL 280L	Inquiry & Analysis in Bio (Lab)	1 time
BIOL 417/517, 417L/517L	Field Ecology	2 times
IDEA 410	Missouri River Science & Ecosystem Management	1 time
ESCI/ELED/SEED 492	Topics: Science, Culture, History of the Missouri River	1 time

Courses Taught at Other Institutions (prior to USD)

BIO 100 (Phoenix College) – Biol. Concepts ~75 stud./sem. (2 lecture, 3 lab sections), F2005-Sp2006

BIO 105 (Mesa Community College) – Environmental Biology ~12 students (lecture and lab), F2004

B. Grants or applications for grants to support teaching or advising: None

C. Graduate Student and Post-Doc Mentoring

C.1 Post-doctoral Supervisor (n=1)

Christopher Merkord (2011-2014)

C.2 M.S. or Ph.D. Supervisor (*indicates completed) (n=19)

Nadeesha Illeperuma (Ph.D.), 2019-present
Amena Ruma (M.S.), 2018-present
Stephanie Nefas (Ph.D., co-advised), 2018-present
Reza Goljani A. (Ph.D., co-advised), 2017-present
Amanda Hegg (M.S., co-advised), 2017-present
*Nadeesha Illeperuma (M.S.), 2017-2019
*Catherine Beall (M.S.), 2016-2019
*Rebekah Jessen (M.S.), 2007-2016
*Victoria Danzeisen (M.S.), 2012-2014
*James Robertson (M.S.), 2012-2016
*Christopher Boever (M.S.), 2012-2016
*Eszter Munes (M.S., co-advised), 2012-2014
*Alex Cahlander-Mooers (M.S.), 2012-2015
Wesley Christensen (M.S./M.A.), 2010-2014 (did not finish)
Elizabeth Hill (M.S.), 2010-2012 (did not finish)
*Danielle Quist (M.S., co-advised), 2009-2014
*Matthew Ley (M.S.), 2009-2012
*Adam Benson (M.S., co-advised), 2008-2011
*Lisa Yager (M.S., co-advised), 2008-2010
Caleb Caton (M.S.), 2007-2013 (did not finish)

Completed M.S. Theses for Students Supervised (n=12)

Beall, Catherine C. 2019. Recent Expansion of Native Woody Vegetation within the Lewis and Clark Reservoir Delta.

Illeperuma, Nadeesha. 2019. Historical Patterns and Impacts of 2011 Flood on Redcedar Distribution along the Missouri River.

Jessen, Rebekah. 2016. Understory Vegetation Patterns in Riparian Forest Stands along the 59-Mile Segment of the Missouri National Recreational River.

Danzeisen, Victoria L. 2016. Cottonwood (*Populus deltoides*) Recruitment in Response to a Large Infrequent Disturbance on a Regulated River: a Missouri River Case Study. 77 pp.

Robertson, James M. 2016. Assessment and Management of Hybrid Aspen Stands (*Populus xsmithii*) in the Niobrara River Valley of Northwest Nebraska. 76 pp.

Boever, Christopher J. 2016. Effects of the 2011 Flood on Floodplain Vegetation along the Missouri River. 186 pp.

Cahlander-Mooers, Alex. 2015. Classification and Mapping of Riparian Forest along the White River in South Dakota. 196 pp.

Quist, Danielle J. 2014. Historical Changes and Impacts of the 2011 Flood on Channel Complexity on the Missouri River. 230 pp.

Munes, Eszter C. 2014. Response of Bird Communities to the 2011 Missouri River Flood. 124 pp.

Ley, Matthew J. 2012. Riparian Forest Vegetation Patterns and Historic Channel Dynamics of the Big Sioux River, South Dakota. 185 pp.

Benson, Adam R. 2011. Effects of Forest Type and Age Class on Songbird Populations

across a Cottonwood Successional Gradient along the Missouri River. 49 pp.

Yager, Lisa A. 2010. Historic Changes and Water Quality Characteristics of Off-Channel Habitats on the 59-Mile Segment of the Missouri National Recreational River (MNRR). 141 pp.

C.3 Ph.D. Dissertation committees (*indicates completed) (n=16)

USD: Lauren Maestas*, Gretchen Newberry*, Drew Davis*, Kristopher Pitcher*, Rachel Demots, Aaron Gregor, Ming Liu*, Erica Mize*, Lynn Riley*, Philip Jones*, Colleen Lynch, Amanda Ervin*, Nathan Thomas*, Kaitlyn Campbell, Anna Kase, Jacinda Maassen (Sustainability)

Other: Malia Volke* (South Dakota State University), *Samantha Greene (University of Wisconsin, Geography)

C.4 M.S. Thesis committees (*indicates completed) (n=11)

USD: Eva Soluk*, Spencer Siddons*, Amber Furness*, Alice Millikin*, Bridget Jacobs*, Emily Blas*, Amy West, Bradley Frazier (Sustainability), Rayhan Hossain* (Chemistry), Naleeka Malwattage, Ryan Dunbeck

Other: Substitute on thesis defense for Donna Shorrock* (Arizona State University, 2005)

D. Non-classroom teaching

D.1 Mentor for Undergraduate Research:

Kim Magnuson (Spring 2019)
Jedidiah Jacobson (Fall 2018 – Spring 2019)
Jacob Myers (Summer 2019) – NSF-REU program (co-advised with D. Swanson)
Sierra Rider (Summer 2019) – NSF-REU program (co-advised with D. Swanson)
Dakota Swisher (Summer 2018) – NSF-REU program (co-advised with D. Swanson)
Leah Bayer (Summer 2018) – NSF-REU program (co-advised with D. Swanson)
Sebastian Ruiz (Summer 2017) – NSF-REU program (co-advised with D. Swanson)
Geoffrey Gray-Lobe (Summer 2017) – NSF-REU program (co-advised with D. Swanson)
Ben Mueggenberg (Spring 2013)
Eric Dressing (Spring 2010)
Adam DeZotell (Spring 2008)
Jordan Hamman (Spring 2008)
Drew Price (Summer 2007) – USD U.Discover Undergraduate Fellow

D.2 Undergraduate Honors Thesis committee (* indicates chaired committee)

Jedidiah Jacobson (2018-2019)*
Rachel Johannsen (2015-2017)
Theresa Barnes (2015-2018)
Ruth Wetzel (Earth Science, 2012-2014)
Genevieve Dailey (2011)
Felicia Barnes (2009)

Completed Honors Theses for Students Supervised (n=1)
Jacobson, Jedidiah. 2019. A Dendrochronological Assessment of Cottonwood and Willow Growth along the Missouri River

E. Advising:
~15-25 undergraduate students per semester (Spring 2007 – present)
See also graduate student and post-doctoral mentoring (above)

II. RESEARCH/CREATIVE ACTIVITY

A. Research Publications (refereed journal articles, book chapters, and published reports)

Criteria: Co-authorship indicates significant intellectual and/or technical contributions to an article originating from a collaborative research effort. In most cases, order of authorship is a rough indicator of relative importance of contribution to the paper.

IF = Impact Factor of Journal for 2016 (or most recent journal year).

Total Times Cited (in Web of Science) in brackets [ ] as of 2017

Total # Citations: 1,398 for 46 articles (Web of Science) or 2,469 (Publish or Perish / Google Scholar, includes Dissertation). Reflects totals for career, as of 5-9-2020.

h-index = 20 (Web of Science) or 24 (Publish or Perish / Google Scholar), the latter includes reports, book chapters, etc. not included in Web of Science (as of 5-9-2020)

Researcher ID: F-2641-2011, **ORCID ID:** http://orcid.org/0000-0002-0345-5655
*Indicates USD graduate student collaborator

A1. Manuscripts in Preparation (submission expected within 1-2 months) (n = 2)

Beall, C.C, M.D. Dixon, M.R. Sweeney, N. Illeperuma, and W.C. Johnson (in prep.) Colonization of woody vegetation on a Missouri River reservoir delta.

Goljani-Amirkhiz, R., M.D. Dixon, and D.L. Swanson (in prep.) Investigating niches and distribution of rare species in a hierarchical framework: Virginia's Warbler (*Leiothlypis virginiae*) at its northeastern range limit.

A2. Submitted Manuscripts in Review or in Revision (not yet published) (n = 3)

Baltensperger, A.P., M.D. Dixon, and D.L. Swanson. (In review.) Implications of future climate- and land-change scenarios on grassland bird abundance and biodiversity in the Upper Missouri River Basin. *Landscape Ecology* (Provided detailed review and input on manuscript).

Swanson, D.L., R. Goljani Amirkhiz, and M.D. Dixon. (In press). The changing status of winter passerines in the Northern Prairie: are recent records associated with warmer winters? *Prairie Naturalist, 51*.

Broadbent, C.D., D.S. Brookshire, D. Goodrich, M.D. Dixon, L.A. Brand, and J. Thacher (In review). Developing Ecological Endpoints for Valuation of Semi-Arid Riparian Ecosystem Services. *Environmental Management* (Provided input on manuscript, assisted with original scenario development and GIS graphics).

A3. Peer Reviewed Publications Published (Whole Career) (total n=49, n=30 at USD)

Wesner, J., D.L. Swanson, M.D. Dixon, D.A. Soluk, D.J. Quist, L.A. Yager, J. Warmbold, E. Oddy, and T. Seidel. 2020. Loss of potential aquatic-terrestrial subsidies along the Missouri River floodplain. *Ecosystems 23(1):111-123*.

Volke, M.A., W.C. Johnson, M.D. Dixon, and M.L. Scott. 2019. Emerging reservoir delta-backwaters: biophysical dynamics and riparian biodiversity. *Ecological Monographs* 89(3(Article e01363)):1-22.

Robertson, J.M., A.R. Cahlander-Mooers, C.H. Summers, and M.D. Dixon. 2019. Population condition of *Populus* x *smithii*, a Pleistocene relict aspen of the Niobrara River Valley, Nebraska, USA. *Natural Areas Journal 39*(3):286-296. (Graduate advisor for J. Robertson, reviewed and assisted with writing, ran some of statistical analyses, assisted with some of field work).

Boever, C.J., M.D. Dixon, W.C. Johnson, M.L. Scott, and T.P. Malloy, Jr. 2019. Effects of a large flood on woody vegetation along the regulated Missouri River, USA. *Ecohydrology 12*(1): e2045. https://doi.org/10.1002/eco.2045. (Graduate advisor for C. Boever and PI on project, reviewed and assisted with writing, provided input on statistical analyses).

Robertson, J.M., A.R. Cahlander-Mooers, and M.D. Dixon. 2018. Effects of management treatments on regeneration of a geographically disjunct, relictual hybrid aspen (*Populus* x*smithii*) population in the central Great Plains, USA. *Environmental Management 62*: 906-914. Link.springer.com/article/10.1007/s00267-018-1092-8. (Graduate advisor for J. Robertson, reviewed and assisted with writing, ran most of statistical analyses, assisted with some of field work).

Schenk, E.R., A.J. Benthem, M.D. Dixon, M. Mittelman, K.J. Skalak, C.R. Hupp, J.M. Galloway, and R.A. Nustad. 2018. Large wood distribution, mobility, and recruitment in an inter-dam river reach: a comparison with geomorphic process on the Garrison Reach of the Missouri River pre and post the historical 2011 flood. *Earth Surface Processes and Landforms, 43*(8):1677-1688. (Provided data and analyses on vegetation, helped write portions of manuscript, reviewed manuscript).

Stoy, P., S. Ahmed, M. Jarchow, B. Rashford, D. Swanson, S. Albeke, G. Bromley, J. Brookshire, M.D. Dixon, J. Haggerty, P. Miller, B. Peyton, A. Royem, T. Sohl, L. Spangler, C. Straub, and B. Poulter. 2018. Opportunities and tradeoffs between BECCS and food, water, energy, biodiversity, and social systems at regional scales. *BioScience* 68(2):100-111. (Provided input on writing).

Swanson, D., M.D. Dixon, and J. Palmer. 2016. A reassessment of Virginia's Warbler distribution in the Black Hills of South Dakota. *Western Birds* 47:214-226. DOI: 10.21199/WB47.3.2 (Conducted statistical analyses).

Millikin*, A.R., M.E. Jarchow, K.L. Olmstead, R.E. Krentz, and M.D. Dixon. 2016. Site preparation drives long-term plant community dynamics in restored tallgrass prairie: A case study in southeastern South Dakota. *Environmental Management* 58(4):597-605. DOI: 10.1007/s00267-016-0736-9, IF 1.878 [0] (Reviewed manuscript, gave advice on writing and statistics, provided input to study as graduate committee member).

Dixon, M.D. and J.C. Stella. 2016. Temporal variability in hydrology modifies the influence of geomorphology on wetland distribution along a desert stream: a commentary on Dong et al. 2015. *Journal of Ecology* 104:31-32. DOI: 10.1111/1365-2745.12499, IF 5.813 [0] (Did original review of Dong et al. and co-wrote commentary).

Munes*, E.C., M.D. Dixon, D. Swanson, C.L. Merkord, and A.R. Benson*. 2015. Large, infrequent disturbance on a regulated river: response of floodplain forest birds to the 2011 Missouri River flood. *Ecosphere,* 6(11 (Article 212)), 19. www.esajournals.org/doi/pdf/10.1890/ES15-00007.1, IF 2.49 [0] (Helped guide student research, provided input on writing and analysis, assisted with field surveys in 2009-2010).

Boudell, J., M.D. Dixon, S.B. Rood, and J.C. Stromberg, J. C. 2015. Restoring Functional Riparian Ecosystems: Concepts and Applications. *Ecohydrology,* 8(5):747-752. DOI: 10.1002/eco.1664, IF 2.852 [2]. (Assisted with writing this Preface for special issue).

Dixon, M.D., C.J. Boever*, V.L. Danzeisen*, C.L. Merkord, E.C. Munes*, M.L. Scott, W.C. Johnson, and T. Cowman. 2015. Effects of a "natural" flood event on the riparian ecosystem of a regulated large-river system: the 2011 flood on the Missouri River, USA. *Ecohydrology* 8(5):812-824. DOI: 10.1002/eco.1613, IF 2.852 [6] (Wrote article, analyzed data, directed student research).

Johnson, W.C., M.A. Volke, M.L. Scott, and M.D. Dixon. 2015. The dammed Missouri: prospects for recovering Lewis and Clark's river. *Ecohydrology* 8(5):765-771. DOI: 10.1002/eco.1534, IF 2.852 [6] (Provided input on manuscript, was PI for project).

Broadbent, C.D., D.S. Brookshire, D. Goodrich, M.D. Dixon, L.A. Brand, J. Thacher, and S. Stewart, S. 2015. Valuing preservation and restoration alternatives for ecosystem services in the southwestern U.S. *Ecohydrology* 8(5):851-862. DOI: 10.1002/eco.1628, IF 2.852 [3] (Provided input on manuscript, helped with graphics and GIS work, helped develop scenarios).

Volke, M.A., M.L. Scott, W.C. Johnson, and M.D. Dixon. 2015. The ecological significance of emerging deltas in regulated rivers. *BioScience* 65(6):598-611. DOI: 10.1093/biosci/biv040, IF 5.378 [4] (Provided input on manuscript and served on graduate committee for M. Volke).

Scott, M.L., G.T. Auble, M.D. Dixon, W.C. Johnson, L.A. Rabbe. 2013. Long-term cottonwood forest dynamics along the upper Missouri River, USA. *River Research and Applications* 29:1016-1029. DOI: 10.1002/rra.2588, IF 2.274 [6] (co-PI on project, provided input on manuscript).

Brand, L.A., M.D. Dixon, T. Fetz, J.C. Stromberg, S. Stewart, G. Garber, D.C. Goodrich, D.S. Brookshire, C.D. Broadbent, and K. Benedict. 2013. Projecting avian guild responses to landscape management along the Middle Rio Grande, New Mexico. *Southwestern Naturalist, 58*(2), 150-162. DOI: 10.1894/0038-4909-58.2.150, IF 0.219 [1] (Conducted analysis of vegetation and GIS data, helped develop vegetation scenarios, contributed to

writing and graphics).
Stromberg, J. C., K.E. McCluney, M.D. Dixon, and T. Meixner. 2013. Dryland riparian ecosystems in the American Southwest: Sensitivity and resilience to climatic extremes. *Ecosystems* 16:411-415. DOI: 10.1007/s10021-012-9606-3, IF 4.198 [11] (Invited short perspective piece, contributed to writing).
Yager, L.A.*, M.D. Dixon, T.C. Cowman, and D.A. Soluk. 2013. Historic changes (1941-2008) in side channel and backwater habitats within an unchannelized reach of the Missouri River. *River Research and Applications* 29:493-501. DOI: 10.1002/rra.1614, IF 2.274 [1] (Co-advisor of M.S. student Yager, contributed to writing, editing, and preparation of graphics).
Dixon, M.D., W.C. Johnson, M.L. Scott, D. Bowen, and L.A. Rabbe. 2012. Dynamics of plains cottonwood (*Populus deltoides*) forests and historic landscape change across the upper Missouri River, USA. *Environmental Management* 49:990-1008. DOI: 10.1007/s00267-012-9842-5, IF 1.878 [23] (Primary author, wrote paper, conducted all analyses, supervised data collection, co-PI on project).
Johnson, W.C., M.D. Dixon, M.L. Scott, L. Rabbe, G. Larson, M. Volke, and B. Werner. 2012. Forty years of vegetation change on the Missouri River floodplain. *BioScience* 62:123-135. DOI::10.1525/bio.2012.62.2.6, IF 5.378 [25] (co-PI on project; contributed to data, statistical analyses, and preparation of graphics and GIS maps; provided input on manuscript).
Brand, L.A., J.C. Stromberg, D.C. Goodrich, M.D. Dixon, K. Lansey, D. Kang, D.S. Brookshire, and D.J. Cerasale. 2011. Projecting avian response to linked changes in groundwater and riparian floodplain vegetation along a dryland river: a scenario analysis. *Ecohydrology* 4(1):130-142. DOI: 10.1002/eco.143, IF 2.852 [10] (Conducted analysis of vegetation data and GIS mapping, provided input on manuscript).
Brookshire, D.S., D. Goodrich, M.D. Dixon, L.A. Brand, K. Benedict, K. Lansey, J. Thacher, C.D. Broadbent, S. Stewart, M. McIntosh, and D. Kang. 2010. Ecosystem services and reallocation choices: A framework for preserving semi-arid regions in the Southwest. *Journal of Contemporary Water Research and Education* 144:60-74. DOI: 10.1111/j.1936-704X.2010.00075.x, (Contributed to writing, analysis, preparation of graphics)
Galbraith, H., M.D. Dixon, J.C. Stromberg, and J.T. Price. 2010. Predicting climate change risks to riparian ecosystems in arid watersheds. Chapter 10 (pages 187-202), In: Kapustka, L., W. Landis, and A. Johnson (eds.), *Environmental Risk Assessment and Management from a Landscape Perspective*. John Wiley & Sons, Inc., Hoboken, NJ. (Conducted vegetation analysis and modeling, contributed to writing)
Stromberg, J.C., S.J. Lite, and M.D. Dixon. 2010. Effects of stream flow patterns on riparian vegetation of a semiarid river: implications for a changing climate. *River Research and Applications* 26(6):712-729. DOI: 10.1002/rra.1272, IF 2.274 [61] (Provided input on manuscript, ideas).
Stromberg, J.C., T.J. Rychener, and M.D. Dixon. 2009. Return of fire to a free-flowing desert river: effects on vegetation. *Restoration Ecology* 17(3):327-338. DOI: 10.1111/j.1526-100X.2007.00347.x, IF 1.724 [6] (Contributed to statistical analysis, data, and provided review comments on manuscript).

Dixon, M.D., J.C. Stromberg, J.T. Price, H. Galbraith, A.K. Fremier, and E.W. Larsen. 2009. Potential effects of climate change on the upper San Pedro riparian ecosystem. Chapter 3, In: Stromberg, J.C. and B. Tellman (eds.), *Ecology and Conservation of the San Pedro River*. University of Arizona Press, Tucson, AZ. (Primary author, conducted all computer modeling, statistical analysis, and writing; most of work completed during postdoc at Arizona State).

Stromberg, J.C., M.D. Dixon, R.L. Scott, T. Maddock III, K.J. Baird, and B. Tellman. 2009. Status of the upper San Pedro River (USA) riparian ecosystem. Chapter 20, In: Stromberg, J.C. and B. Tellman (eds.), *Ecology and Conservation of the San Pedro River*. University of Arizona Press, Tucson, AZ. (Provided feedback on manuscript and some supporting data and analysis; most of work completed during postdoc at Arizona State).

Stromberg, J.C., S.J. Lite, M.D. Dixon, and R.L. Tiller. 2009. Riparian vegetation: pattern and process. Chapter 1, In: Stromberg, J.C. and B. Tellman (eds.), *Ecology and Conservation of the San Pedro River*. University of Arizona Press, Tucson, AZ. (Provided feedback on manuscript and some supporting data and analysis; most of work completed during postdoc at Arizona State).

Stromberg, J.C., V.B. Beauchamp, M.D. Dixon, S.J. Lite, and C. Paradzick. 2007. Importance of low-flow and high-flow characteristics to restoration of riparian vegetation along rivers in arid southwestern United States. *Freshwater Biology* 52:651-679. DOI: 10.1111/j.1365-2427.2006.01713.x, IF 3.255 [137] (Provided feedback on manuscript and some supporting data and analysis; most of work completed during postdoc at Arizona State).

Dixon, M.D., and M.G. Turner. 2006. Simulated recruitment of riparian trees and shrubs under natural and regulated flow regimes on the Wisconsin River, USA. *River Research and Applications* 22(10):1057-1083. DOI: 10.1002/rra.948, IF 2.274 [29] (Primary author, conducted data collection, analysis, and wrote paper; product of Ph.D. research; published prior to time at USD).

Stromberg, J.C., S. J. Lite, T.J. Rychener, L. Levick, M.D. Dixon, and J.W. Watts. 2006. Status of the riparian ecosystem in the upper San Pedro River, Arizona: Application of an assessment model. *Environmental Monitoring and Assessment* 115:145-173. DOI: 10.1007/s10661-006-6549-1, IF 1.687 [32] (Contributed to GIS mapping work and data analysis; completed during postdoc at Arizona State; published prior to time at USD).

Stromberg, J.C., S.J. Lite, M. Dixon, T. Rychener, and E. Makings. 2006. Relations between streamflow regime and riparian vegetation composition, structure and diversity within the San Pedro Riparian National Conservation Area, Arizona. Chapter C, pp. 57-106, In: J.M. Leenhouts, J.C. Stromberg, and R.L. Scott, *Hydrologic Requirements of and Consumptive Ground-water Use by Riparian Vegetation along the San Pedro River, Arizona*, US Geological Survey Scientific Investigations Report 2005-5163. (Contributed to data analysis and wrote one section; completed during postdoc at Arizona State; published prior to time at USD)

Jansson, R., H. Backx, A. J. Boulton, M. Dixon, D. Dudgeon, F. Hughes, K. Nakamura, E. Stanley, and K. Tockner. 2005. Stating mechanisms and refining criteria for ecologically successful river restoration: A comment on Palmer et al. (2005). *Journal of Applied Ecology* 42:218-222. DOI: 10.1111/j.1365-2664.2005.01022.x, IF 5.301 [54] (Contributed to idea formation, discussion, and editing of manuscript; completed during postdoc at Arizona State).

Sabo, J.L., R. Sponseller, M. Dixon, K. Gade, T. Harms, J. Heffernan, A. Jani, G. Katz, C. Soykan, J. Watts, and J. Welter. 2005. Riparian zones increase regional species diversity by harboring different, not more species. *Ecology* 86(1):56-62. DOI: 10.1890/04-0668, IF 4.809 [187] (Assisted with data collection and analysis, provided feedback on manuscript; completed during postdoc at Arizona State).

Miller, J.R., M.D. Dixon, and M.G. Turner. 2004. Response of avian communities in large-river floodplains to environmental variation at multiple scales. *Ecological Applications* 14:1394-1410. DOI: 10.1890/02-5376, IF 4.314 [36] (Contributed to field data collection and provided feedback on manuscript).

Turner, M.G., S.E. Gergel, M.D. Dixon, and J.R. Miller. 2004. Distribution and abundance of trees in floodplain forests of the Wisconsin River: environmental influences at different scales. *Journal of Vegetation Science* 15:729-738. DOI: 10.1658/1100-9233(2004)015[0729:daaoti]2.0.co;2, IF 2.924 [52] (Contributed to data collection and provided feedback on manuscript).

Galbraith, H., J. Price, M. Dixon, and J. Stromberg. 2004. Using HSI models to evaluate risks to riparian wildlife habitat from climate change and urban sprawl, In: Kapustka, L. A., H. Galbraith, M. Luxon, and G. R. Biddinger (eds.), *Landscape Ecology and Wildlife Habitat Evaluation: Critical Information for Ecological Risk Assessment, Land-Use Management Activities, and Biodiversity Enhancement Practices*, ASTM STP 1458, ASTM International, West Conshohocken, PA 2004. (Conducted some analyses and provided feedback on manuscript; completed during postdoc at Arizona State).

Dixon, M.D. 2003. Effects of flow pattern on riparian seedling recruitment on sandbars in the Wisconsin River, Wisconsin, USA. *Wetlands* 23(1):125-139. DOI: 10.1672/0277-5212(2003)023 [0125:eofpor]2.0.co;2, IF 1.573 [43] (Primary author; product of Ph.D. research).

Dixon, M.D., M.G. Turner, and C. Jin. 2002. Riparian tree seedling distribution on Wisconsin River sandbars: Controls at different spatial scales. *Ecological Monographs* 72(4):465-485. DOI: 10.2307/3100052, IF 8.759 [43] (Primary author; collected all data, wrote paper, conducted most of statistical analysis; product of Ph.D. research).

Gergel, S.E., M.D. Dixon, and M.G. Turner. 2002. Consequences of human-altered floods: levees, floods, and floodplain forests along the Wisconsin River. *Ecological Applications* 12(6):1755-1770. DOI: 10.1890/1051-0761(2002)012[1755:cohafl]2.0.co;2, IF 4.314 [81] (Contributed to field data collection, provided review of and feedback on manuscript).

Osterkamp, W.R., W.C. Johnson, and M.D. Dixon. 2001. Biophysical gradients related to channel islands, middle Snake River, Idaho. In: Dorava, J., B. Palcsak, F. Fitzpatrick, and D. Montgomery (eds.), *Geomorphic Processes and Riverine Habitat: American Geophysical Union Monograph*. (Collected and analyzed vegetation data, provided feedback on manuscript).

Dixon, M.D., and W.C. Johnson. 1999. Riparian vegetation along the middle Snake River: Zonation, geographical trends and historical changes. *Great Basin Naturalist* 59(1):18-34. IF 0.491 [23] (Primary author, wrote paper, analyzed data, supervised and conducted data collection).

Dixon, M.D., W.C. Johnson, and C.S. Adkisson. 1997. Effects of weevil larvae on acorn use by Blue Jays. *Oecologia* 111:201-208. DOI: 10.1007/s004420050226, IF 3.13 [28] (Primary author, MS research).

Dixon, M.D., W.C. Johnson, and C.S. Adkisson. 1997. Effects of caching on acorn tannin levels and Blue Jay dietary performance. *Condor* 99:756-764. DOI: 10.2307/1370486, IF 2.654 [24] (Primary author, MS research).

Johnson, W.C., C.S. Adkisson, T.R. Crow, and M.D. Dixon. 1997. Nut caching by Blue Jays (*Cyanocitta cristata* L.): Implications for tree demography. *American Midland Naturalist* 138:357-370. DOI: 10.2307/2426828, IF 0.636 [45] (Conducted most of statistical analysis and assisted with writing).

Johnson, W.C., M.D. Dixon, R. Simons, S. Jenson, and K. Larson. 1995. Mapping the response of riparian vegetation to possible flow reductions in the Snake River, Idaho. *Geomorphology* 13:159-173. IF 2.958 [37] (Contributed to GIS work, statistical analysis, and writing).

Petit, K.E., M.D. Dixon, and R.T. Holmes. 1988. A case of polygyny in the Black-throated Blue Warbler. *Wilson Bulletin* 100(1):132-134. IF 0.656 [?] (Contributed to field data collection).

A.4 Published Book Reviews

Dixon, M.D. 2015. *Book review. Wetland Environments: A Global Perspective* (vol. 75, pp. 507-508). *Ecological Engineering*. dx.doi.org/10.1016/j.ecoleng.2014.09.002

Dixon, M.D. 2010. Book review of: *Waiting for Coyote's Call: An Eco-memoir from the Missouri River Bluff*, by Jerry Wilson. *Great Plains Quarterly* 30(1):71-72.

Dixon, M.D. 2008. Book review of: *The Ribbon of Green: Change in Riparian Vegetation in the Southwestern United States*, by Robert H. Webb, Stanley A. Leake, and Raymond M. Turner. *Quarterly Review of Biology* 83(3): 320.

Dixon, M.D. 2007. Book review of: *Corridor Ecology: The Science and Practice of Linking Landscapes for Biodiversity Conservation*, by Jodi A. Hilty, William Z. Lidicker Jr., and Adina M. Merenlender. *Condor* 109(3):715-716.

A.5 Unpublished Reports (partial list)

Dixon, M.D. 2017. Rare Plant and Vegetation Monitoring within the Missouri National Recreational River. Final Report to the National Park Service, Missouri National Recreational River, March 31, 2017, 52 pp.

Stewart, J. and M. Dixon. 2016. Mapping Potential Sites of Calcareous Fens in Eastern South Dakota Using Ecological Niche Modeling. Report to SD Department of Game, Fish, and Parks. Project ID: T-47-R-1, Study #: 2455. 34 pp.

Sweeney, M., T. Cowman, M. Dixon, and J. Wesner. 2016. Characterization of the Geomorphology, Sediment Sources, Vegetation, and Macroinvertebrate Diversity of the Lewis and Clark Lake Delta. Report for Research Agreement No. 2015-USD-MRI-002 between the University of South Dakota Missouri River Institute and the Missouri Sedimentation Action Coalition. November 30, 2016. 54 pp.

Dixon, M.D., C.J. Boever, V.L. Danzeisen, E.C. Munes, D.J. Quist, C.L. Merkord, W.C. Johnson, M.L. Scott, D.L. Swanson, T. Cowman, and T. Malloy. 2015. Ecological Responses to the 2011 Flood along the Missouri River: Impacts on Cottonwood Forests, Songbirds, and Landscape Change. Final Report to the U.S. Army Corps of Engineers. Project #W912HZ-12-

2-0009. 348 pp.
Dixon, M.D. 2014. Ecological Effects of Redcedar Clearing at Bow Creek Recreation Area Uplands (2008-2011). Part I: Vegetation. Final report to National Park Service, Missouri National Recreational River, December 30, 2014, 40 pp.
Cahlander-Mooers, A., M. Volke, M. Dixon, and W.C. Johnson. 2014. Classification and Mapping of Riparian Forest along the White River in South Dakota. Final Report to South Dakota Department of Game, Fish, and Parks, Grant # T-50-R-1, September 14, 2014, 142 pp.
Dixon, M.D., W.C. Johnson, M.L. Scott, and D. Bowen. 2010. Status and Trend of Cottonwood Forests along the Missouri River. Final Report to U.S. Army Corps of Engineers. Contract # W9912DQ-07-C-0011. 111 pp. http://digitalcommons.unl.edu/usarmyceomaha/78/
Dixon, M., J. Kerby, and D. Swanson. 2010. Final Report for the National Park Service, Missouri National Recreational River for "Assessment of Forest Songbird, Marsh Bird and Frog Community Composition along the Missouri National Recreational River using Auditory and Visual Census Techniques", Task Agreement # J6288100006. 39 pp.
Ley, M.J. and M.D. Dixon. 2010. 2010 Annual Report – Big Sioux River Riparian Vegetation Project. Annual Report to SD Game, Fish, and Parks. 30 pp.
Benson, A.R., M.D. Dixon, and D.L. Swanson. 2010. Effects of Landscape and Stand-level Factors on Forest Songbird Populations and Diversity across a Cottonwood Successional Gradient along the Missouri River. Final Progress Report to SD Game, Fish and Parks for 2009 Wildlife Small Grants Program, #UP0900209. 8 pp.
Dixon, M.D., W.C. Johnson, M.L. Scott, and D. Bowen. 2009. 2008 Annual Report – Missouri River Cottonwood Study. Report for U.S. Army Corps of Engineers. Contract # W9912DQ-07-C-0011.
Benson, A. and M. Dixon. 2009. Monitoring Ecological Responses to Prairie and Oak Savannah Restoration in the Missouri River Uplands. Progress Report to National Park Service (Missouri National Recreational River). 7 pp.
Dixon, M.D. and W.C. Johnson. 2008. 2007 Annual Report – Missouri River Cottonwood Study. Report for U.S. Army Corps of Engineers. Contract # W9912DQ-07-C-0011.
Johnson, W.C., G.E. Larson, and M.D. Dixon. 2006. Cottonwood Forests of the Missouri National Recreational River: Their Measurement and Ecological Health. Final Report to the Army Corps of Engineers. Project CENWK-PM-PR.

B. Grants and Contracts

B.1 Intramural Grants and Support (total $4,000 at USD)

Influence of Flow Regulation on Missouri River Floodplain Forest (2006-2007), Research Catalyst Program Award from University of South Dakota, Office of Research and Sponsored Programs, $4000.

B.2 Extramural Grants and Contracts Received or Active

Total at USD with Dixon as the PI or co-PI = $3,348,889 (awards or subawards to USD)
Total at USD with Dixon as Supporting Faculty = $6,383,719 ($2,244,719 to USD)

Evaluate the Biologic Response of a Restored Missouri River Backwater, (2020), Agency: U.S. National Park Service, $29,695. PI: D. Swanson, co-PIs; J. Wesner and M. Dixon.

Evaluating Post-Flood Sandbar Succession and Species Biodiversity Related to Listed Species Habitat, (2018-2021), Agency: U.S. National Park Service, $299,996 (+$64,428 USD in-kind cost share). PI: M. Dixon, co-PIs: D. Swanson and M. Sweeney.

Sustainable Socio-economic, Ecological, and Technological Scenarios for Achieving Global Climate Stabilization through Negative CO2 Emission Policies, (2016-2020), Agency: National Science Foundation (EPSCOR RII Track-2 FEC), $6,000,000 (USD subaward $1,860,000). PIs: B. Poulter (Montana State U.), co-PIs: P. Stoy (Montana State U.), B. Rashford (U. Wyoming), M. Jarchow, D. Swanson, Supporting: M. Dixon and J. Kerby.

Sustainable RIVER (Remediating InVasives to Encourage Resilience) (2016-2019), Agency: National Science Foundation (REU Site), $363,662, PI: M. Jarchow, Supporting: B. Jordan, J. Kerby, M. Dixon, D. Posthumus, S. Rosenfeld, M. Sayre, D. Swanson, M. Sweeney, and J. Wesner.

Genetic Diversity, Ecological Niche Modeling and Physiological Response to Climate Change for Management of Pleistocene Relict Hybrid Aspens in the Niobrara River Valley, NE, (2015-2018), Agency: U.S. National Park Service, $356,000 (USD subaward $26,285). PIs: M. Nepokroeff (USD) and J. Cavender-Bares (U. Minnesota), co-PI: M. Dixon.

Rare Plant and Vegetation Monitoring within the Missouri National Recreational River, (2015-2016), Agency: U.S. National Park Service, $24,971. PI: M. Dixon, Supporting: B. Korman (NPS).

Characterization of Sediment Sources in the Lewis and Clark Lake Delta, (2015-2016), Agency: Missouri Sedimentation Action Coalition (funding from US Environmental Protection Agency), $21,057. PIs: M. Sweeney, co-PI: T. Cowman, Supporting: J. Wesner and M. Dixon.

Ecological Responses to the 2011 Flood along the Missouri River: Impacts on Cottonwood Forests, Songbirds, and Landscape Change, (2012-2015), Agency: U.S. Army Corps of Engineers, $1,557,932. PI: M. Dixon, co-PIs: W.C. Johnson (SDSU), M.L. Scott (Utah State), D. Swanson. C. Merkord, T. Cowman, and T. Malloy (Benedictine College).

Classification and Mapping of Riparian Forest along the White River in South Dakota, (2011-2014), Agency: South Dakota Game, Fish and Parks, $122,500 (+$34,361 USD and SDSU in-kind cost share). PIs: M. Dixon and W.C. Johnson (South

Dakota State University).

Historic River Channel and Wetland Habitat Dynamics along the Missouri River, (August – December 2011), Agency: U.S. Army Corps of Engineers, contract to the Louis Berger Group, Inc., subcontract to University of South Dakota for $14,059. PI: M. Dixon.

Lewis and Clark Lake Sediment Accumulation Illustration Project, (2011-2012), Agency: Environmental Protection Agency award to Missouri Sedimentation Action Committee, subcontract to Missouri River Institute at the University of South Dakota for $12,000 (+$15,627 match from MSAC). PI: T. Cowman, Co-PIs: M. Dixon and M. Sweeney.

Projecting Long-term Landscape Change along the Missouri River: Implications for Cottonwood Forests and Songbird Populations, (2011-2013), Agency: Plains and Prairie Potholes Landscape Conservation Cooperative (U.S. Fish and Wildlife Service), $ 188,242. PIs: M. Dixon and D. Swanson, co-PI: W.C. Johnson (SDSU).

Monitoring Ecological Responses to Prairie and Oak Savannah Restoration in the Missouri River Uplands, (2011-2012), Agency: National Park Service, NRPP Regional Block Grants, $16,771 (+$250 in-kind contribution from USD). PI: M. Dixon, Partners: S.K. Wilson (NPS).

Mapping and Characterization of Calcareous Fens in Eastern South Dakota, (2010-2015), Agency: South Dakota Department of Game, Fish and Parks, South Dakota Wildlife Action Plan Competitive Grants, $74,997 (+$28,309 USD and SDSU in-kind cost share). PIs: M. Dixon and G. Larson (SDSU). Partners: T. Cowman.

Assessment of Forest Songbird, Marsh Bird and Frog Community Composition along the Missouri National Recreational River using Auditory and Visual Census Techniques, (2010), Agency: National Park Service, $7,658. PIs: M. Dixon, J. Kerby, and D. Swanson.

Classification and Mapping of Riparian Vegetation along the Big Sioux River, (2009-2012), Agency: South Dakota Game, Fish and Parks Department, South Dakota Wildlife Action Plan Competitive Grants, $74,981 (+$26,531 USD in-kind cost share). PI: M. Dixon, Partners: W. C. Johnson (SDSU), T. Cowman, G. Larson (SDSU).

Effects of Landscape and Stand-level Factors on Forest Songbird Populations and Diversity across a Cottonwood Successional Gradient along the Missouri River, (2009-2010), Agency: South Dakota Game, Fish and Parks, Small Grants Program, $6,975. PIs: A. Benson (graduate student) and M. Dixon.

Vegetation Collection, Age-class and Quality Analysis in a GIS Format for Cottonwood Forests along Moderate and High Priority River Reaches for Bald Eagles along the Missouri River, (2007-2009), Agency: US Army Corps of Engineers,

contract to Dr. W. Carter Johnson for $985,500 (subcontract to USD for $866,469). Awarded March 2007, with supplemental funding in Sept. 2007. PIs: W.C. Johnson (SDSU) and M. Dixon.

Hydrologic Thresholds for Biodiversity in Semiarid Riparian Ecosystems, (2006-2009), Agencies: US Environmental Protection Agency (EPA) and Department of Energy (DOE), Linked Aquatic – Terrestrial Ecosystem Responses, $841,881, subcontract to University of South Dakota for $25,358. PIs: K. Baird, M. Dixon, J. Hogan, S. Lite, T. Meixner, and J. Stromberg.

Stream Channel Migration and Riparian Tree Establishment, San Pedro River, (2003-2005), Agency: US Department of Agriculture and Department of Defense, $43,428 to Arizona State University. PIs: J. Stromberg, M. Dixon, and D. Goodrich.

Woody Vegetation Dynamics on Wisconsin River Sandbars: Spatial and Temporal Controls on Seedling Recruitment, (1998-2001), Agency: US-EPA-STAR (Science to Achieve Results) Graduate Fellowship, University of Wisconsin, M. Dixon.

C. Presentations

Only those for 2015 and later are shown (n = 59), Total for Career (n =190)
Includes those for which I was co-author, but did not present personally
* Denotes invited presentation.
Presentations are talks, unless indicated otherwise (i.e., if poster).
First author is presenter, unless noted otherwise
Bold indicates current or past USD graduate or undergraduate student (or REU student)

Nefas, S.M., M.D. Dixon, and D.L. Swanson. 2019. Bird use of early successional sandbar vegetation: what do we lose by managing for plovers and terns? Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, November 21, 2019.

Hegg, A., M.D. Dixon, and D.L. Swanson. 2019. Effects of invasive Russian olive and eastern red cedar on bird nest survival in Missouri River riparian forests. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, November 21, 2019.

Baltensperger, A., M.D. Dixon, and D.L. Swanson, D. (Presenter & Author). 2019. Modeling the implications of future bioenergy scenarios on bird diversity and abundance in the upper Missouri River basin. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, November 21, 2019.

Goljani-Amirkhiz, R., M.D. Dixon, J. Palmer, and D.L. Swanson. 2019. Applying an Ensemble of Small Models to Predict Breeding Distribution of a Rare Species: Virginia's Warbler (*Oreothlypis virginiae*) at the Northeastern Periphery of its Range. South Dakota Ornithologists' Union, Pierre, SD, October 5, 2019.

Hegg, A., M.D. Dixon, and D.L. Swanson. 2019. Impacts of Invasive Trees on Nest Survival of Birds in Missouri River Riparian Forests. South Dakota Ornithologists' Union," Pierre, SD, October 5, 2019.

Swanson, D.L., A. Baltensperger, and M.D. Dixon. 2019. Modeling the Implications of Future

Bioenergy Scenarios on Bird Diversity and Abundance in the Northern Great Plains. South Dakota Ornithologists' Union, Pierre, SD, October 5, 2019.

Goljani-Amirkhiz, R., J. Palmer, M.D. Dixon, and D.L. Swanson, D. (Presenter & Author). 2019. Applying an ensemble of small models to predict breeding distribution of Virginia's Warbler at the northeastern periphery of its range. American Ornithological Society, Anchorage, AK, June 28, 2019.

Swanson, D.L., **S.M. Nefas,** and M.D. Dixon. 2019. Early cottonwood-willow successional forest avian diversity: What do we lose by managing sandbars for plovers and terns? American Ornithological Society, Anchorage, AK, June 28, 2019.

Hegg, A., M.D. Dixon, and D.L. Swanson. 2019. Invasive plants and bird nesting success in Missouri River riparian forests. American Ornithological Society, Anchorage, AK, June 28, 2019.

Baltensperger, A., **R. Goljani-Amirkhiz**, M.D. Dixon, and D.L. Swanson. 2019. Modeling the implications of future bioenergy scenarios on bird diversity and abundance in the northern Great Plains. American Ornithological Society, Anchorage, AK, June 27, 2019.

Swanson, D.L., M.D. Dixon, and A. Baltensperger. 2019. Grassland bird population projections for different climate and land-use scenarios in the Upper Missouri River Basin. NSF RII Track 2 – Water, Agriculture, Food, Energy, Research Nexus Annual Meeting, Vermillion, SD, June 10, 2019.

***Illeperuma, N.**, **M. Harishchandra**, and M.D. Dixon. 2019. A remote sensing and machine learning approach to map the historical expansion of eastern redcedar along the Missouri River. Invited Riparian Symposium talk at U.S. Chapter of the International Association for Landscape Ecology Annual Symposium, Fort Collins, CO, April 9, 2019.

*Dixon, M.D., M.A. Volke, **C.C. Beall**, M.L. Scott, and W.C. Johnson. 2019. Emerging Delta-backwaters on the Regulated Missouri River: Implications for Cottonwood Recruitment. Invited Riparian Symposium talk at U.S. Chapter of the International Association for Landscape Ecology Annual Symposium, Fort Collins, CO, April 9, 2019.

Swanson, D.L., J. Wesner, M.D. Dixon**, J. Warmbold, D. Quist, L.A. Yager**, **E. Oddy**, and **T. Seidel**. 2019. Loss of aquatic-terrestrial subsidies in the Missouri River after 122 years of habitat modification. Missouri River Natural Resources Conference, Pierre, SD, March 7, 2019.

Swanson, D.L., **S.M. Nefas**, and M.D. Dixon. 2019. Bird use of early successional sandbar vegetation for nesting: what do we lose by managing for terns and plovers? Missouri River Natural Resources Conference, Pierre, SD, March 6, 2019.

Swanson, D.L., **A. Hegg**, and M.D. Dixon. Invasive plants and bird nesting success in Missouri River riparian forests. Missouri River Natural Resources Conference, Pierre, SD, March 6, 2019.

Dixon, M.D., **C.C. Beall**, M. Sweeney, M.A. Volke, W.C. Johnson, and M.L. Scott. 2018. Deltas as Unique Habitats on the Missouri River. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, November 15, 2018.

Nefas, S.M., M.D. Dixon, and D.L. Swanson. 2018. Evaluating Post-Flood Sandbar Avian Species Biodiversity. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, November 15, 2018.

Illeperuma, N., and M.D. Dixon. 2018. Historical Patterns and Impacts of the 2011 Flood on Eastern Red Cedar Distribution along the Missouri River. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, November 15, 2018.

Hegg, A., M.D. Dixon, and D.L. Swanson. 2018. Impacts of Invasive Tree Species on Bird Nesting Success in Missouri River Riparian Forests. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, November 15, 2018.

Beall, C.C., and M.D. Dixon. 2018. Vegetation Dynamics and Cottonwood Recruitment on the Lewis and Clark Delta. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, November 15, 2018.

Sweeney, M., and M.D. Dixon. 2018. Are Missouri River reservoir deltas sustainable? A closer look at Lewis and Clark Lake delta. USD Sustainability Seminar (SUST 790), Department of Sustainability and Environment, University of South Dakota, Vermillion, SD, October 23, 2018.

Goljani Amirkhiz, R., M.D. Dixon, J. Palmer, and D.L. Swanson. 2018. Ensemble modeling to predict Virginia's Warbler (*Oreothlypis virginiae*) breeding distribution at the northeastern periphery of its range. Ecological Society of America, New Orleans, LA, August 2018.

Bayer, L., D. Swisher, A. Hegg, M.D. Dixon, and D.L. Swanson. 2018. Evaluating nesting success in Russian olive (*Elaeagnus angustifolia*) and native trees along the Missouri River, SD. South Dakota EPSCoR Undergraduate Research Symposium, Pierre, SD, July 26, 2018.

Swanson, D.L., **A. Hegg**, and M.D. Dixon. 2018. Effects of invasive trees on nesting productivity for breeding birds in Missouri River floodplain forests. Missouri River Ecosystem Coordination Group, DeSoto National Wildlife Refuge, IA, June 21, 2018.

Beall, C.C., and M.D. Dixon. 2018. Woody vegetation dynamics on a Missouri River reservoir delta. Society of Wetland Scientists, Denver, CO, June 1, 2018.

Dixon, M.D. 2018. Introduction to Riparian Symposium Session II: Physical & Biotic Drivers of Change. Society of Wetland Scientists, Denver, CO, May 31, 2018.

Swanson, D.L., **A. Hegg**, **G. Gray-Lobe**, **S. Ruiz**, and M.D. Dixon. 2018. Effects of invasive trees on nesting productivity for breeding birds in Missouri River floodplain forests. Missouri River Natural Resources Conference, Nebraska City, NE, March 2018.

Dixon, M.D., M.E. Jarchow, and D.L. Swanson. 2018. Sustainable RIVER: Research Experiences for Undergraduate Students on Missouri River Science. Missouri River Natural Resources Conference, Nebraska City, NE, March 22, 2018.

Illeperuma, N., M.D. Dixon, and J.E. Vogelmann. 2018. Historical Patterns and Impacts of the 2011 Flood on Redcedar Distribution along the Missouri River. Missouri River Natural Resources Conference, Nebraska City, NE, March 21, 2018.

Beall, C.C., and M.D. Dixon. 2018. Woody Vegetation Dynamics on the Niobrara River / Lewis and Clark Reservoir Delta. Missouri River Natural Resources Conference, Nebraska City, NE, March 21, 2018.

Beall, C.C., and M.D. Dixon (Presenter & Author). 2018. Vegetation Composition and Dynamics within the Lewis and Clark Delta," Emergent Sandbar Habitat Program, Nebraska & South Dakota Interagency Meeting, US Army Corps of Engineers, Gavins Point Dam Visitor Center, Crofton, NE, January 25, 2018.

Gray-Lobe, G., **S. Ruiz**, **J. Emmick**, **A. Hegg**, M.D. Dixon, and D.L. Swanson. 2017. Impacts of Invasive Trees on Breeding Birds in Riparian Forests. South Dakota EPSCoR Undergraduate Research Symposium, Pierre, SD, August 2017.

*Dixon, M.D., K.J. Skalak, **D.J. Quist**, M.L. Scott, and W.C. Johnson. 2017. Longitudinal Controls on Landform and Vegetation Dynamics on Inter-Dam Segments of the Missouri River. Invited symposium talk at U.S. Chapter of the International Association for Landscape Ecology Annual Symposium, Baltimore, MD, April 10, 2017.

Dixon, M.D. 2017. Spatial patterns of vegetation dynamics on inter-dam segments of the Missouri River Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, March 29, 2017.

Beall, C.C. and M.D. Dixon. 2017. Spatial patterns of vegetation within the Lewis and Clark Delta. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, March 29, 2017.

Beall, C.C. and M.D. Dixon. 2017. Spatial Patterns in Vegetation Composition within a Novel Reservoir Delta on the Missouri River (poster presented by C. Beall). Missouri River Natural Resources Conference, Nebraska City, NE, March 22, 2017.

*Dixon, M.D. 2017. Effects of River Management on Cottonwood Forests & Songbirds along the Missouri River. Invited talk to University of South Dakota Biology Club, Vermillion, SD, March 1, 2017.

Merkord, C.L., M.D. Dixon, and D.L. Swanson. 2017. Bird-habitat relationships in floodplain forests along the middle Missouri River. Midwest Fish and Wildlife Conference, Lincoln, Nebraska, February 6, 2017.

Dixon, M.D., C.L. Merkord, D.L. Swanson, W.C. Johnson, and M.L. Scott. 2017. Trajectories of decline in cottonwood forests along the Missouri River: Implications for songbirds. Midwest Fish and Wildlife Conference, Lincoln, Nebraska, February 6, 2017.

Dixon, M.D., **C.J. Boever**, **V.L. Danzeisen**, C.L. Merkord, M.L. Scott, and W.C. Johnson. 2016. The "Cottonwood Conundrum" and the 2011 Flood on the Missouri River. South Dakota Academy of Science, Sioux Falls, SD, April 9, 2016.

Dixon, M.D., C.L. Merkord, **E.C. Munes**, **A.R. Benson**, D.L. Swanson, and W.C. Johnson. 2016. Cottonwood Forests and Landbirds along the Missouri River: Current Trends and Future Prospects. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, April 7, 2016.

Robertson, J.M., M.D. Dixon, **A. Cahlander-Mooers**, and **C.C. Beall**. 2016. Assessment and Management of Hybrid Aspen Stands (*Populus xsmithii*) in the Niobrara River Valley of Northwest Nebraska. 2016 Annual Meeting Midwestern Section American Society of Plant Biologists, Brookings, SD, March 19, 2016.

Beall, C.C. and M.D. Dixon. 2016. Spatial Patterns in Vegetation Composition within a Novel Reservoir Delta on the Missouri River (poster by C. Beall). 2016 Annual Meeting Midwestern Section American Society of Plant Biologists, Brookings, SD, March 19, 2016.

Boever, C.J., M.D. Dixon, W.C. Johnson, and M.L. Scott. 2016. The Flood of 2011: Effects of a Large Infrequent Disturbance on Riparian Forest Vegetation along the Missouri River. 2016 Annual Meeting Midwestern Section American Society of Plant Biologists, Brookings, SD, March 19, 2016.

Dixon, M.D., **C.J. Boever**, **V.L. Danzeisen**, **E.C. Munes**, C.L. Merkord, D.L. Swanson, M.L. Scott, and W.C. Johnson. 2016. Cottonwood Forest Dynamics and Impacts of the 2011 Flood on the Missouri River. Biology Seminar, Department of Biology, University of South Dakota, Vermillion, SD, February 29, 2016.

*Dixon, M.D., M.A. Volke, W.C. Johnson, M.L. Scott, and C.L. Merkord. 2016. The "Cottonwood Conundrum" & the Potential Role of Reservoir Deltas on the Missouri River. Invited webinar to Plains and Prairie Potholes Landscape Conservation Cooperative (U.S. Fish and Wildlife Service), February 3, 2016.

Munes, E.C., C.L. Merkord, M.D. Dixon, and D.L. Swanson. 2015. Projecting long-term effects of the 2011 Missouri River flood on floodplain bird populations (poster designed by Munes, presented by Swanson). NSF Food, Energy Water Nexus Workshop, SD EPSCoR/NSF, Rapid City, SD, October 2015.

Dixon, M.D., **C.J. Boever**, **V.L. Danzeisen**, C.L. Merkord, M.L. Scott, W.C. Johnson, and T. Malloy. 2015. Impacts of a large flood event on cottonwood forests along the regulated Missouri River, USA, International Society for River Science 4th Biennial Symposium, La Crosse, Wisconsin, August 24, 2015.

Dixon, M.D., **C.J. Boever**, **V.L. Danzeisen**, C.L. Merkord, M.L. Scott, W.C. Johnson, and T. Malloy. 2015. Effects of a Large Infrequent Flood Disturbance on Cottonwood Forests along the regulated Missouri River (talk presented by Merkord). International Association of Landscape Ecology, 9th World Congress, Portland, OR, July 9, 2015.

*Dixon, M.D., **C.J. Boever**, **V.L. Danzeisen**, C.L Merkord, W.C. Johnson, M.L. Scott, and T. Malloy. 2015. The "Cottonwood Conundrum" & the Flood of 2011. Invited talk in Big Muddy Speaker Series, Missouri River Relief, Rocheport, MO, May 12, 2015.

Dixon, M.D. 2015. Cottonwood Forest Dynamics along the Missouri River. Informal presentation to lab group of Dr. Hong He, Forestry Department, Univ. Missouri, Columbia, MO, April 16, 2015.

Dixon, M.D., C.J. Boever, V.L. Danzeisen, C.L. Merkord, W.C. Johnson, M.L. Scott, and T. Malloy. 2015. Effects of River Regulation and the Flood of 2011 on Missouri River Cottonwood Forests. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, April 9, 2015.

Boever, C.J., M.D. Dixon, W.C. Johnson, M.L. Scott, and T. Malloy. 2015. Effects of the flood of 2011 on riparian forest structure and composition along the Missouri River. Missouri River Institute Symposium, University of South Dakota, Vermillion, SD, April 9, 2015.

Dixon, M.D., **C.J. Boever**, **V.L. Danzeisen**, C.L. Merkord, W.C. Johnson, M.L. Scott, and T. Malloy. 2015. Effects of the 2011 Flood on Cottonwood Forests along the Missouri River. Missouri River Natural Resources Conference, Nebraska City, NE, March 11, 2015.

Boever, C.J., M.D. Dixon, M.L. Scott, and W.C. Johnson. 2015. Post-flood Changes in Riparian Forest Structure Along the Missouri River from 2012-2014 (poster by C. Boever). Missouri River Natural Resources Conference, Nebraska City, NE, March 11, 2015.

*Dixon, M.D., **C.J. Boever**, **V.L. Danzeisen**, C.L. Merkord, W.C. Johnson, M.L. Scott, and T. Malloy. 2015. Effects of the 2011 Flood on Cottonwood Forests along the Missouri River. Invited Brown Bag Seminar/Webinar to USDA-Agricultural Research Service, Sidney, MT, March 6, 2015).

*Dixon, M.D., **C.J. Boever**, **V.L. Danzeisen**, C.L. Merkord, W.C. Johnson, M.L. Scott, and T. Malloy. 2015. Effects of the 2011 Missouri River Flood on Cottonwood Forests in the Northern Great Plains. Invited Brown Bag Seminar, US Geological Survey - Columbia Environmental Research Center, Columbia, MO, March 4, 2015.

Dixon, M.D. 2015. Cottonwood Forest Dynamics along the Missouri River. Informal presentation to Robb Jacobson lab group, US Geological Survey - Columbia Environmental Research Center, Columbia, MO, January 9, 2015.

IV. SERVICE AND ENGAGEMENT

A. Specific Administrative Appointments (e.g., chair, dean): None

B. External Service

1. Extramural Review Panels

Technical Advisory Panelist on Terrestrial Focal Natural Resources for Missouri River Ecosystem Restoration Plan (January 2010 – October 2011). Provided technical input to the MRERP program (US Army Corps of Engineers and US Fish and Wildlife Service) for development of conceptual models for terrestrial focal natural resources (key ecosystem types and species). Models will be used to assess current conditions and stressors, develop ecological indicators, and plan restoration of key natural resources along the entire Missouri River. Duties included participating in workshops and conference calls, reviewing technical documents, and providing literature and data sources to the team. (Note: Also listed below under Consulting/Contract Work).

2. Editorships/Reviewing

Reviewer, Ad Hoc Reviewer, Pre-tenure progress for faculty member (Brian Buma), Department of Integrative Biology, University of Colorado - Denver. (August 5, 2019 - September 15, 2019).

Reviewer, Ad Hoc Reviewer, Promotion of full professor for faculty member (John Stella) Department of Forestry & Natural Resources Management, SUNY-Syracuse. (December 13, 2018 - December 15, 2018).

Reviewer, Grant Proposal, National Science Foundation. (May 22, 2018).

Courtesy reviewer for manuscript for Brazilian ecologist, (February 22, 2017). Volunteered to review manuscript and provided feedback prior to journal submission.

Reviewed book chapter: "Restoration Ecology of Intermittent Streams" for book: *Intermittent Rivers and Ephemeral Streams: Ecology and Management* (May 2016)

Co-Organizer/Guest Editor, Special Issue in journal *Ecohydrology*, entitled "Restoring Functional Riparian Ecosystems: Concepts and Applications" (Sept. 2013-July 2015).

Book review: *Wetland Environments: A Global Perspective* (see published book reviews, June 2014).

Courtesy reviewer for book chapter: "Landscape Ecology of Wetlands: Overview" for *The Wetland Book I: Structure and Function, Management, and Methods*. Reviewed pre-submission version of chapter and provided feedback to colleague (June 2013).

Reviewed draft sections of Missouri National Recreational River Natural Resource Condition Assessment (on land-use, land birds, cottonwood forests) for National Park Service (MNRR), Spring 2011.

Reviewer of grant application to the Swiss National Science Foundation (January 2011)

Invited technical peer reviewer for manuscripts (3) and conference papers/abstracts (4) from US Geological Survey employees (2010-2015)

Reviewer of vegetation portions of Missouri River Ecosystem Restoration Plan (MRERP) Research Compendium key questions documents for US Army Corps of Engineers (January 2008)

Official reviewer of application of candidate for Killam Research Fellowship from the Canada Council for the Arts (Sept. 2007). The Killam Research Fellowship is a prestigious $70,000 (Canadian) two-year release-time award given to selected Canadian academic scholars with outstanding research records.

Reviewer of historical condition vegetation system descriptions for Western Great Plains Floodplain Systems and Eastern Great Plains Floodplain Systems for the LANDFIRE project of The Nature Conservancy (July 2007). LANDFIRE is a 5-year multi-partner ecosystem, fire, and fuel-mapping project for the U.S. (www.landfire.gov).

***Ad hoc* Reviewer,** Appointed (2012-2019), ~100 articles across >20 journals since 2012.

***Ad hoc* Peer Reviewer** for the following 27 journals (~ 4-8 per year) up to Fall 2011: *Journal of Applied Ecology, American Midland Naturalist, Ecological Applications, Ecology, Ecological Monographs, Great Basin Naturalist, Southwest Naturalist, Landscape Ecology, Plant Ecology, Ecosystems, Tree Physiology, Wetlands, BioScience, Journal of Biogeography, Conservation Biology, Journal of Vegetation*

Science, Journal of the American Water Resources Association, Urban and Landscape Planning, Biological Conservation, Ecological Modelling, River Research and Applications, Basic and Applied Ecology, Restoration Ecology, Plant Species Biology, Water Resources Research, Journal of Arid Environments, Trees – Structure and Function

Reviewed final report (avian ecology, vegetation, and integrated sections) on environmental impacts of dams in the Grand Canyon for US Geological Survey: "Inventory and Monitoring of Terrestrial Riparian Resources in the Colorado River Corridor of Grand Canyon: An Integrated Approach", Summer 2006 (prior to USD).

External reviewer for Habilitation Thesis, "Cultural landscapes and anthropogenic ecosystems – linking history and ecology," for Dr. Matthias Bürgi, Swiss Federal Institute of Technology Zurich (ETH) – January 2006

Reviewed Grant Proposals (pre-2006) for: Cal-Fed Ecosystem Restoration and Science programs, USDA Managed Ecosystems program, and International Arid Lands Consortium

3. State Service

4. Consulting/Contract Work

Expert Witness for U.S. Department of Justice, Environmental and Natural Resources Division, Appointed (Aug. 2016-Oct. 2019). Provide expert opinion/testimony on riparian vegetation for federal water rights case related to the upper San Pedro River in Arizona. Trial was in late January 2019.

Technical Advisory Panelist on Terrestrial Focal Natural Resources for Missouri River Ecosystem Restoration Plan (January 2010 - present). Provide technical input to the MRERP program (US Army Corps of Engineers and US Fish and Wildlife Service) for development of conceptual models for terrestrial focal natural resources (key ecosystem types and species). Models will be used to assess current conditions and stressors, develop ecological indicators, and plan restoration of key natural resources along the entire Missouri River. Duties included participating in workshops and conference calls, reviewing technical documents, and providing literature and data sources to the team (Note: Also listed above under Extramural Review Panels).

San Pedro River and Middle Rio Grande Economic Valuation Study (August 1, 2007 – Dec. 15, 2008). Subcontract from the University of Arizona. Responsible for GIS work, vegetation modeling, and scientific input to study evaluating non-market values of intact and altered riparian ecosystems in the Southwest, with focus on San Pedro River (Arizona) and the Middle Rio Grande (New Mexico).

Vegetation and Permanence of Goat Island, Missouri River, South Dakota (2006-

2007). Subcontractor to W. C. Johnson; contract to Johnson from Office of Attorney General, State of South Dakota. Assisted with determination of approximate age and permanence of Goat Island, based on field visits, analysis of historic documents and maps, and mapping using a Geographic Information System

5. Other Activities

Other Professional Service

Co-Organizer & Presenter, Special Session on Riparian Ecosystems, Society of Wetland Scientists 2018 Conference, Denver, CO. (October 2017 - May 31, 2018). Session was May 31, 2018. Am also organizing and serving as a guest editor on a special feature in *Wetlands* based loosely on the organized session.

Technical Expert for Confederated Tribes and Bands of the Yakama Nation, Invited/Appointed (Sept. 15, 2017). Provided technical advice (via 1.5 hour phone conversation) on restoration and monitoring of cottonwood forests along the Yakima River within Yakama Nation Reservation Lands (Wapato Reach), Toppenish, Washington. Information gained experts will be compiled into a technical memo to help inform ecosystem restoration and management planning for this reach of the Yakima River.

Expert Witness for U.S. Department of Justice, Environmental and Natural Resources Division, Appointed (Aug. 2016 – Oct. 2019). Provide expert opinion/testimony on riparian vegetation for federal water rights case related to the upper San Pedro River in Arizona. Trial was in Jan. 2019. See also above under Consulting.

Attendee/Participant, Missouri River Research Strategy Meeting related to Missouri River ecosystem productivity with Nebraska Game and Parks Commission (April 20, 2016). Group decided to have Missouri River symposium at 2017 Midwest Fish and Wildlife Conference.

Attendee/Participant, MNRR Science Collaboration Workshop with US National Park Service - Missouri National Recreational River (Feb. 25, 2016). Discussed research needs/priorities, data sharing and compilation, etc. for aquatic and terrestrial biota on Missouri River.

Attendee/Presenter, Meeting with NPS-MNRR on possible conflicts between Emergent Sandbar Habitat (ESH) management and cottonwood regeneration on Missouri River (Nov. 19, 2014)

Attendee/Presenter at Annual NE/SD Emergent Sandbar Habitat Meeting with US Army Corps of Engineers, Yankton, SD (Oct. 29-30, 2014).

Attendee/Presenter, USGS workshop entitled "Large Midwestern Rivers: Quantifying Ecosystem Connectivity" (Aug. 25, 2014). Brainstormed over key research needs and opportunities for collaboration with USGS on Missouri and Niobrara rivers.

Co-Organizer & Presenter, Special Session entitled "Riparian Research and Management Challenges in Large River Systems", Ecological Society of America 2014 Annual Meeting, Sacramento, CA (Nov. 2013 – Aug. 2014). Session was Aug. 12, 2014.

Co-Organizer/Moderator/Presenter, Symposium entitled "Restoring Functional Riparian Ecosystems: Concepts and Applications" at Society for Ecological Restoration 2013 World Conference, Oct. 8, 2013 in Madison, WI (Oct. 2012 – Dec. 2013).

Attendee, Public Meetings on Conceptual Site Plant Development for North Alabama and Audubon Bend properties of the US Army Corps of Engineers, Vermillion, SD (Aug. 8, 2012) and Wynot, NE (Aug. 9, 2012)

Organizer and Presenter, Symposium on Cottonwood Biology – "Cottonwoods: Status, Trends, and Futures" – at Missouri River Natural Resources Conference and BiOp Forum, Pierre, SD, March 15, 2012.

Invited participant/panelist in National Park Service Missouri National Recreational River ORV (Outstanding Remarkable Values) Workshop in Vermillion, SD (August 22-24, 2011). Provided input to designation of Outstanding Remarkable Values and designation of river reaches with those values for ecological resources within the Missouri National Recreational River.

Organizer and Moderator of Organized Oral Session, "Integration of Science with Ecological Valuation of Semi-arid Riparian Ecosystems" at Ecological Society of America annual conference in Albuquerque, NM, August 2009.

Participant in Cottonwood Community Habitat Model Workshop, sponsored by US Army Corps of Engineers, Vermillion, SD (March 31-April 3, 2009).

Presenter and participant in Habitat Evaluation Procedures (HEP) Analysis for Cottonwood Riparian Community, MNRR Mitigation for Bald Eagle RPMs, Baseline Results and Without Project Trends Meeting, sponsored by US Army Corps of Engineers, Vermillion, SD (February 20-22 and Nov. 18-21, 2008).

Invited lecturer for Land and Water Interactions seminar class at South Dakota State University, October 30, 2007, Brookings, SD (Note: Also included in Presentations)

Participant and presenter in Cottonwood Management Plan Programmatic Environmental Assessment Scoping Meeting and Habitat Modeling Workshop in Yankton, SD (August 21-23, 2007), sponsored by U.S. Army Corps of Engineers.

Participated in Missouri River Research Compendium workshop for US Army Corps of Engineers (Feb. 6, 2007) to develop key questions and conceptual models of ecological function and restoration in the Missouri River.

Participant in Bill Williams River Ecosystem Flows Workshop (sponsored by The Nature Conservancy and US Army Corps of Engineers), March 16-18, 2005 at Arizona State University

Mentor for SEEDS (program for minority students in ecology) student at 2002 ESA Conference

Chair/Moderator of Session: "Riparian Ecology", 2002 Ecological Society of America Conference

Chair/Moderator of Session: "Vegetation Pattern and Plant-Environment Relationships", 2001 US Chapter of the International Association for Landscape Ecology (US-IALE) Conference

Community Outreach:

Interviewed by Joplin Globe newspaper for article "Cottonwood Loss Another Change Observed along Missouri River", Feb. 5, 2017 (Jan. 31 – Feb. 5, 2017).

Interviewed by Yankton Press & Dakotan newspaper (with Tim Cowman and David Swanson) for article "A Repeat? Five Years After 2011 Flood, Officials Work to Answer Questions, Forecast Future", Oct. 29, 2012 (Oct. 28-29, 2016).

Interviewed by KCAU-TV Channel 9 (ABC Affiliate in Sioux City, IA) for story "This Week is the 5-Year Anniversary of the Flooding of the Missouri River: One Man Recalls the Chaos", (aired May 31, 2016).

Guest Speaker, Big Muddy Seminar Series, Missouri River Relief, Rocheport, MO. Gave talk "The 'Cottonwood Conundrum' and the Flood of 2011" (May 12, 2015)

Guest Speaker, Missouri River Watershed School Festival. Gave poster presentation on cottonwood forests to 6 groups (~75-100 kids total) of local middle and high school students (May 2, 2014).

Interviewed by SD Public Broadcasting (along with Tim Cowman about

ecological impacts of Missouri River flood for documentary "Challenging Waters" (aired June 12, 2012).

Interviewed by Yankton Press & Dakotan newspaper for article about 2011 Missouri River flood and upcoming Missouri River Educational Lecture series (interview on March 20, 2012, article published June 7, 2012).

Interviewed by KDLT-TV News (NBC affiliate in Sioux Falls, SD) about class on Missouri River at Ponca State Park (Science, Culture, and History of the Missouri River), July 20, 2011 ("USD Instructors Promote Missouri River Flood Education"). http://www.kdlt.com/index.php?option=com_content&task=view&id=10758&Itemid=57

Gave presentation on my research to USD Biology Club (Dec. 11, 2009).

Hosted visit to my lab by Vermillion Middle School students (4 groups, ~30 students total) as part of a science inquiry theme (August 30, 2008). Talked about questions, approaches, and findings of my landscape ecological research on the Missouri River.

Presenter at 3rd Annual Clay County 5th Graders "River Appreciation Day" in Vermillion, SD. Co-lead sessions on river plants with Ron Thaden (April 25, 2008)

Assisted with Science Olympiad, Ecology section, for South Dakota Middle School and High School students at University of South Dakota (April 5, 2008 and March 28, 2009)

Participant and presenter in public program and panel discussion on the future of cottonwood forests along the Missouri River, Betty Strong Encounter Center, February 17, 2008, Sioux City, Iowa. **Interviewed on KCAU-TV Channel 9 Eyewitness News** (ABC affiliate in Sioux City).
Hosted four visiting undergraduate students from Benedictine College (Atchison, Kansas) during a visit to my lab to learn ArcGIS and aerial photography interpretation basics (February 14, 2008)

Invited speaker for Missouri River Futures (stakeholder group for issues on the Missouri River) full-group meeting, November 7, 2007, Ponca, NE (also in Presentations section).

Invited speaker at monthly meeting of Living River Group chapter of the Sierra Club, March 20, 2007, Vermillion, SD (also in Presentations section).

Panelist in USD School of Business International Forum: "Global warming and South Dakota: When will the Missouri dry up?" February 28, 2007 (noon) at Al Neuharth Media Center, University of South Dakota. (also see Presentations

section).

C. University Service

C.1 University Committees

Campus Tree Advisory Committee, (April 2017-present). Help meet requirements to re-establish USD as a Tree Campus USA by National Arbor Day Foundation. Provide input to campus tree care plan and service learning activities.

U.Discover Evaluation Committee, Committee Member (February 2017 - Present). Evaluated U.Discover summer research program applications, helped interview candidates, and helped select awardees.

Graduate Council, University level committee, Elected (Fall 2009 – Spring 2013)
Committee approves policies for the graduate programs at the University, decides on changes of curriculum requests, approves designation of faculty to graduate status, and selects student awardees for several graduate research scholarships. In addition, I (with two other committee members) helped develop a more standardized protocol for students to apply for awards and for the Graduate Council to score and select awardees.

C.2 College/Division Committees and Offices

College of Arts and Sciences Enrollment Management Committee, (September 2018 - Present).

Promotion and Tenure Committee for Biology Department, Committee Chair (Sept. 15 – Nov. 5, 2019). Organized meeting, reviewed application packet for full professor for one candidate, and wrote letter stating recommendations of committee.

Nolop Nomination Committee, Committee Member (November 5, 2018 - January 7, 2019). Reviewed applications and made recommendations for Nolop Professorship and Nolop Distinguished Professorship in Biology Department.

Promotion and Tenure Committee for Physics Department, Outside Member (Oct. 6 - 30, 2017 - Present). Review one application for promotion.

Promotion and Tenure Committee for English Department, Outside Member (Oct. 2 – Nov. 13, 2017). Review one application for tenure and promotion and three pre-tenure reviews.

College Blue Ribbon Task Force on Student Recruitment, Member (Sept. 2017-August 2018). Help develop and implement strategies for increasing undergraduate student recruitment at USD. Serve as contact person for Biology (see below).

Arts & Sciences Scholarship Committee, College of Arts and Sciences, Appointed (Spring 2008-Spring 2009, Fall 2015-present). Helped review and select awardees for several student scholarships offered through the College of Arts and Sciences.

Sustainability Program Affiliate Faculty (Aug. 2015-present)

Missouri River Institute Internal Advisory Committee, Member (April 2013-June 2014). Provide input on funding initiatives, etc. for Missouri River-related research.

Missouri River Institute Affiliated Faculty (Aug. 2006-present)

Science Division Vice Chair, College of Arts and Sciences, Elected (Fall 2008-Fall 2009)

C.3 Biology Department Committees

Spatial Modeler Faculty Search Committee, Member (Sept. 21 – Dec. 15, 2018). Reviewed applications, helped conduct Skype interviews, and helped select finalists who were invited to campus to interview.

Ecological Modeler Postdoc Search Committee, Member (May 1, 2018 - July 24, 2018). Reviewed applications, helped conduct Skype interviews, and helped select candidate.

Ecological Modeler Faculty Search Committee, Member (November 2017 - April 2018). Reviewed applications, helped conduct Skype interviews, and helped select finalists who were invited to campus to interview.

Biology Public Relations Committee, Member (Sept. – Oct. 2017). Help develop materials and ideas for promoting the Biology Department, particularly for student outreach. Help develop updated brochure for Biology major.

Biology Contact for Student Recruitment, Appointed (Sept. 2016-present). Serve as contact in Biology Department for College Blue Ribbon Task Force on Student Recruitment (see above). Contact/correspond with potential Biology undergraduate students (emailed ~1500 in Spring 2017), help draft outreach materials, periodically meet and talk with students and families during campus visits, assist chair by serving as departmental point person at recruiting events, as needed.

Curriculum Planning and Review Committee, Member, (Aug. 2006-Aug. 2013, Feb. 2016-present)

Graduate Steering Committee, Chair, (Sept. 2011-Sept. 2014), Member (Sept. 2015-present). As Chair, drafted and submitted substantive program modifications for MA, MS, and PhD programs. As member, helped develop policy, screen and select students for graduate program, and select Ph.D. students for departmental RA positions.

Ad Hoc Committee re: Senior Seminar & Writing Intensive Course Requirement, Member, (Feb. -Sept. 2016)

Ad Hoc Committee for Departmental Improvement, Member (Sept.-Dec. 2014)

Biology Space Committee, Chair, (Sept.-Dec. 2014)

Ecosystem Biologist Search Committee, Chair, (Sept. 2012-Feb. 2013). Helped advertise, select candidates, schedule interviews, host candidate visits. Search succeeded in hiring Dr. Jeff Wesner.

Public Relations Committee, Chair, (Sept. 2011-Aug. 2012), Member (Fall 2009-Sept. 2011)
Helped develop departmental annual newsletters in 2011 and 2013, with information about faculty research areas, student awards, alumni updates, etc. Newsletter was circulated to alumni and for fundraising purposes.

Biology Travel Committee, Member (Fall 2011-Spring 2012). Helped select graduate student awardees for departmental travel grants.

Ad Hoc Committee on Biology Curriculum Revision, Member (Fall 2008). Discussed changes to Biology curriculum, particularly on whether biology introductory sequence should be changed from four to two semesters. Curriculum was changed to two-semester introductory biology sequence.

Aquatic Biologist faculty position search committee, Member (Fall 2007-Spring 2008). Helped review applications, select short-list of interview candidates, and conduct interviews.

Missouri River Institute Executive Director search committee, Member (Fall 2006-Spring 2007). Helped recruit applicants, review applications, select short-list of interview candidates, and conduct telephone and in-person interviews.

Biology Library Committee, Member (Fall 2007-Spring 2008)

Biology Equipment Committee, Member (Fall 2007-Spring 2008)

Biology Foundation Committee (Fall 2006-Spring 2007)

Appendix IV: Curriculum Vitae of Olden, Julian, D., Ph.D.

Julian D. Olden
Professor
School of Aquatic and Fishery Sciences
University of Washington

Professional Preparation

University of Wisconsin	Limnology	Pos. D., 2006
Colorado State University	Ecology	Ph.D., 2004
University of Toronto	Zoology	M.Sc., 2000
University of Toronto	Zoology	B.Sc., 1998

Professional Appointments

Professor	Univ. Washington	2016 -
Associate Professor	Univ. Washington	2011 - 2016
Adjunct Research Fellow	Griffith University	2006 -
Assistant Professor	Univ. Washington	2006 - 2011

Publications (selected from 260 total publications, h-index=70)

Olden, J.D., J.R.S. Vitule, J. Cucherousset, and M.J. Kennard. 2020. There's more to fish than just food: Exploring the diverse ways that fish contribute to human society. Fisheries, in press.

Tickner, D., J.J. Opperman, R. Abell, M. Acreman, A.H. Arthington, S.E. Bunn, S.J. Cooke, J. Dalton, W. Darwall, G. Edwards, I. Harrison, K. Hughes, T. Jones, D. Leclère, A.J. Lynch, P. Leonard, M.E. McClain, D. Muruven, J.D. Olden, S.J. Ormerod, J. Robinson, R.E. Tharme, M. Thieme, K. Tockner, M. Wright, L. Young. 2020. Bending the curve of global freshwater biodiversity loss – an emergency recovery plan. BioScience 70: 330-342.

Kuehne, L., Strecker, A., and J.D. Olden. 2020. Knowledge exchange and social capital for freshwater ecosystem assessments. BioScience 70: 174-183.

Tonkin, J.D., Poff, N.L., Bond, N.R., Horne, A., Merritt, D.M., Olden, J.D., Reynolds, L.V., Ruhi, A., and D.A. Lytle. 2019. Preparing river ecosystems for an uncertain future. *Nature* 570: 301-303.

Grill, G., B. Lehner, M. Thieme, B. Geenen, D. Tickner, F. Antonelli, S. Babu, P. Borrelli, L. Cheng, H. Crochetiere, H. Ehalt Macedo, R. Filgueiras, M. Goichot, J. Higgins, Z. Hogan, B. Lip, M. McClain, J.-h. Meng, M. Mulligan, C. Nilsson, J. D. Olden, J. Opperman, P. Petry, C. Reidy Liermann, L. Saenz, S. Salinas-Rodríguez, P. Schelle, R. J. P. Schmitt, J. Snider, F. Tan, K. Tockner, P. H. Valdujo, A. van Soesbergen, and C. Zarfl. 2019. Mapping the world's free-flowing rivers. *Nature* 569: 215-221.

Couto, T.B.A., and J.D. Olden. 2018. Global proliferation of small hydropower plants – science and policy. *Frontiers in Ecology and the Environment* 16:91-100.

Giam, X., Simberloff, D., and J.D. Olden. 2018. Impact of coal mining on stream biodiversity in the US and its regulatory implications. *Nature Sustainability* 1: 176-183.

Ruhí‡, A., Messager, M. and J.D. Olden. 2018. Tracking the pulse of the Earth's fresh waters. *Nature Sustainability* 1: 198-203.

Chen, W. and J.D. Olden. 2017. Designing flows to resolve human and environmental water needs in a dam-regulated river. *Nature Communications. doi:10.1038/s41467-017-02226-4*

Poff, N.L., and J.D. Olden. 2017. Can dams be designed for sustainability? *Science* 358:1252-1253.

Comte, L. and J.D. Olden. 2017. Climatic vulnerability of the world's freshwater and marine fishes. *Nature Climate Change.* doi:10.1038/nclimate3382

Tonkin, J. D., Merritt, D.M., Olden, J.D., L.V. Reynolds, L.V., Lytle, D.A. 217. Flow regime alteration degrades ecological networks in riverine ecosystems. *Nature Ecology and Evolution*, doi:10.1038/s41559-017-0379-0.

Kopf, R.K., Nimmo, D.G., Humphries, P., Baumgartner, L.J., Bode, M., Bond, N.R., Byrom, A.E., Cucherousset, J., Keller, R.P., King, A.J., McGinness, H.M., Moyle, P.B., and J. D. Olden. 2017. Confounding the risks of rapid, large-scale invasive species control. *Nature Ecology and Evolution* 1, 0172. doi: 10.1038/s41559-017-0172.

Moore, J.W. and J.D Olden. 2017. Response diversity, non-native species, and disassembly rules buffer freshwater ecosystem processes from anthropogenic change. *Global Change Biology* 23:1871-1880.

Kuehne, L., Olden, J.D., Strecker, A., Lawler, J.J., and D. Theobald. 2017. Past, present, and future of ecological integrity assessment for fresh waters. *Frontiers in Ecology and the Environment* 15: 197- 205.

Closs, G.P., M. Krkosek, and J.D. Olden. 2016. *Conservation of Freshwater Fishes* (Editors). Cambridge University Press.

Early, R.I., Bradley, B.A., Dukes, J.S., Lawler, J.J., Olden, J.D., Blumenthal, D.M., D'Antonio, C.M., Gonzalez, P., Grosholz, E.D., Miller, Ibanez, I., L.P., Sorte, C.J.B. and A.J. Tatem. 2016. Global threats from invasive alien species in the 21st Century and national response capacities. *Nature Communications* 7. doi:10.1038/ncomms12485.

Kuehne, L. and J.D. Olden. 2015. Lay summaries needed to enhance science communication. *Proceedings of the National Academy of Sciences, USA* 112: 3585-3586.

Olden, J.D., C. Konrad, T. Melis, M. Kennard, M. Freeman, M. Mims, E. Bray, K. Gido, N. Hemphill, D. Lytle, L. McMullen, M. Pyron, C. Robinson, J. Schmidt and J. Williams. 2014. Are large-scale flow experiments informing the science and management of freshwater ecosystems? *Frontiers in Ecology and the Environment* 12: 176-185.

Lawler, J.J., Ruesch, A., Olden, J.D., and B. McRae. 2013. Projected faunal migration routes for a changing climate. *Ecology Letters* 16: 1014-1022.

Olden, J.D., Kennard, M.K., Lawler, J.J., and N.L. Poff. 2011. Challenges and opportunities for implementing managed relocation of species for freshwater conservation. *Conservation Biology* 25: 40-47.

Poff, N.L., Olden, J.D., Merritt, D.M., and D.M. Pepin. 2007. Homogenization of regional river dynamics by dams and global biodiversity implications. *Proceedings of the National Academy of Sciences, U.S.A.* 104: 5732-5737.

Grants (selected)

Department of Defense. *Flow-population models for tracking non-stationary changes in riparian and aquatic ecosystems* (2015-2019). Co-PI	$1,630,000
U.S. Fish and Wildlife Service. *Assessing aquatic integrity in western US* (14-16). Lead-PI	$170,000
Department of Defense. *Predicting, measuring, and monitoring aquatic invertebrate biodiversity on dryland military bases.* (2012-2016). Co-PI	$1,560,000
Department of Defense. *Hydroecology of intermittent streams: will landscape connectivity sustain aquatic organisms in a changing climate?* (2010-2014). Lead-PI	$1,478,000
U.S. Geological Survey (Aquatic GAP Program). *Conservation planning for fishes in the Upper Colorado River Basin* (2010-2013). Co-PI	$780,000
U.S. Geological Survey (National Fish Habitat Initiative). *Assessing the threats to freshwater fishes in the Lower Colorado River Basin* (2009-2011). Co-PI	$379,000

Awards

H.B.N. Hynes Lecturer, Canadian Rivers Institute (2015)
Aldo Leopold Leadership Fellow, Stanford Woods Institute for the Environment (2015-present) Ecological Society of America – Early Career Fellow (2013)
Stevenson Memorial Lecturer Award - Canadian Conference for Fisheries Research (2011) Early Career Conservationist Award - Society for Conservation Biology (2010)
Outstanding Researcher Award - College of the Environment, University of Washington (2010)

Synergistic Activities

Center for Creative Conservation, Co-director – University of Washington (2015-2018): The Center for Creative Conservation is a hybrid think-tank, research group, and collaborative innovation network of diverse partners that develops and implements strategies to ensure ecosystem sustainability in natural and built environments.

Doris Duke Conservation Scholars Program, Steering Committee – University of Washington (2013- present): This ambitious project seeks to shift the demographic landscape at major conservation institutions to more accurately reflect the multicultural, multiethnic and interdisciplinary society of today and tomorrow. A tightly-bind cohort of undergraduates from across the nation participates in a 3-year journey exploring why conservation can make a difference.

Freshwater Working Group, Board Member - Society of Conservation Biology (2013-present): Working group that reports directly to SCB Executive Office on matters related to the biggest pressures and key processes threatening fresh waters and consequences for human livelihood and health.

Policy Rapid Response Team - Ecological Society of America (2012-present): Working closely with the ESA's Public Affairs Office to identify the potential ecological consequences of proposed federal regulations and legislation, respond quickly to media inquiries, assist ESA with position statements, present ecological research at ESA congressional briefings,

and interact with congressional offices.

Science Communication Task Force, Member - College of the Environment, University of Washington (2012-present): Developing the College's position statement on advancing science communication by faculty, staff and graduate students. The task force is charged with changing the culture of science communication in the College by seeking opportunities to better engage in outreach.

National Invasive Species Council – Advisory Committee (2012): Provided expertise regarding emerging vectors of biological invasions in the United States associated with the electronic commerce era.

Freshwaters Illustrated, Board of Directors (2010-2018): Serving on the Board of Directors for this nonprofit organization whose mission is to educate diverse public audiences about the life, study, and conservation of freshwater ecosystems through illustrative science-based efforts, and to provide illustrative resources and services to scientists, educators, and media specialists.

Climate Change and Global Health Joint Initiative Faculty Fellow - University of Washington (2010-2018): A trans-disciplinary initiative that focuses on food security and water resources, where 10 faculty fellows collaborate to realize new approaches to water and food security.

Editor for Ecological Applications (2013-present), Frontiers in Ecology and the Environment (2010- present), Elementa (2012-present), Ideas in Ecology and Evolution (2008-present), Conservation Biology (2010-2012), Global Ecology and Biogeography (2006-2010).

Appendix V: Curriculum Vitae of Rosi, Emma J., Ph.D

Emma J. Rosi, Ph.D. Senior Scientist
Cary Institute of Ecosystem Studies

EDUCATION
PhD. 2002. University of Georgia, Institute of Ecology, Athens, Georgia. Advisor Judy L. Meyer.
M.S. 1997. University of Georgia, Department of Entomology, Athens, Georgia. Advisor J. Bruce Wallace.
B.S. 1994. University of Michigan, Anthropology/Zoology.

RESEARCH FOCUS
Stream ecosystem processes and biogeochemistry, aquatic food webs, urban ecology, agricultural effects on streams, aquatic macroinvertebrates, large river ecology, and contaminants.

ACADEMIC POSITIONS
Senior Scientist, July 2015-Present, Cary Institute of Ecosystem Studies, Millbrook NY.
Associate Scientist, July 2009-2015, Cary Institute of Ecosystem Studies, Millbrook NY.
Associate Professor, May 2009-June 2009, Departments of Biology and Natural Science, Loyola University of Chicago.
Assistant Professor, September 2004-2009, Departments of Biology and Natural Science, Loyola University of Chicago.
Post-Doctoral Research Associate, September 2002-2004, Department of Biological Sciences, University of Notre Dame. Advisors: Jennifer L. Tank and Gary A. Lamberti.

SYNERGISTIC ACTIVITIES
Director (Lead PI), Baltimore Ecosystem Study, Long-term Ecological Research Site, Jan 2016-present
Science Advisory Roles: Ecological Processes and Effects Committee, US EPA Science Advisory Board, 2013-present. Connectivity of Waters of the US, US EPA Science Advisory Board, July 2013-2014. LTER Executive Board, 2013-2016.
Society for Freshwater Science, Special Assistant to the President (Vice President), May 2014-2017.
Awards Committee Member May 2013-present.
Associate Editor, Ecosystems, March 2010-present. Editorial Board Member, Freshwater Biology, June 2016-present.
Awards: Kaeser Scholar, Center for Limnology, University of Wisconsin, Oct 2015 (Kaeser scholars are selected by the graduate students). Fine Fellow, Fine Outreach for Science: Gigapan, Carnegie Mellon University, October 2009. Sujack Award for Excellence in Teaching, College of Arts and Sciences, Loyola University Chicago, Spring 2007.
Legislative Briefings: Pennsylvania State Assembly Briefing "Environmental consequences of pharmaceuticals in surface waters", Feb. 2017. Cheseapeake Bay Commission Briefing

"Environmental consequences of pharmaceuticals in surface waters", Jan 2017. US Congress briefing for the Long Term Ecological Research: regional data for large scale environmental issues congressional briefing organized by AIBS. Talk title: "The sanitary to the sustainable city: Long-term ecological research of the Baltimore urban ecosystem," June 2014. US Congress briefing focused on science related to the Water Resources Development Act organized by the Consortium of Aquatic Science Societies (CASS) Talk title: "Rivers: Dynamic, connected ecosystems", May 2013.

PUBLICATIONS

LaDeau, S.L., B.A. Han, E.J. Rosi-Marshall, and K.C. Weathers. 2017. The next decade of big data in ecosystem science. Ecosystems 20: 1-10. 10.1007/s10021-016-0075-y.

Griffiths1a Natalie A. , Jennifer L. Tank, Todd V. Royer, Emma J. Rosi, Arial J. Shogren, Therese C, and Matt R. Whiles. 2017. Occurrence, leaching, and degradation of Cry1Ab protein from transgenic maize detritus in agricultural streams. Science of the Total Environment 592: 97–105. 10.1016/j.scitotenv.2017.03.065

Reisinger, A. J., E. J. Rosi, H. A. Bechtold, T. R. Doody, S. S. Kaushal, and P. M. Groffman. 2017. Recovery and resilience of urban stream metabolism following Superstorm Sandy and other floods. Ecosphere 8(4):e01776. 10.1002/ecs2.1776

Bernhardt, E.S., E.J. Rosi, and M.O. Gessner. 2017. Synthetic chemicals: a neglected driver of global change. Submitted to Frontiers in Ecology and the Environment.

Bechtold, H. A., E. J. Rosi, D. R. Warren, and W. S. Keeton. 2017. Forest Age Influences In-stream Ecosystem Processes in Northeastern US. Ecosystems DOI: 10.1007/s10021-016-0093-9.

Reisinger, A.J., P.M. Groffman, and E.J. Rosi-Marshall. 2016. Nitrogen-cycling process rates across urban ecosystems. 2016. FEMS Microbiology Ecology 92. doi:10.1093/femsec/fiw198

Groffman, P.M, M. L Cadenasso, J. Cavender-Bares, D. L Childers, N. B Grimm, J M. Grove, S. E Hobbie, L. R Hutyra, G D. Jenerette, T. McPhearson, D. E Pataki, S.TA Pickett, R. V Pouyat, E. Rosi-Marshall, B. L Ruddell. 2016. Moving Towards a New Urban Systems Science. Ecosystems. 10.1007/s10021-016-0053-4.

Lee, S.S., A. Paspalof, D. Snow, E. Richmond, E.J. Rosi-Marshall, and J.J. Kelly. 2016. Occurrence and potential biological effects of amphetamine in stream ecosystems. Environmental Science and Technology 50:9727-35. doi:10.1021/acs.est.6b03717

Richmond, E.K., E.J. Rosi-Marshall, S.S. Lee, R.M. Thompson, and M.R. Grace. 2016. Antidepressants affect stream ecosystems: selective serotonin reuptake inhibitors (SSRIs) decrease algal production, but increase insect emergence. Freshwater Science 35 (3), 845-855.

Pickett, S.T.A , M.L. Cadenasso, E.J. Rosi-Marshall, K.T. Belt, P.M. Groffman, J.M. Grove, E.G. Irwin, S.S. Kaushal, S.L. LaDeau, C.H. Nilon, C.M. Swan, and P.S. Warren. 2016. Dynamic heterogeneity: a framework to promote ecological integration and hypothesis generation in urban systems. Urban Ecosystems. doi:10.1007/s11252-016-0574-9

Rosi-Marshall, E., E.S. Bernhardt, G.E. Likens, C.T. Driscoll, and D.C Buso. 2016. Acid rain mitigation experiment shifts a forested watershed from a net sink to a net source of nitrogen. PNAS 113:7580-7583.

Rosi-Marshall, E., K.L. Vallis, C.V. Baxter, and J.M. Davis. 2016. Retesting a prediction of the River Continuum Concept: autochthonous versus allochthonous resources in the diets of invertebrates. Freshwater Science 35:534-543. doi:10.1086/686302

Costello, D.M., E.J. Rosi-Marshall, L.E. Shaw, M.R. Grace, and J.J. Kelly. 2015. A novel method to assess effects of chemical stressors on biofilm structure and function. Freshwater Biology. doi:10.1111/fwb.12641

Reisinger, A.J., J.L. Tank, E.J. Rosi-Marshall, R.O. Hall, Jr., and M.A. Baker. 2015. The varying role of water column nutrient removal along a river continua in contrasting landscapes. Biogeochemistry 125:115-131. doi:10.1007/s10533-015-0118-z

Wagner, A., J. DalSoglio, J. Harris, P. Labus, D. Larson, E. Rosi-Marshall, and K. Skrabis. 2015. A guide for establishing restoration goals for contaminated ecosystems. Integrated Environmental Assessment and Management 12:264-272. doi:10.1002/ieam.1709

Hall, R.O., J.L. Tank, M.A. Baker, E.J. Rosi-Marshall, and E.R. Hotchkiss. 2015. Metabolism, gas exchange, and carbon spiraling in rivers. Ecosystems 19:73. doi:10.1007/s10021-015-9918-1

Rosi-Marshall, E.J., H.A. Wellard Kelly, R.O. Hall, Jr., and K.A. Vallis. 2015. Methods for quantifying aquatic macroinvertebrate diets. Freshwater Science. doi:10.1086/684648

Walters, D.M., E.J. Rosi-Marshall, T.A. Kennedy, W.F. Cross, and C.V. Baxter. 2015. Mercury and selenium accumulation in the Colorado River food web, Grand Canyon, USA. Environmental Toxicology and Chemistry 10:2385-2394.

Rosi-Marshall, E.J., and J. J. Kelly. 2015. Antibiotic stewardship should consider environmental fate of antibiotics. Environmental Science and Technology 49. doi:10.1021/acs.est.5b01519

Hall Jr., R.O., C.B. Yackulic, T.A. Kennedy, M.D. Yard, E.J. Rosi-Marshall, N. Voichick, and K.E. Behn. 2015. Turbidity, light, and hydropeaking control daily variation in primary production in the regulated Colorado River in Grand Canyon, Arizona. Limnology and Oceanography 60:512- 526. doi:10.1002/lno.10031

Zahn Seegert, S.E., E.J. Rosi-Marshall, C.V. Baxter, T.A. Kennedy, R.O. Hall, Jr., and W.F. Cross. 2015. Diet overlap suggests competition between native small-bodied fishes and non-native fathead minnow in the Colorado River, Grand Canyon, Arizona. Transactions of the American Fisheries Society 143:1072-1083.

Subalusky, A., C. Dutton, E.J. Rosi-Marshall, and D.M. Post. 2015. The hippopotamus conveyor belt: vectors of carbon and nutrients from terrestrial grasslands to aquatic systems in sub-Saharan Africa. Freshwater Biology 60:512-525. doi:10.1111/fwb.12474

Rosi-Marshall, E.J., D. Snow, S.L. Bartelt-Hunt, *A. Paspalof, and J.L. Tank. 2015. A review of ecological effects and environmental fate of illicit drugs in aquatic ecosystems. Journal of Hazardous Materials 282:18-25. http://dx.doi.org/10.1016/j.jhazmat.2014.06.062

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Hotchkiss, E.R., R.O. Hall Jr., M.A. Baker, E.J. Rosi-Marshall, and J.L. Tank. 2014. Modeling priming effects on microbial consumption of dissolved organic carbon in rivers. Journal of Geophysical Research: Biogeosciences 119:982-995. doi:10.1002/2013JG002599

Strayer, D.L., J.J. Cole, S.E.G. Findlay, D.T. Fischer, J.A. Gephart, H.M. Malcom, M.L. Pace, and E.J. Rosi-Marshall. 2014. Decadal-scale change in a large-river ecosystem. Bioscience 64:496-510.

Roales, J., J.H. Durán, *H.A. Bechtold, P.M. Groffman, and E.J. Rosi-Marshall. 2013. High resolution measurement of light in terrestrial ecosystems using photodegrading dyes. PLoSOne 8:e75715. doi:10.1371/journal.pone.0075715

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Drury, B., J. Scott, E.J. Rosi-Marshall, and J.J. Kelly. 2013. Triclosan exposure increases triclosan resistance and alters taxonomic composition of benthic bacterial communities. Environmental Science and Technology 47:8923-8930. dx.doi.org/10.1021/es401919k

Warren, D.R., W.S. Keeton, H.A. Bechtold, and E.J. Rosi-Marshall. 2013. Comparing streambed light availability and canopy cover in streams with old-growth versus early-mature riparian forests in western Oregon. Aquatic Sciences 75:547. doi:10.1007/s00027-013-0299-2

Griffiths, N.A., J.L. Tank, T.V. Royer, S.S. Roley, E.J. Rosi-Marshall, M.R. Whiles, J.J. Beaulieu, and L.T. Johnson. 2013. Agricultural land use alters the seasonality and magnitude of stream metabolism. Limnology and Oceanography 58:1513-1529.

Cross, W.F., C.V. Baxter, E.J. Rosi-Marshall, R.O. Hall, Jr., T.A. Kennedy, K.C. Donner, H.A. Wellard Kelly, and S. Zahn Seegert. 2013. Food web dynamics in a river discontinuum. Ecological Monographs 83:311-337.

Davis, J.M., C.V. Baxter, E.J. Rosi-Marshall, J.L. Pierce, and B.T. Crosby. 2013. Anticipating stream ecosystem responses to climate change: toward predictions that incorporate effects via land– water linkages. Ecosystems 16:909-922. http://dx.doi.org/10.1007/s10021-013-9653-4

Rosi-Marshall, E.J., D. Kincaid, H.A. Bechtold, T.V. Royer, M. Rojas, and J.J. Kelly. 2013. Pharmaceuticals suppress algal growth and microbial respiration and alter bacterial communities of stream biofilms. Ecological Applications 23:583-593.

Wellard Kelly, H.A., E.J. Rosi-Marshall, T.A. Kennedy, R.O. Hall, Jr., W.F. Cross, and C.V. Baxter. 2013. Turbidity in a large regulated river drives patterns of resource use by macroinvertebrates. Freshwater Science 32:397-410.

Drury, B., E.J. Rosi-Marshall, and J.J. Kelly. 2013. Wastewater treatment effluent reduces the abundance and diversity of benthic bacterial communities in urban and suburban rivers. Applied and Environmental Molecular Biology 79:1897. doi:10.1128/AEM.03527-12

Bechtold, H.A., E.J. Rosi-Marshall, D.R. Warren, and J.J. Cole. 2012. A practical method for measuring integrated solar radiation reaching streambeds. Freshwater Science 31:379-388.

Rosi-Marshall, E.J. and T.V. Royer. 2012. Pharmaceutical compounds and ecosystem function: an emerging research challenge for aquatic ecologists. Ecosystems 15:867-880. doi:10.1007/s10021- 012-9553-z

Hall, R.O. Jr., T.A. Kennedy, and E.J. Rosi-Marshall. 2012. Air-water oxygen exchange in a large, whitewater river. Limnology and Oceanography: Fluids and Environments 2:1-11. doi:10.1215/21573689-1572535

Hoppe, P.D., E.J. Rosi-Marshall, and H.A. Bechtold. 2012. The antihistamine cimetidine alters invertebrate growth and population dynamics in artificial streams. Freshwater Science 31:379- 388.

Griffiths, N.A., J.L. Tank, T.V. Royer, T.J. Warrner, T.C. Frauendorf, E.J. Rosi-Marshall, and M.R. Whiles. 2011. Temporal variation in organic carbon spiraling in Midwestern agricultural streams. Biogeochemistry 108:149-169. doi:10.1007/s10533-011-9585-z

Cross, W.F., C.V. Baxter, K.C. Donner, E.J. Rosi-Marshall, T.A. Kennedy, R.O. Hall, Jr., *H.A. Wellard Kelly, and R.S. Roger. 2011. Ecosystem ecology meets adaptive management: food web response to a controlled flood on the Colorado River, Glen Canyon. Ecological Applications 21:2016-2055.

Hoellein, T.J., J.L. Tank, S.A. Entrekin, E.J. Rosi-Marshall, M.L. Stephen, and G.A. Lamberti. 2013. Effects of benthic habitat restoration on nutrient uptake and ecosystem metabolism in three headwater streams. River Research and Applications 28:1451-1461. doi:10.1002/rra.1547

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Hoellein, T., J.L. Tank, J.J. Kelly, and E.J. Rosi-Marshall. 2010. Seasonal variation in nutrient limitation of microbial biofilms colonizing organic and inorganic substrata in streams. Hydrobiologia 649:331-345.

Cross, W. F., E. J. Rosi-Marshall, K. Behn, T. A. Kennedy, R. O. Hall, A. E. Fuller, and C. V. Baxter. 2010. Invasion and production of New Zealand mud snails in the Colorado River, Glen Canyon. Biological Invasions doi:10.1007/s10530-010-9694-y

Chambers, C. P., M. R. Whiles, E. J. Rosi-Marshall, J. L. Tank, T. V. Royer, N. A. Griffiths, M. A. Evans-White, and A. Stojak. 2010. Responses of stream macroinvertebrates to Bt maize leaf detritus. Ecological Applications 20:1949-1960.

Tank, J. L., E. J. Rosi-Marshall, N. A. Griffiths, S. A. Entrekin, and M. L. Stephen. 2010. A review of allochthonous organic matter dynamics and metabolism in streams. Journal of the North American Benthological Society, Special 25th Anniversary Issue 29:118-146e.

Warrner, T. J., T. V. Royer, J. L. Tank, N. A. Griffiths, E. J. Rosi-Marshall, and M. R. Whiles. 2010. Origin and bioavailability of dissolved organic carbon in agricultural headwater streams in Indiana, USA. Biogeochemistry 95:295–307.

Entrekin, S. A., J. L. Tank, E. J. Rosi-Marshall, T. J. Hoellein, and G. A. Lamberti. 2009. Response of secondary production by macroinvertebrates to large wood addition in three Michigan streams. Freshwater Biology 54(8):1741-1758.

Hoellein T. J., J. L. Tank, E. J. Rosi-Marshall, and S.A. Entrekin. 2009. Temporal variation of substratum-specific rates of N uptake and metabolism and their relative contribution at the stream-reach scale. Journal of the North American Benthological Society 28:305–318.

Griffiths, N. A., J. L. Tank, T. V. Royer, C. P. Chambers, M. A. Evans-White, T. C. Frauendorf, E. J. Rosi-Marshall, and M. R. Whiles. 2009. Microbial respiration and decomposition of conventional and genetically-engineered corn detritus in Midwestern US agricultural streams. Ecological Applications 19:133–142.

Schofield, K. A., C. M. Pringle, J. L. Meyer, and E. J. Rosi-Marshall. 2008. Functional redundancy of macroconsumers across human-impacted landscape. Freshwater Biology 53:2587–2599.

Tank, J. L., E. J. Rosi-Marshall, M. A. Baker, and R. O. Hall. 2008. Are rivers just big streams? Using a novel method to quantify nitrogen demand in a large river. Ecology 89:2935–2945.

Cordova, J. M., E. J. Rosi-Marshall, J. L. Tank, and G. Lamberti. 2008. Coarse particulate organic matter transport in low-gradient streams of the Upper Peninsula of Michigan. Journal of the North American Benthological Society 27:760–771.

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Marvier, M., Y. Carriere, N. Ellstrand, P. Gepts, P. Kareiva, E. J. Rosi-Marshall, B. Tabashnik, L. L.Wolfenbarger. 2008. Harvesting data from USA's grand experiment with genetically engineered crops. Science 320:452-453.

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BOOK CHAPTERS

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PUBLISHED REPORTS

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OUTREACH PUBLICATIONS

Rosi-Marshall, E.J. 2011. “Deadly frog disease illustrates dangers of wildlife trade” Poughkeepsie Journal, 4 Dec.

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GRANTS

Rosi, E.J. and others. “LTER: Dynamic heterogeneity: Investigating causes and consequences of ecological change in the Baltimore urban ecosystem” National Science Foundation. Total award $2,254,000. March 1 2017- Feb 2018, 2010.

Egan, S. P., J. L. Feder, D. M. Lodge, J. L. Tank, C. E. Tanner, S. T. Ruggiero, A. Aubeneua, and E. J. Rosi, “Monitoring the Dispersal of Genetically Engineered Organisms and Their Byproducts Using Light Transmission Spectroscopy II, USDA Biotechnology Risk Assessment Research Grants Program ($43,956 via sub-award from Rice University), October 1,2016 – September 30, 2018.

C. Redmond and N. Grimm, Arizona State University. “Urban River Sustainability Research Network”. National Science Foundation. Total award $12,000,00. Award amount to Co-PI Rosi-Marshall and Groffman at Cary Institute $799,656. Sept 15, 2015- Sept 2018.

Groffman, P. M., E. J. Rosi-Marshall, and S. LaDeau. “Collaborative Coastal SEES: Restoration, redevelopment, revitalization and nitrogen in a coastal watershed.” National Science Foundation DEB, $702,875. October 2014-September 2017.

Rosi-Marshall, E. J. “Collaborative Research: Wildlife subsidies interact with discharge to influence ecosystem function of a large African river.” (In Collaboration with D. Post, Yale University) National Science Foundation DEB, $437,620. April 2014-May 2017.

Egan, S. P., J. L. Feder, D. M. Lodge, J. L. Tank, S. Howard, C. E. Tanner, S. T. Ruggiero, and E. J. Rosi-Marshall. “Monitoring the dispersal of genetically engineered organisms and their byproducts using light transmission spectroscopy.” US Department of Agriculture, $500,000 (Rosi-Marshall subcontract: $56,958.) 2013-2015.

Grace, M. (Monash University), P. Marriott (Monash University), E. J. Rosi-Marshall, R. Coleman (Melbourne Water Corporation), and V. Pettigrove (Melbourne Water Corporation and the University of Melbourne). "Impacts of pharmaceuticals and personal care products on Australian aquatic ecosystems." Australian Research Council Linkage Grant, ID# LP130100040, $428,000 (A$). July 2013-June 2016.

Rosi-Marshall, E. J. Cary Institute of Ecosystem Studies Artificial Stream Facility for Pharmaceutical Research. Wallace-Genetic Foundation and Cornell-Douglas Foundation, $170,000. 2012-2014.

Berkowitz, A., E. J. Rosi-Marshall, S. Findlay, and F. Keesing. REU Site: Translation Ecology for Undergraduates. National Science Foundation, $595,927. 2010-2015.

Pickett, S. et al. (Rosi-Marshall is a Co-PI). Baltimore Ecosystem Study, Long-Term Ecological Research: Phase III – Adaptive Processes in the Baltimore Socio-Ecological System: From the Sanitary to the Sustainable City. National Science Foundation, $5,640,000. 2011-2016.

LaDeau, S., E. J. Rosi-Marshall, J. J Cole, and J. Wallace. Collaborative Research: Trophic regulation and support of mosquitoes: An ecosystem approach to pest emergence along an urban gradient. National Science Foundation, $150,000. 2010-2012.

Strayer, D., S. Findlay, J. J. Cole, M. Pace, and E. J. Rosi-Marshall. LTREB: Long-term effects of a species invasion on an aquatic ecosystem. National Science Foundation, $450,000. 2010-2015.

Rosi-Marshall, E. J., D. Warren, W. Keeton, and J. J. Cole. Evaluating the influence of riparian forest structure on stream ecosystems across the northern forest. Northeastern States Research Cooperative, $149,568. 2010-2013.

Rosi-Marshall, E. J. Research Experience for Undergraduates Supplement, 2010. National Science Foundation, $6,000 (2009).

Kelly, J. J, E. J. Rosi-Marshall, and T. Chow. Ecotoxicology of antimicrobial pharmaceutical and personal care products in Illinois rivers and streams. Illinois Waste Management and Research Center, $129,800. 2008-2010.

Rosi-Marshall, E. J. (Collaborative proposal with J. L. Tank, M. A. Baker, R. O. Hall, and M. R. Sivapalan). Using empirical and modeling approaches to extend nutrient spiraling from rivulets to rivers. National Science Foundation, $782,000. 2009-2012.

Hall, R. O. and E. J. Rosi-Marshall. Linking whole-system carbon cycling to quantitative food webs in the Colorado River. US Geological Survey, $1,217,000. 2006-2011.

Soranno, P., K. S.Cheruvelil, E. J. Rosi-Marshall, and J. L. Tank. Water resources assessment of the Indiana Dunes National Lakeshore. National Park Service, $75,000. 2005-2006.

Rosi-Marshall, E. J. Occurrence and ecological effects of pharmaceutical chemicals in Chicago metropolitan area streams. Illinois Water Resources Association, $40,000. 2005-2007.

Tank, J. L., E. J. Rosi-Marshall, M. R. Whiles, and T. V. Royer. Cycling of novel allochthonous carbon in Midwestern agricultural streams. National Science Foundation, $591,000. 2005-2008.

PUBLIC EDUCATION

Teale Lecture, Our Rivers on Drugs, University of Connecticut Storrs, November 2016. Public Lecture at the Cary Institute, Our Rivers on Drugs. February 2015.

Presenter at Baltimore Science for a Sustainable City, Clean waters – what pollutants are we dealing with on the Gwynns Falls, Gwynns Run and Watershed 263. Baltimore, MD. October 2014.

Presenter at the Beacon Sloop Club, March 2015. Our Rivers on Drugs.

Keynote Speaker at the Hudson River Watershed Alliance meeting, Ecological effects of contaminants of emerging concern. Hyde Park, NY. 7 October 2014.

Keynote Speaker at the Southern Connecticut Science Fair, Your River on Drugs: inputs, fate and ecology effects of pharmaceuticals on aquatic ecosystems. Connecticut. April 2013.

Lecture for Skeneateles High School. Invited to be the annual Environmental Studies Speaker. Supported by the Skeneateles Lake Association, Your River on Drugs: inputs, fate and ecology effects of pharmaceuticals on aquatic ecosystems. Skeneateles, NY. April 2013.

Lecture to the College Board AP Biology Readers Program. Your River on Drugs: inputs, fate and ecology effects of pharmaceuticals on aquatic ecosystems. There were 450 AP Biology teachers and college professors in attendance. Kansas City, MO. June 2012.

Celebrating 40 Years of the Clean Water Act, A Conference of the Hudson River Environmental Society. Outside the scope of the Clean Water Act: The ecological consequences contaminants of emerging concern on freshwater ecosystems. March 2012. Cary Institute Hydrofracking Forum, Moderator, April 2012.

North Country Garden Club, Your River on Drugs. Long Island, NY. March 2012. University of Maryland Baltimore County, Center for Urban Environmental Research and Education, Novel contaminants in aquatic ecosystems: inputs, fates and potential ecological effects. February 2012.

Public Lecture at the Cary Institute, Genetically Modified Crops and the Environment: An Evolving story. October 2011.

Freshwater Forum at the Cary Institute, Human Impacts to Freshwater. May 2011. Nine Partners Garden Club, Adventures in Aquatic Ecology. June 2011.

Clarkston Environmental Summer Invited speaker, Human Impacts to Freshwater. March 2011. Short lecture/hike with Dave Strayer on Freshwater Ecology, Autumn Celebration, Cary Institute, October 2010.

Adventures in Aquatic Ecology, The challenges of studying food webs of the Colorado River, Grand Canyon. Ecodiscovery Day. Cary Institute of Ecosystem Studies. May 2010.

Fates and Sources of pharmaceuticals and personal care products in aquatic ecosystems. Hudson River Environmental Society - What's in our Water Conference. Poughkeepsie, NY. April 2010.

GRADUATE STUDENTS SUPERVISED

P. Hoppe, MS, Loyola University of Chicago, Advisor 2006-2010.
H. Wellard Kelly, MS, Loyola University Chicago, Advisor 2006-2010.
S. Zahn, MS, Loyola University Chicago, Advisor 2007-2010.
K. Vallis, MS, Loyola University Chicago, Advisor 2008-2011.
K. Donner, MS, Idaho State University, Committee Member 2008-2010.
R. VanDuzor, MS, Loyola University Chicago, Committee Member 2007-2010.
L. Dandridge, MS, Loyola University Chicago, Committee Member 2006-2010.
A. J. Reisinger, PhD, University of Notre Dame, Committee Member 2010-Present.
A. Subalusky, PhD. Yale University, Committee Member 2011-Present.
A. Paspalof, M.S. University of Nebraska Lincoln, Co-Advisor 2013-Present.
E. Richmond, PhD, Monash University, Co-Advisor, 2014-Present.
K. MacNeil, PhD. Cornell University, Committee Member, 2013-Present.
A. Shogren, PhD. University of Notre Dame, Committee Member 2014-Present.
R. Marinos, PhD, Duke University, Committee Member, 2014-Present.
A. Sparkman, PhD., University of Maryland College Park, Committee Member, 2015-Present.
J. Blaszczak, PhD. Duke University, Committee Member, 2015-Present.

POST-DOCS SUPERVISED

W. Cross, University of Wyoming, Co-Mentored, 2006-2009.
J. Davis, Idaho State University, Co-Mentored, 2009-2011.
H. Bechtold, Cary Institute, Mentor, 2010-2013.
S. Lee, Cary Institute, Mentor, 2013-Present.
A.J. Reisinger, Cary Institute, Mentor, 2015-Present.
A. Subalusky, Cary Institute, Mentor, 2016-Present.

Appendix VI: Curriculum Vitae of Sweeney, Mark R., Ph.D.

Mark R. Sweeney
Department of Sustainability & Environment
University of South Dakota

EDUCATION

Ph.D. 2004	Washington State University	Geology
M.S. 1999	University of Nebraska-Lincoln	Geosciences
B.S. 1997	University of Nebraska-Lincoln	Geology

EXPERIENCE

University of South Dakota	Professor	2018-present
University of South Dakota	Associate Professor	2012-present
University of South Dakota	Assistant Professor	2006-2012
Desert Research Institute	Post-Doctoral Research Associate	2004-2006

RESEARCH INTERESTS

- Eolian processes: primarily the formation, transport, and deposition of dust
- Eolian-Fluvial interactions
- Quaternary geomorphology and sedimentology of loess and its links to paleoclimatology
- Arid land geomorphology and paleoclimatology

AWARDS OR RECOGNITIONS

- 2017, University of South Dakota College of Arts & Sciences Richard and Sharon Cutler Award in Liberal Arts (Science and Math Division)
- 2009, Geological Society of America Gladys W. Cole Memorial Research Award, "Late Holocene geomorphic response of Kelso Wash, eastern Mojave Desert: climatic versus base level control of a desert dust source.", $9,900

TEACHING EXPERIENCE

- Dynamic Earth (ESCI 101, 4 cr), Physical Geology
- Earth & Life Through Time (ESCI 103, 4 cr), Historical Geology
- National Parks and Monuments (ESCI 201, 2 cr)
- Environmental Earth Science (ESCI 205, 3 cr)
- Conducted Field Trip (ESCI 396, 1-2 cr), to Death Valley
- Principles of Geomorphology & Lab (ESCI 411/511, 3 cr)
- Global Climate Change (ESCI 416/516; was ESCI 360, 3 cr)
- Introduction to River Studies (ESCI 442, 3 cr)
- Principles of Sedimentology & Lab (ESCI 443, 4 cr)
- Fundamentals of Hydrogeology (ESCI 473/573, 3 cr)
- Capstone Course in Earth Sciences (ESCI 495, 1 cr)
- The Future of Water (UHON 390, 3 cr), honors course

GRANTS RECEIVED (SINCE 2010)

- 2019-2021, “Testing the feasibility of critical terrain condition prediction for military planning and operations using soil-landscape system features and related climatic parameters,” U.S. Army Corps of Engineers, subaward from Desert Research Institute, $66,261.
- 2018-2021, “Evaluating post-flood sandbar succession and species biodiversity related to listed species habitat”, National Park Service, PIs: M. Dixon, D. Swanson and M. Sweeney, $299,996.
- 2017-2020, “Land surface processes, dust sources and particulate fluxes for the 1930s Dust Bowl Drought area, Great Plains, USA”, National Science Foundation Geography and Spatial Sciences, PI: Steve Forman (Baylor U.), $220,033, USD subaward years 2-3: $44,788.
- 2016-2019, “Modeling linkages among soil-terrain-atmospheric processes critical for military operations”, U.S. Army Corps of Engineers, subaward from Desert Research Institute, $25,735.
- 2015-2016, "Characterization of sediment sources in the Lewis and Clark Lake Delta", Missouri Sedimentation Action Coalition, PI: M. Sweeney, $21,057.
- 2015-2016, "Sustainable Rivers: Integrating Earth Science & Sustainability Across the Curriculum", National Science Foundation InTeGrate subaward, PIs: M. Sweeney, M. Jarchow, $43,620.
- 2011-2013, “Lewis and Clark Lake Sediment Accumulation Illustration Project”, Missouri Sediment Action Coalition, PI: T. Cowman, Co-PIs: M. Dixon and M. Sweeney, $15,627.
- 2011-2012, “Acquisition of a Portable In Situ Wind Erosion Lab (PI-SWERL) for research in Earth Sciences”, National Science Foundation Instrumentation & Facilities (EAR-1029116), PI: M. Sweeney, $53,500.
- 2011: “Collaborative Research: Mechanisms Producing Variation in Lake Salinity in Dune Environments: Nebraska” National Science Foundation subaward (EAR-0609982), $11,110.

SELECTED PEER-REVIEWED PUBLICATIONS

Sweeney, M.R., McDonald, E.V., Chabela, L.P., Hanson, P.R., 2020, The role of eolian-fluvial interactions and dune dams in landscape change, late Pleistocene-Holocene, Mojave Desert, USA. Geological Society of America Bulletin, doi:10.1130/B35434.1

Bolles, K., **Sweeney, M.**, Forman, S., 2019, Meteorological catalysts of dust events and particle source dynamics of affected soils during the 1930s Dust Bowl drought, Southern High Plains, USA. Anthropocene, v. 27, p. 1-23, doi:10.1016/j.ancene.2019.100216.

Sweeney, M.R., Fischer, B., Wormers, K., Cowman, T., 2019, Eolian and fluvial modification of Missouri River sandbars deposited by the 2011 flood, USA. Geomorphology, v. 327, p. 111-125. doi:10.1016/j.geomorph.2018.10.018

Sweeney, M.R., McDonald, E.V., Gaylord, D.R., 2017, Generation of the Palouse loess: Exploring the linkages between glaciation, outburst megafloods, and eolian deposition in Washington State. Geological Society of America Field Guide 49. doi:10.1130/2017.0049

Bolles, K., Forman, S.L., **Sweeney, M.R.**, 2017, Eolian processes and heterogeneous dust emissivity during the 1930s Dust Bowl Drought and implications for projected 21st century megadroughts. The Holocene, doi:10.117/0959683617702235

Sweeney, M.R., Zlotnik, V.A., Joeckel, R.M., Stout, J.E., 2016, Geomorphic and hydrologic controls of dust emissions during drought from Yellow Lake playa, West Texas, USA. Journal of Arid Environments, v. 133, p. 37-46. doi:10.1016/j.aridenv.2016.05.007

Sweeney, M.R., Lu, H., Cui, M., Mason, J.A., Feng, H., Xu, Z., 2016, Sand dunes as potential sources of dust in northern China. Science China Earth Sciences, v. 59, p. 760-769. doi: 10.1007/s11430-015-5246-8.

Sweeney, M. R., McDonald, E. V., Markley, C.E., 2013, Alluvial sediment or playas: what is the dominant source of sand and silt in desert soil Av horizons, southwest USA. Journal of Geophysical Research – Earth Surface, 118, doi:10.1002/jgrf.20030.

McDonald, E.V., **Sweeney, M.R.,** Busacca, A.J., 2012, Glacial outburst floods and loess sedimentation documented during oxygen isotope stage 4 on the Columbia Plateau, Washington State. Quaternary Science Reviews, v. 45, p. 18-30.

Sweeney, M.R., McDonald, E.V., Etyemezian, V., 2011, Quantifying dust emissions from desert landforms, eastern Mojave Desert, USA. Geomorphology, v. 135, p. 21-34.

Sweeney, M., V. Etyemezian, T. Macpherson, W. Nickling, J. Gillies, G. Nikolich, and E. McDonald, 2008, Comparison of PI-SWERL with dust emission measurements from a straight-line field wind tunnel, Journal of Geophysical Research, 113, F01012, doi:10.1029/2007JF000830.

Appendix VII: Curriculum Vitae of Wohl, Ellen E., Ph.D.

Ellen E. Wohl
Professor of Geology and University Distinguished Professor
Dept of Geosciences
Colorado State University

WEBSITES: https://sites.warnercnr.colostate.edu/ellenwohl/
https://sites.warnercnr.colostate.edu/fluvial-geomorphology/

DEGREES: Arizona State University, Tempe, Arizona
BS in Geology, 1984
University of Arizona, Tucson, Arizona
PhD in Geosciences, 1988

OTHER POSITIONS:

1989-1989	Faculty Research Associate, Dept of Geosciences, University of Arizona
1989-1995	Assistant Professor, Dept of Earth Resources, Colorado State University
1995-2000	Associate Professor, Dept of Earth Resources, Colorado State University

MEMBERSHIP IN PROFESSIONAL SOCIETIES:

Geological Society of America (Fellow)
American Geophysical Union (Fellow)

SCHOLARSHIPS, AWARDS, AND HONORS:

Graduation with honors from Arizona State University, magna cum laude
Sulzer Scholarship (University of Arizona), 1984-1985
Graduate Academic Scholarship (University of Arizona), 1984-1985, 1987-1988
SOCAL Fund Grant (University of Arizona), 1986-1987
Sigma Xi Grant-in-Aid-of-Research, 1986-1987
Geological Society of America Research Grant, 1986-1987
Fulbright-Hays Postgraduate Research Grant, 1986-1987
Butler Scholarship (University of Arizona), 1987-1988
Gladys W. Cole Memorial Award, Geological Society of America, 1995
Fellowship, Japan Society for the Promotion of Science, 1995-1996
Water Center Award for Outstanding Contributions to Interdisciplinary Water Education, Research, and Outreach (Colorado State University), 2001
G.K. Gilbert Award, Association of American Geographers, 2000 and 2003
Kirk Bryan Award, Geological Society of America, 2009
Distinguished International Fellow, Department of Geography, Durham University, England, 2010
Scholarship Impact Award, Colorado State University, 2015

Outstanding Mentor Award, Warner College of Natural Resources, Colorado State University, 2015
Ralph Alger Bagnold Medal, European Geosciences Union, 2017
CSU University Distinguished Professor, 2017
Distinguished Career Award, GSA Quaternary Geology and Geomorphology Division, 2018
G.K. Gilbert Award, Earth and Planetary Surfaces Section, AGU, 2018
Doctor Honoris Causa, University of Lausanne, Switzerland, 2019
Borland Hydraulics Award, Colorado State University, 2020
Mel Marcus Distinguished Career Award, AAG, 2020
Member of Phi Beta Kappa, Phi Kappa Phi, Sigma Xi

Theses and dissertations supervised and completed: 52 MS theses, 29 PhD dissertations

EXTERNAL GRANTS:

66. Assessing the Stream Network on the Old Elk Ranch (2018-2019)
    $95,000 from the Richardson Foundation
65. Longitudinal Variability in Large Wood Along the Merced River, Yosemite National Park
    $70,000 from the US National Park Service (2018-2019)
64. Collaborative Research: Emergent Hydrological Properties Associated with Multiple Channel-
    Spanning Logjams (2018-2021)
    $265,984 from the National Science Foundation (co-PI Kamini Singha, CO School of Mines & Audrey Sawyer, Ohio State U)
63. Wood-based carbon discharge to the Arctic Ocean (2018-2020)
    $341,379 from the National Science Foundation
62. Assessing the potential for beaver restoration and likely environmental benefits (2017-2018)
    $19,880 from the City and County of Boulder, Colorado
61. Quantifying and predicting the attenuation of downstream fluxes associated with beaver meadows (2016-2018)
    $279,066 from the National Science Foundation (co-PI T. Covino, CSU)
60. Longitudinal patterns of organic carbon storage in mountainous river networks (2016-2019)
    $257,828 from the National Science Foundation
59. Collaborative Research: RAPID: Calibrating Shallow Geophysical Techniques to Detect Large
    Wood Buried in River Corridors (2016)
    $14,619 from the National Science Foundation (co-PI K. Sinha, CO School of Mines)
58. The 47th Annual Binghamton geomorphology Symposium (2016)
    $42,000 from the National Science Foundation (co-PIs S. Rathburn, CSU, F. Magilligan, Dartmouth)
57. Floodplain carbon storage in mountain rivers (2016-2017)
    $15,749 from the National Science Foundation (DDRI for Nicholas Sutfin)
56. Geophysical characterization of the Sand Creek site
    $27,000 from the National Park Service
55. The active channel and the ordinary high water mark (2015-2016)

$27,834 from DOD-Army Corps of Engineers

54. Organic carbon storage in beaver meadows (2015-2016)
$7,270 from the National Geographic Society

53. Floodplain-instream wood interactions in the Central Yukon River Basin (2014-2015)
$15,810 from the National Geographic Society

52. Carbon fluxes to the Arctic Ocean via wood export from the Mackenzie River drainage basin (2012-2013)
$9,575 from the National Geographic Society

51. Leaky Rivers: Nutrient Retention and Productivity in Rocky Mountain Streams Under Alternative Stable States (2012-2015)
$633,745 from National Science Foundation (co-PI D. Walters, USGS)

51. Tropical Hydrology Workshop (2011)
$13,070 from the US Army Research Office

50. Landscapes in the Anthropocene: Exploring the human connections (2010)
$49,558 from National Science Foundation (co-PI A. Chin, University of Colorado)

49. Environmental flow strategy validation (2010-2012)
$45,000 from USDA Forest Service

48. White River analysis (2009-2012)
$75,000 from USDA Forest Service

47. Watershed to local scale characteristics and function of intermittent and ephemeral streams on military lands (2010-2014) $1,499,657 from U.S. Army Strategic Environmental Research and Development Program (co-PIs D. Cooper, S. Kampf, CSU)

46. RAPID: Pre-disturbance surveys of wood loads in headwater streams of the Colorado Front Range (2009-2010)
$30,435 from National Science Foundation

45. SGER: Influence of postglacial rebound on river longitudinal profiles in Sweden (2007-2009) $35,000 from National Science Foundation

44. Development of a national protocol for riparian assessment (2007-2009)
$117,500 from USDA Forest Service

43. Wood loading in headwater neotropical forest streams (2007-2010)
$283,030 from National Science Foundation

42. Measurements of roughness coefficient for steep channels (2007-2009)
$257,204 from National Science Foundation

41. Mapping longitudinal distribution of wood along forest streams (2005-2006)
$21,071 from USDA Forest Service

40. Testing the existence of a threshold discharge in bedrock channels (2005-2008)
$203,617 from National Science Foundation

39. Develop service-wide concepts for riparian habitat and stream restoration (2004-2007)
$303,692 from National Park Service (co-PI D. Cooper, CSU)

38. Assessing snow-making impacts to stream channels (2004-2006)
$75,004 from USDA Forest Service (co-PI B. Bledsoe, CSU)

37. Geomorphic effects of a jokulhlaup (2004-2005)
$61,474 from National Science Foundation

36. Rivers, roads, and people: Complex interactions of overlapping networks in watersheds (2003-2007) $1,700,000 from National Science Foundation (co-PIs, J. Loomis, J. Ramirez, M.
Laituri, CSU)
35. International Collaboration: Flow hydraulics along step-pool channels (2003-2004)
$6804 from National Science Foundation
34. Assessment of historical and contemporary land-use impacts on pool habitat in the Upper South Platte River drainage basin (2003-2006) $73,212 from USDA Forest Service
33. Anabranching channels in jointed bedrock: an integrated flume and field study (2003-2005)
$124,781 from National Science Foundation (co-PI G. Springer, Ohio University)
32. Flow hydraulics along step-pool channels (2003-2004)
$8,000 from National Science Foundation
31. Gradient-related trends in mountain channel geometry (2003)
$11,300 from National Science Foundation
30. Quantifying historical and contemporary coarse sediment input and storage and fine sediment storage along Black Canyon (2002-2003)
$50,012 from US National Park Service
29. Hierarchical physical classification of western streams (2000-2004)
$788,144 from EPA (co-PIs B. Bledsoe, L. Poff, C. Watson, CSU)
28. Wetland, Aquatic and Riparian Protocols (2000-2005)
$142,550 from USDA Forest Service (co-PIs D. Cooper and L. Poff, CSU)
27. North Fork Gunnison River Improvement Project (2000-2001)
$50,000 from the North Fork River Improvement Association (co-PI D. Cooper, CSU)
26. Quantitative modeling of channelized flow within a karst stream (2000-2002)
$102,185 from National Science Foundation
25. Hydraulic resistance of large woody debris in step pool channels (2000-2001)
$2175 from the National Science Foundation (REU supplement)
24. Characterizing channel disturbance regimes in hydroclimatically extreme regions (2000-2003)
$162,639 from the US Army Research Office
23. Chemical weathering in granitic channels of India and the United States (1999-2001)
$12,192 from the National Science Foundation
22. Hydraulic resistance of large woody debris in step pool channels (1999-2001)
$78,200 from the National Science Foundation
21. Acquisition of hydraulics instrumentation for field-based research (1999-2004)
$54,068 from the National Science Foundation
20. Instrumentation for disturbance regimes of hydrologically extreme regions (1999-2000)
$122,562 from US Army Research Office
19. Modeling flows for fish habitat maintenance (1998-2000)
$45,000 from the Colorado Division of Wildlife
18. Inventory of current and historic erosion-control projects in the Rio Puerco basin and quantification of sediment yields (1998-2000)
$45,150 from the US Bureau of Land Management
17. Mitigation of mountain-channel sedimentation resulting from reservoir sediment releases (1998- 2000) $72,670 from the National Science Foundation

16. Channel response to reservoir sedimentation (1997-1998)
    $25,000 from Colorado Water Conservation Board, Trout Unlimited, and U.S. Bureau of Reclamation
15. Flow resistance of large woody debris in headwater streams (1997-1999)
    $70,400 from NCASI (Ntnl Council of the Paper Industry for Air and Stream Improvement)
14. Lithologic controls on bedrock channel morphology (1995-1996)
    $35,000 from the Japan Society for the Promotion of Science
13. Flood hazards associated with glacier-lakes in the eastern Himalaya Mountains (1994-1997)
    $82,756 from the National Science Foundation
12. Energy expenditure in deep, narrow bedrock canyons (1994)
    $7000 from the Geological Society of America
11. Integrative riparian ecosystem modeling along the Yampa River, Colorado (1994-1996)
    $39,777 from The Nature Conservancy's Ecosystem Research Program
10. Integration of palynological and geomorphological analyses to determine paleoenvironmental conditions at the Hudson-Meng site (1993)
    $11,925 from the USDA Forest Service (co-investigator E. Kelly, CSU)
9. Reconstruction of past river discharge in central Russia (1992)
    $3400 from the National Research Council and the National Academy of Science
8. Regional flood hazard analysis (1991-1993)
    $299,930 from the National Science Foundation (co-investigator J. Salas, CSU)
7. Validation of water yield thresholds on the Kootenai National Forest (1992-1994)
    $110,745 from the USDA Forest Service (co-investigator L. MacDonald, CSU)
6. Paleoflood records in the southern Negev Desert (1991-1992)
    $7200 from the US-Israel Educational Foundation
5. An evaluation of flooding in the vicinity of Harpers Ferry, West Virginia (1991-1992)
    $40,000 from the USDI National Park Service
4. Controls on subalpine channel morphology (1991-1992)
    $20,000 from the USDA Forest Service
3. Fluvial terraces: A tool for integrating geomorphic processes, climatic and tectonic events, and landscape development (1990-1992) $102,608 from the National Science Foundation (co-investigator D. Merritts, F&M College)
2. Holocene paleofloods of northern Australia (1989-1991)
    $24,050 from the National Geographic Society (co-investigator V. Baker, U. Az.)
1. Paleoflood history of Redfield Canyon, Arizona (1989)
    $5711 from the Arizona Department of Water Resources

BIBLIOGRAPHY:
Refereed Publications

231. Doughty MN, E **Wohl**, AH Sawyer, K Singha. 2020. Mapping increases in hyporheic exchange from channel-spanning logjams. Journal of Hydrology 587: 124931.
230. Scott DN, E **Wohl**. In press. Geomorphology and climate interact to control organic carbon stock and age in mountain river valley bottoms. Earth Surface Processes and Landforms.
229. Swanson FJ, SV Gregory, A Iroume, V Ruiz-Villanueva, E **Wohl**. In press. Reflections on

the history of research on large wood in rivers. Earth Surface Processes and Landforms.
228. Scamardo JE, E **Wohl**. 2020. Sediment storage and shallow groundwater response to beaver dam analogs in the Colorado Front Range, USA. River Research and Applications 36: 398-409.
227. **Wohl** E. 2020. Wood process domains and wood loads on floodplains. Earth Surface Processes and Landforms 45: 144-156.
226. Scott, DN, **Wohl** E, Yochum SE. 2019. Wood jam dynamics database and assessment model (WooDDAM): A framework to measure and understand wood jam characteristics and dynamics. River Research and Applications 35: 1466-1477.
225. **Wohl** E, E Iskin. 2019. Patterns of floodplain spatial heterogeneity in the Southern Rockies, USA. Geophysical Research Letters 46: 5864-5870.
224. **Wohl** E, KB Lininger, SL Rathburn, NA Sutfin. 2020. How geomorphic context governs the influence of wildfire on floodplain organic carbon in fire-prone environments of the western United States. Earth Surface Processes and Landforms 45: 38-55.
224. **Wohl** E. 2019. Forgotten legacies: Understanding and mitigating historical human alterations of river corridors. Water Resources Research 55: 5181-5201.
223. Ruiz-Villanueva V, B Mazzorana, E Blade, I Ribarren, L Mao, F Nakamura, D Ravazzolo, D Rickenmann, M Sanz-Ramos, M Stoffel, E **Wohl**. 2019. Characterization of wood-laden flows in rivers. Earth Surface Processes and Landforms 44: 1694-1709.
222. Sutfin NA, E **Wohl**. 2019. Elevational differences in hydrogeomorphic disturbance regime influence sediment residence times within mountain river corridors. Nature Communications 10: 2221.
221. Lininger KB, E **Wohl**. 2019. Floodplain dynamics in North American permafrost regions under a warming climate and implications for organic carbon stocks: a review and synthesis. Earth-Science Reviews 193: 24-44.
220. Lininger KB, E **Wohl**, JR Rose, SJ Leisz. 2019. Significant floodplain soil organic carbon storage along a large high latitude river and its tributaries. Geophysical Research Letters 46: 2121-2129.
219. **Wohl** E, SK Hinshaw, JE Scamardo, PE Gutierrez-Fonseca. 2019. Transient organic jams in Puerto Rican mountain streams after hurricanes. River Research and Applications 35: 280-289.
218. **Wohl** E, N Kramer, V Ruiz-Villanueva, DN Scott, F Comiti, A Gurnell, H Piegay, KB Lininger, K Jaeger, D Walters, K Fausch. 2019. The natural wood regime in rivers. BioScience 69: 259-273.
217. **Wohl** E. in press. Rivers in the Anthropocene: the US perspective. Geomorphology.
216. **Wohl** E, G Brierley, D Cadol, TJ Coulthard, T Covino, KA Fryirs, G Grant, RG Hilton, SN Lane, FJ Magilligan, KM Meitzen, P Passalacqua, RE Poeppl, SL Rathburn, and LS Sklar. 2019. Connectivity as an emergent property of geomorphic systems. Earth Surface Processes and Landforms 44: 4-26.
215. Laurel D, E **Wohl**. 2019. The persistence of beaver-induced geomorphic heterogeneity and organic carbon stock in river corridors. Earth Surface Processes and Landforms 44: 342-353.
214. Scott DN, E **Wohl**. 2019. Bedrock fracture influences on geomorphic process and form across process domains and scales. Earth Surface Processes and Landforms 44: 27-45.
213. **Wohl** E, KB Lininger, DN Scott. 2018. River beads as a conceptual framework for building

carbon storage and resilience to extreme climate events into river management. Biogeochemistry 141: 365-383.
212. Scott DN, EE **Wohl**. 2018. Geomorphic regulation of floodplain soil organic carbon concentration in watersheds of the Rocky and Cascade Mountains, USA. Earth Surface Dynamics 6: 1101-1114.
211. Wollheim WM, S Bernal, DA Burns, JA Czuba, CT Driscoll, AT Hansen, RT Hensley, JD Hosen, S Inamdar, SS Kaushal, LE Koenig, YH Lu, A Marzadri, PA Raymond, D Scott, RJ Stewart, PJ Vidon, E **Wohl**. 2018. River network saturation concept: factors influencing the balance of biogeochemical supply and demand of river networks. Biogeochemistry 141: 503-521.
210. Scott DN, EE **Wohl**. 2018. Natural and anthropogenic controls on wood loads in river corridors of the Rocky, Cascade, and Olympic Mountains, USA. Water Resources Research 54: 7893-7909.
209. **Wohl** E. 2018. The challenges of channel heads. Earth-Science Reviews 185: 649-664.
208. **Wohl** E, DN Scott, KB Lininger. 2018. Spatial distribution of channel and floodplain large wood in forested river corridors of the Northern Rockies. Water Resources Research 54: 7879-7892.
207. **Wohl** E. 2018. Geomorphic context in rivers. Progress in Physical Geography 42: 841-857.
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40. Springer GS and EE **Wohl**. 2002. Empirical and theoretical investigations of sculpted forms in Buckeye Creek Cave, West Virginia. Journal of Geology 110: 469-481.
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38. Cenderelli DA and EE **Wohl**. 2001. Peak discharge estimates of glacial lake outburst floods and "normal" climatic floods in the Mount Everest region, Nepal. Geomorphology 40: 57-90.
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35. **Wohl** EE and DM Thompson. 2000. Velocity characteristics along a small step-pool channel. Earth Surface Processes and Landforms 25: 353-367.
34. **Wohl** EE and DA Cenderelli. 2000. Sediment deposition and transport patterns following a reservoir sediment release. Water Resources Research 36: 319-333.
33. **Wohl** EE. 2000. Substrate influences on step-pool sequences in the Christopher Creek drainage, Arizona. Journal of Geology 108: 121-129.
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31. Thompson DM, JM Nelson and EE **Wohl**. 1998. Interactions between pool geometry and

hydraulics. Water Resources Research 34: 3673-3681.
30. Blizard CR and EE **Wohl**. 1998. Relationships between hydraulic variables and bedload transport in a subalpine channel, Colorado Rocky Mountains, USA. Geomorphology 22: 359-371.
29. Kelly EF, SW Blecker, CM Yonker, CG Olson, EE **Wohl** and LC Todd. 1998. Stable isotope composition of soil organic matter and phytoliths as paleoenvironmental indicators. Geoderma 82: 59-81.
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22. **Wohl** EE and H Ikeda. 1997. Experimental simulation of channel incision into a cohesive substrate at varying gradients. Geology 25: 295-298.
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17. Hilmes MM and EE **Wohl**. 1995. Changes in channel morphology associated with placer mining. Physical Geography 16: 223-242.
16. **Wohl** EE. 1995. Estimating flood magnitude in ungaged mountain channels, Nepal. Mountain Research and Development 15: 69-76.
15. **Wohl** EE and AG Georgiadi. 1994. Holocene paleomeanders along the Sejm River, Russia. Zeitschrift fur Geomorphologie 38: 299-309.
14. Mejia-Navarro M and EE **Wohl**. 1994. Geological hazard and risk evaluation using GIS: Methodology and model applied to Medellin, Colombia. Bulletin of the Association of Engineering Geologists XXXI: 459-481.
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6. **Wohl** E. 1993. Bedrock channel incision along Piccaninny Creek, Australia. The Journal of Geology 101: 749-761.
5. **Wohl** EE, KR Vincent and DJ Merritts. 1993. Pool and riffle characteristics in relation to channel gradient. Geomorphology 6: 99-110.
4. **Wohl** E. 1992. Gradient irregularity in the Herbert Gorge of northeastern Australia. Earth Surface Processes and Landforms 17: 69-84.
3. **Wohl** EE. 1992. Bedrock benches and boulder bars: Floods in the Burdekin Gorge of Australia. Geological Society of America Bulletin 104: 770-778.
2. Murray A, E **Wohl** and J East. 1992. Thermoluminescence and excess ^{226}Ra decay dating of late Quaternary fluvial sands, East Alligator River, Australia. Quaternary Research 37: 29-41.
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Book Chapters

31. **Wohl** E, PR Bierman and DR Montgomery. 2017. Earth's dynamic surface: the past 50 years in geomorphology. In, M.E. Bickford, ed., The Web of Geological Sciences: Advances, Impacts, and Interactions: New Papers to Celebrate GSA's 125th Anniversary, Geological Society of America Special Paper 523. Geological Society of America, Boulder, Colorado, doi:10.1130/2016.2523(01).
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29. **Wohl** E. 2014. Dryland channel networks: resiliency, thresholds, and management metrics. In, R.S. Harmon, S.E. Baker, and E.V. McDonald, eds., Military Geosciences in the Twenty-First Century, Geological Society of America, Boulder, CO, pp. 147-158.

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20. **Wohl** E. 2007. Review of effects of large floods in resistant-boundary channels. In, H. Habersack, ed., Gravel-bed rivers: from process understanding to river restoration. Elsevier, pp. 181-212.
19. **Wohl** E. 2005. Downstream hydraulic geometry along a tropical mountain river. In, R. Harmon, ed., The Rio Chagres: A multidisciplinary profile of a tropical watershed. Kluwer Academic Publishers, p. 169-188.
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17. Montgomery DR and EE **Wohl**. 2004. Rivers and riverine landscapes. In, A. Gillespie, S.C. Porter, and B.F. Atwater, eds., The Quaternary period in the United States. Elsevier, Amsterdam, pp. 221-246.
16. **Wohl** E and T Oguchi. 2004. GIS and mountain hazards. In, M.P. Bishop, ed., Geographic Information Science and Mountain Geomorphology. Praxis Scientific Publishing, Chichester, UK, pp. 309-341.
15. Rathburn SL and EE **Wohl**. 2003. Sedimentation hazards downstream from reservoirs. In, W.L. Graf, ed., Dam removal research: status and prospects. The John Heinz Center for Science, Economics and the Environment, Washington, D.C., pp. 105-118.

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10. **Wohl** E. 1999. Boulders on the move: geomorphic hazards from floods and debris flows along mountain rivers. In, Z.-Y. Wang, T.-W. Soong, and B.C. Yen, eds., Sediment transport and disasters. Special Issue of International Journal of Sediment Research (China), v. 14, p.285- 293.

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5. **Wohl** E and D Cenderelli. 1998. Flooding in the Himalaya Mountains. In, V.S. Kale, ed., Flood studies in India, Geological Society of India, Memoir 41, Bangalore, pp. 77-99.
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3. **Wohl** EE and Y Enzel. 1995. Data for palaeohydrology. In, K.J. Gregory, L. Starkel, and V.R. Baker, eds., Global continental palaeohydrology. John Wiley and Sons, p. 23-59.
2. Mejia-Navarro M, EE **Wohl** and SD Oaks. 1994. Geological hazards, vulnerability, and risk assessment using GIS: Model for Glenwood Springs-Carbondale, Colorado. In, M. Morisawa, ed., Geomorphology and Natural Hazards, Elsevier, p. 331-354.
1. Salas JD, EE **Wohl** and RD Jarrett. 1994. Determination of flood characteristics using systematic, historical and paleoflood data. In, G. Rossi, N. Harmancioglu, and V. Yevjevich, eds., Coping with floods. Kluwer Academic Publishers, Dordrecht, p. 111-134.

Books, Edited Volumes, and Other Special Publications

21. **Wohl** E, DN Scott, SE Yochum. 2019. Managing for Large Wood and Beaver Dams in Stream Corridors. USDA Forest Service General Technical Report RMRS-GTR-404, 136 pp.
20. **Wohl** E. 2019. Saving the dammed: why we need beaver-modified ecosystems. Oxford University Press.
19. **Wohl** E. 2018. The upstream extent of a river network: a review of scientific knowledge of channel heads. Cold Regions Research and Engineering Laboratory, US Army Corps of Engineers, Washington, D.C., ERDC/CRREL CR-18-1, 47 pp.
18. **Wohl** E. 2017. Sustaining river ecosystems and water resources. Springer.
17. **Wohl** E, MK Mersel, AO Allen, KM Fritz, SL Kichefski, RW Lichvar, TL Nadeau, BJ Topping, PH Trier, FB Vanderbilt. 2016. Synthesizing the scientific foundation for ordinary high water mark delineation in fluvial systems. Cold Regions Research and Engineering Laboratory, US Army Corps of Engineers, Washington, D.C., ERDC/CRREL SR-16-5, 198 pp.

16. **Wohl** E. 2016. Rhythms of change in Rocky Mountain National Park. University Press of Kansas.
15. **Wohl** E. 2015. Transient landscapes: insights on a changing planet. University Press of Colorado.
14. Yochum SE, F Comiti, E **Wohl**, GCL David and L Mao. 2014. Photographic guidance for selecting flow resistance coefficients in high-gradient channels. USDA Forest Service General Technical Report RMRS-GTR-323, 91 pp. http://www.fs.fed.us/rm/pubs/rmrs_gtr323.pdf
13. **Wohl** E. 2014. Rivers in the landscape: science and management. Wiley-Blackwell, Chichester, UK.
12. **Wohl** E. (Ed.). 2013. Treatise on fluvial geomorphology. Elsevier, Amsterdam.
11. **Wohl** E. 2013. Wide rivers crossed: the South Platte and the Illinois of the American Prairie. University Press of Colorado.
10. **Wohl** E. 2011. A world of rivers: environmental change on ten of the world's great rivers. University of Chicago Press.
9. **Wohl** E. 2010. Mountain rivers revisited. American Geophysical Union, Water Resources Monograph 19, 573 pp.
8. **Wohl** E. 2009. Of rock and rivers: seeking a sense of place in the American West. University of California Press.
7. **Wohl** E. 2009. Island of grass. University Press of Colorado.
6. **Wohl** E. 2004. Disconnected rivers: Draining the vitality of U.S. Waterways. Yale University Press.
5. **Wohl** EE. 2001. Virtual Rivers: lessons from the mountain rivers of the Colorado Front Range. Yale University Press, New Haven, 210 pp.
4. **Wohl** E. 2000. Mountain rivers. American Geophysical Union, Water Resources Monograph 14, 320 pp.
3. **Wohl** E. 2000. (Ed.) Inland flood hazards: Human, riparian, and aquatic communities. Cambridge University Press, 498 pp.

2. Tinkler KJ and EE **Wohl**. 1998. (Eds.) Rivers over rock: fluvial processes in bedrock channels. Am. Geophys. Union Geophysical Monograph 107, 323 pp.
1. **Wohl** E. 1994. Rain forest into desert. University Press of Colorado.

PROFESSIONAL SERVICE

Manuscript Reviews

American Journal of Science; Arabian Journal of Science and Engineering; Arctic, Antarctic, and Alpine Research; Canadian Journal of Forest Research; Catena; Earth and Planetary Science Letters; Earth-Science Reviews; Earth Surface Processes and Landforms; Ecological Applications; Environmental Management; Forest Ecology and Management; Frontiers in Ecology and the Environment; Geodinamica Acta; Geological Society of America Bulletin; Geological Society of America Special Paper series; Geology; Geomorphology; Geophysical Research Letters; Global and Planetary Change; GSA Today; Hydrological Processes; International Journal of Computers and Applications; International Journal of Sediment Research; Journal of the American Water Resources Association; Journal of Geology; Journal of

Geophysical Research; Journal of Hydraulic Engineering; Journal of Hydrology; Journal of Range Management; Journal of Sedimentary Petrology; Journal of Sedimentary Research; Limnology and Oceanography; Mountain Research and Development; National Park Service Proceedings Series; Natural Areas Journal; Polish Journal of Environmental Studies; Quaternary Research; Regulated Rivers; U.S. Geological Survey Professional Papers; U.S. Geological Survey Water-Resources Investigations; Water, Air and Soil Pollution; Water Management; Water Resources Research; Wetlands

Service to Societies and Journals

Editorial board of *Geomorphology*, 1996-present
Associate Editor, *Geological Society of America Bulletin*, 1997-2006
Associate Editor, *Water Resources Research*, 2001-2011
Editorial board of *Environmental Management*, 2007-2013
Editorial board of *Geography Compass*, 2007-present
Editorial board of *Earth Surface Processes and Landforms*, 2008-2009; Associate Editor, 2010-present
Associate Editor, *Journal of Hydrology*, 2010-2013
Editor-in-Chief, Oxford Bibliography of Environmental Science, 2013-present, http://www.oxfordbibliographies.com/obo/page/environmental-science
Board member, Geological Society of America Foundation, 2017-present
Officer, Quaternary Geology & Geomorphology Division, Geological Society of America, 2001-2005 (Chair, 2003-2004)
Member, Ordinary High Water Mark National Technical Committee, 2014-present
Member, Erosion & Sedimentation Committee, Am. Geophys. Union, 2001-2008
Member, Earth and Planetary Surface Process Focus Group, Am. Geophys. Union, 2009-present
Geol. Soc. Am. Committee on Committees, 1996
Geol. Soc. Am. Joint Technical Program Committee, 2004
GSA Quaternary Geology & Geomorphology Division Nominating Committee, 1996
GSA Quaternary Geol. & Geomorph. Division Panel Member, 1996-1998
GSA Quaternary Geol. & Geomorph. Division Abstracts Reviewer, 1993
GSA Quaternary Geol. & Geomorph. Division Mackin/Howard Committee, 1990-91, 1996-98, 2001-02
GSA Session Chair, annual meetings in 1993, 1996, 1997, 2002, 2007
Am. Geophys. Union Session Chair, Hydrology Days, 1992-1994, 1997-1998
AGU Student Presentation Judge, 1998, 2001, 2003, 2007
Member, Colorado Natural Hazards Mitigation Council, 1991-present
Trustee, Rocky Mountain Hydraulic Research Center, 1992-present
Panel member, NSF Hydrologic Sciences Program, 1999-2003
Am. Soc. Civil Engineers Paleoflood Hydrology Committee, 1999
Panel member, NSF Geomorphology and Land-Use Dynamics Program, 2005-2007
Panel member, NSF Geography and Spatial Sciences Doctoral Dissertation Improvement Grant Program, 2016-2017
Member, National Technical Committee on the Ordinary High Water Mark (Army Corps of Engineers and US EPA), 2014-present

Invited Lectures, Review Panels, Advisory Boards

Invited lectures

US universities
Baylor University
Boise State University
Central Washington University
College of Idaho
Colorado College
Idaho State University
Iowa State University
Ohio State University
Ohio Wesleyan University
Oregon State University
Skidmore College
St. Louis University
Texas A&M University
University of Arizona
University of California, Berkeley
University of California, Davis
University of California, Santa Barbara
University of Colorado, Boulder
University of Colorado, CO. Springs
University of Denver
University of Illinois
University of Iowa
University of New Mexico
University of North Carolina, Charlotte
University of Oklahoma
University of South Carolina
University of Vermont
University of Washington
University of Wyoming

Other universities
Aberystwyth University (Wales)
Chuo University (Japan)
Durham University (England)
ETH Zurich (Switzerland)
GFZ Potsdam (Germany)
Griffith University (Australia)
Hebrew University (Israel)
Hokkaido University (Japan)
Loughborough University (England)
Mid-Sweden University
Newcastle University (England)
Queen Mary University of London (England)
Umeå University (Sweden)
Universidad Complutense Madrid (Spain)
University of Cambridge (England)
University of Edinburgh (Scotland)
University of Glasgow (Scotland)
University of Hull (England)
University of Lausanne (Switzerland)
University of Nottingham (England)
University of Padova (Italy)
University of Salzburg (Austria)
University of Southampton (England)
University of Tokyo (Japan)
University of Tsukuba (Japan)
University of Western Ontario (Canada)
Pontificia Universidad Católica de Chile
Universidad de los Andes (Colombia)
University of Melbourne (Australia)
University of Wollongong (Australia)

Other
Am. Geophys. Union Gilbert Club
Army Research Office Workshop on Desert Processes
Australian Stream Management Conference, 2016
Chinese-American Frontiers of Science Meeting, 1999, 2000
Colorado Archeological Society
COACh International invited participant (Argentina 2013, Jamaica 2014, Namibia 2015, Rwanda 2016)
Colorado Natural Hazards Mitigation Council
Colorado Scientific Society
CUAHSI Biennial Symposium (2018)
Estes Valley Land Trust

Geological Survey of Norway
Institute of Geography (Russia)
National Institute of Water and Atmospheric Sciences (New Zealand)
NSF Workshop on Sediment-Induced Disasters
The Nature Conservancy
U.S. Forest Service
U.S. Geological Survey
Wood Buffalo National Park, Canada

Invited keynote speaker at Binghamton Geomorphology Symposium (1994, 2006, 2012); North American Benthological Society (2000); American Water Resources Association conference (2004); Colorado Riparian Association conference (2004); Second International Symposium on Riverine Landscapes, Sweden (2004); Gravel-Bed Rivers VI Workshop, Austria (2005); 7th IAHR Symposium on River, Coastal and Estuarine Morphodynamics, China (2011); 4th Interagency Conference on Research in the Watersheds (2011); Mid-Atlantic Stream Restoration Conference (2011); MTNCLIM (Consortium for Integrated Climate Research in Western Mountains, 2012); River Restoration Northwest Conference (2012); American Society of Environmental Historians (2013); Southwest Stream Restoration Conference (2014); Wood in World Rivers III (2015); 8th Australian Stream Management Conference (2016); Catskills Environmental Research and Monitoring Conference (2016); RiverFlow (2016); Rocky Mountain Stream Restoration Conference (2016); Sustaining Colorado Watersheds Conference (2016); European Geosciences Union (2017); Society for Freshwater Science (2018); Natural Channels Conference (2018)

Review panels for Upper Colorado River Endangered Fish Recovery Program (1995); San Juan River Recovery Program (1997-2005); Chair, Physical Sciences Review Panel for Grand Canyon Monitoring and Research Center (1998-2000); CALFED Battle Creek Restoration Plan (2003-2004); Building with Nature (The Netherlands, 2013); US Environmental Protection Agency Science Advisory Board Panel for the review of the EPA Water Body Connectivity Report (2013); The New Delta (The Netherlands, 2014)

External PhD examiner for Macquarie University, Australia (2001, 2015); Umea University, Sweden (2004); University of Trento, Italy (2007); Southern Cross University, Australia (2010); University of Auckland, New Zealand (2014); University of Melbourne, Australia (2014); University of the West Indies, Jamaica (2014); University of Newcastle, Australia (2016); University of Wollongong, Australia (2016); ETH Zurich (2018)

Advisory board for The Nature Conservancy's Colorado Scientific Advisory Network (1997-present), Grand Canyon Monitoring and Research Center Science Advisors Board (2006-present)

International visitors hosted at Colorado State University
Takashi Oguchi, University of Tokyo, Japan (2001)
Yuichi Hayakawa, University of Tokyo, Japan (2005)
Francesco Comiti, University of Padova, Italy (2007)
Mario Jiménez, Universidad Nacional de Colombia, Colombia (2010)
Jonathan Ryan, University of Nottingham, England (2011)

Jose Ortega, Universidad Autónoma de Madrid, Spain (2012, 2015)
Michaela Wörndl, University of Innsbruck, Austria (2014)
Margherita Righini, University of Padova, Italy (2015)
William Amponsah, University of Padova, Italy (2015)
Fernando Ugalde, Pontificia Universidad Catolica de Chile, Chile (2015)
Lina Polvi Sjöberg, Umeå University, Sweden (2015)
Alfonso Pisabarro, University of Valladolid, Spain (2016)
Tania Santos, Universidad de los Andes, Colombia (2017-18)
Yuko Asano, University of Tokyo, Japan (2018-19)

Primary advisor for the following graduate students (completion date)

MS

Kathy Adenlof (1992)
Susan Fuertsch (1992)
Mario Mejia-Navarro (1992)
Michael Grimm (1993)
Marsha Hilmes (1993)
Clifford Blizard (1994)
Lauren Hammack (1994)
Michael Martin (1994)
Rebecca Smith (1994)
Douglas Thompson (1994)
Michael Liquori (1995)
Susan Madsen (1995)
Jill Minter (1996)
Jonathan Pruess (1996)
Carolyn Trayler (1997)
Janet Curran (1999)
Jasper Hardison (2000)
Stephanie Phippen (2000)
William MacFarlane (2001)
Gregory Stewart (2001)
Ronald Zelt (2002)
Chris Jaquette (2003)
Tracy Phelps (2003)
Kurt Sable (2004)
Ian Dubinski (2005)
Jaime Goode (2005)

***MS** (cont.)*

Francis Rengers (2005)
Dan Cadol (2007)
Gabrielle David (2007)
Amy Nowakowski (2007)
Paul Dante (2009)
Lina Polvi (2009)
Zan Rubin (2010)
Jameson Henkle (2010)
Elizabeth Gilliam (2011)
Natalie Kramer (2011)
Tyanna Schlom (2012)
Nicholas Sutfin (2012)
Jonathan Garber (2013)
Simeon Caskey (2013)
Bridget Livers (2013)
Heidi Klingel (2013)
Karen Jackson (2014)
DeAnna Laurel (2014)
Dena Hicks (2015)
Dan Scott (2015)
Elizabeth Oswald (2015)
Krista Garrett (2016)
Andrew Pfeiffer (2017)
Julianne Scamardo (2019)
Ethan Ader (2019)
Sarah Hinshaw (2019)

Ph.D.

Mario Mejia-Navarro (1995)
Nancy Hoefs (1996)
Brian Cluer (1997)
Mette Jordan (1997)
Douglas Thompson (1997)
Edmund Wick (1998)
Dan Cenderelli (1998)
David Merritt (1999)
Sara Rathburn (2001)
Gregory Springer (2002)
Allen Gellis (2003)
Andrew Wilcox (2005)
Nancy Brown (2006)
Ian Dubinski (2009)
Jaime Goode (2009)
Kristin Jaeger (2009)
Dan Cadol (2010)
Gabrielle David (2011)
Lina Polvi (2011)
Natalie Beckman (2012)
Susan Howe (2013)
Dai Thomas (2014)
Umit Duru (2015)
Nick Sutfin (2015)
Natalie Kramer Anderson (2016)
Bridget Livers (2016)
Katherine Lininger (2018)
Dan Scott (2018)
DeAnna Laurel (2019)