Dr. William Kleindl – Assistant Research Professor, LRES: Grant Application
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Title: Foundations of a Wetland Benefits Assessment (WBA) Tool

1. Proposal Narrative

Abstract: The goals of the 1990 No-Net-Loss (NNL) of Wetlands policy and Clean Water Act 404(b)(1) regulatory guidelines for compensatory mitigation are no net loss of wetland **area**, **functions**, and **values**. Achieving NNL is the prime motivation for most wetland regulatory decision. Tools exist to determine - in a rapid and repeatable manner - wetland **area** and wetland **function** based on established ecological theory. However, no rapid and repeatable tools exist to assess the **value** of ecosystem services provided by a specific wetland. This effort will provide a foundation for constructing rapid wetland service assessment tools that will improve regulatory decision making by incorporating economic and other values. This framework will blend local wetland ecological data with principles of environmental economics to create proposed wetland ecosystem service metrics to include qualities that promote human well-being. The tool's broader applications will assist decision-makers integrate ecosystem services into urbanizing America.

a. Statement of Specific Aims of the Project

In the 1990 Memorandum of Agreement between US Army Corp of Engineers (ACOE) and US Environmental Protection Agency (EPA), ACOE strives "to achieve a goal of no overall net loss of area, functions and values" (NNL) for wetlands (USEPA 1990). Over the last 25 years, this memorandum and subsequent regulatory guidance has driven the AOCE compensatory mitigation guidelines and all wetland permitting within the nations. To facilitate in regulatory decision, this policy also led to the development and refinement of multiple assessment tools to measure wetland function and/or condition. These tools ensure that compensatory mitigation is correctly done, or that the correct fees are charged for in-lieu-fee or wetland bank alternatives of required mitigation.

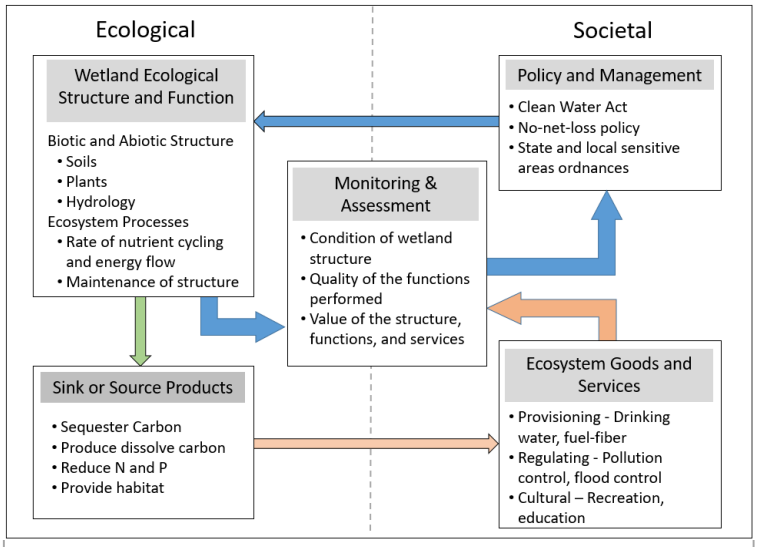

Fig. 1. Socioecological relationship between wetland and the regulatory processes. Blue arrows indicate how monitoring and assessment translate ecological data for decision makers, and the green arrow indicate the scientific knowledge between wetland structure and function and the products it produces. The red arrows indicate where our proposed work will help strengthen the linkages between scientific

These assessment tools have been developed using theoretical foundations of ecological processes and a history of biotic and abiotic assessment that is nearly as old as the science of ecology (Kolkwitz and Marsson 1908, Cairns and Pratt 1993, Verdonschot 2000). Because NNL also requires an assessment of value, the quality of the assessment ecological condition alone does not completely drive policy and management (Fig. 1), and often additional scientific knowledge does not necessarily drive the outcome (Sarewitz 2004, Miller et al. 2014). Management and policy decisions are driven by a combination of political contexts, available technologies, established infrastructure and economics, scientific knowledge, as well as social values (Fischer et al. 2012, Miller et al. 2014). However, there has been little effort to develop assessment tools that measure wetland value in a rapid and repeatable manner, likely due to the lack of foundational work linking the condition of the ecological structure and function to the economic value of the services generated (*viz.* de Groot et al. 2002). The introduction of ecosystem services has fundamentally altered sustainability science by providing decision makers a conceptual linkage between ecological process and human well-being often through economic relationships (Brown et al. 2007, Gómez-Baggethun et al. 2010). These recent advances in the ability to measure the benefits that people obtain from ecosystems make it possible to do develop rapid assessment of wetland value, based on new conceptual frameworks (MEA 2005) and economic tools to measure value (Woodward and Wui 2001, Boyer and Polasky 2004, Barbier et al. 2013). Therefore, this is an opportune time to blend the existing framework of ecological assessment with these newly developed economic approaches for use in permitting, restoration, and preservation decisions to meet and

inform existing policy and management goals. Additionally, if pubic mandates direct policy toward service based priorities, such as the State of Montana's larger aquatic strategic goals articulated in the State's water and wetland planning efforts (MT-DEQ 2013, MT-DNRC 2015), then a tool to be available to assist the policy makers with these efforts.

I propose to develop the foundations of a Rapid Wetland Benefit Assessment (WBA) tool in line with EPA's three-tiered approach for monitoring and assessing wetlands: Level 1 - landscape assessments, Level 2 - rapid assessments, and Level 3 – highly-detailed assessments with intensive data collection and analysis (Kentula 2007). Rapid, in case of Level 2 Assessments, is defined as an assessment that can be done with one-half day in the field and one-half day in the office (Fennessy et al. 2007). Level 2 Rapid Assessments are designed to be a cost-effective and efficient approach to providing the data necessary for permitting decisions-making, and is the most common wetland ecological assessment strategy within the U.S. (Fennessy et al. 2007). For assessments of ecological goods and services, several methods have been developed to provide monetary valuations of specific ecosystems within limited geographic regions (Stelk and Christie 2014). However, these tools require intensive data collection and analysis, and are analogous to a Level 3 effort. Although these Level 3 efforts are necessary for particular management or permitting decisions, most regulatory decisions do not require that degree of detailed and costly data, nor do they burden the applicant with the expense necessary for Level 3 efforts. Therefore, there is an essential need for a Level 2 Rapid Assessment approach of wetland ecosystem goods and services that is supported by both ecological and economic theory and - as with ecological rapid assessment - provides results that are *repeatable* and *defendable* within acceptable limitations. Establishing the foundations of such a rapid assessment tool is the core of this proposal (see Fig 1).

U.S. Army Corps of Engineers wetland regulatory agents are focused on well-established assessment of wetland **area** and **function** yet receive inconsistently applied assessments of **value** (Fennessy et al. 2007). To develop a rapid wetland service assessment that will improve regulatory decision making by incorporating economic values, a few important efforts must be accomplished to encourage regulatory agents to include such a tool into their decision making process. First, clarity is required to equate the multiple functions a wetland performs (e.g. energy flow, nutrient cycling, structural support) to other ecological goods and services that are currently discussed within the ecological service literature (e.g. provisioning, regulating, cultural, and supporting services). For example, the ecological function of surface water storage in a riverine wetlands can be directly related to a natural hazard regulating service of flood control (Wardrop et al. 2011). Coupling the qualities of wetland structure and function determined by existing function/condition assessment tools with the ecosystem services they provide has yet to be done in the peer-reviewed literature.

The second effort would be to develop and qualify indicators that evaluate relevant spatial and non-spatial attributes to determine how goods and services are valued. This is beyond the scope of this grant, but initial work can be done to identify potential indicators that could provide reliable information when assessed in a rapid manner. For instance, wetland functions exist regardless of human presence, but because humans benefit from these functions, the goods and services should be scalable to both the quality of the system (as assessed by the existing ecological assessment tools) and/or its landscape position, relative to social, cultural and economic aspects of the community (Boyd and Wainger 2002, Wainger 2014). Some spatial attributes will be important, such as the number of people in the area that benefits from the service ("service-shed"), the availability of substitutes, or vulnerability to risks. Other attributes may not, such as the importance of wetlands in wilderness for aesthetics (Boyd and Wainger 2002, Bateman et al. 2006, Wainger et al. 2010). The challenge will be in examining the parameters of existing environmental economic models such as benefit transfer, stated and revealed preferences, and market based approaches (Stelk and Christie 2014) and derive a list of potential surrogate metrics that can be assessed rapidly using spatial and on-site wetland attributes to develop a rapid assessment of ecological benefits. Such metrics would provide measures for an ecological benefits *rapid* assessment that provide an interpretation of the wetland's *capacity* to provide *relative measures of potential benefits*, it would *not provide an actual monetized* valuation of ecosystem goods and services. If a permitted action requires a monetized valuation, that would lie in the realm of a Level 3 effort.

b. Significance of the Project

Beyond the No-Net-Loss policy mentioned above, there are other Federal directives that intend to address

ecological benefits of wetlands. For example, the permitting process outlined in §404(b)1 guidelines for the Clean Water Act states that "significant degradation" includes adverse effects on "recreational, aesthetic and economic values" (ACOE 2016). Recently, the Executive Office of the President released a memorandum directing Federal agencies to factor in ecosystem services into Federal planning and decision-making (Executive Office of the President 2016). These Federal directives affect how wetland management decisions are made within Montana. The eventual integration of an effective tool that measures wetland ecosystem goods and services and can be rapidly applied across a range of physiographic regions and wetland types would not only help the State and tribal jurisdictions meet the Federal Directives, but would assist in larger aquatic strategic goals articulated in the State's planning efforts (MT-DEQ 2013, MT-DNRC 2015).

At local levels, small cities in urbanizing areas are finding that their sensitive areas ordinances are insufficient to keep up with the expanding populations. For instance, the City of Bozeman population is expanding at a rate of about 4% per year only recently has the City developed storm water regulations. The City found a need to develop such regulations to address pollution within the City's streams as they have exceeded the total maximum daily load (TMDL) and are considered impaired by the State and EPA for nitrates and excessive sediment (37% above the limit). The City, concerned of potential regulatory implications from State and Federal levels, implemented storm water policies and sought to leverage the ecosystem services available through the City's aquatic infrastructure to help attenuate the pollution. The City is currently developing two such areas; at the new in Story Mill Park location and Bogart Park at a cost of about $1.2 million to create improved riparian areas enhance ecological services that would both retain sediment and cycle nutrients. These self-maintaining ecosystem services are both cheaper than hard-structure and more expensive in-line treatment options and integrate into the City as a natural amenity. For this grant effort, I will also focus on wetland systems that are important to the City of Bozeman at Story Mill. My project will strengthen that linkage between wetland ecology, the goods and services they provide, and tools to rapidly assess these to inform policy makers and managers (Fig. 1).

c. Innovation

There is a clear need for an assessment of ecological benefits tool that is both rapid and repeatable for Federal wetland permitting process. However, there is also an important need for such tool to assist decision-makers in America's urbanizing small towns. For instance, over the last decade the inner-mountain west has grown about 20% and have made up the most rapid growth in the nation. These urbanizing small cities of the inner-mountain west are finding it necessary to implement storm water management into a culture that is resistant to regulation and with limited tax-base. Such a tool would help improve regulatory decisions based on the growing emphasis to preserve and enhance ecological areas that can provide good and services, allowing these growing communities to spend less money, have lower exposure to liability, and assist in the application of regulatory directives and public mandates to address ecological value.

The ultimate project goal is to develop a framework and generalized methodology for the rapid assessment of wetland ecosystem goods and service. As mentioned above, this framework does not currently exist in the wetland scientific and regulatory landscape. To facilitate the incorporation of such a tool into the regulatory process, the results will also be communicated in white papers and policy brief to provide the best available science, and economic information to the management and policy communities. Ultimately, our efforts will be communicated to both economic and scientific communities in peer-reviewed journals such as *Ecological Economics* and *Wetlands*, but this is beyond the scope of this grant effort. The proposed effort here will provide the ground-work for a larger effort to the develop a rapid assessment of goods and services module that can be integrated into the existing rapid wetland ecological function or condition assessment tools that are currently implemented across the nation. I already have collaborators for this future effort that will be proposed to U.S. EPA National Wetland Program Development Grant where I will work with collaborators in Pennsylvania (wetland scientist Dr. Rob Brooks), Maryland ecological service economist Dr. Lisa Wainger) and Florida (wetland scientist Dr. Mark Rains) to establish and test a national scale tool based on the initial efforts here. The larger effort meets the EPA's National Priority of Core Elements Framework in two ways, first by helping state, tribal, and local governments with the public perception of the value of wetlands, and second, increase their capacity for monitoring and assessment.

d. Approach (Design and Methods):

The following mirrors common initial tasks in the development wetland assessment models (Smith et al. 1995, Sutula et al. 2006). These tasks have produced many successful ecological assessment modeling efforts and have demonstrated iterative advancements that have improved the interaction between model development teams and model end-users across the nation. This5 major tasks would represent the first of several tasks necessary to make a complete assessment guidebook for application by ACOE and EPA:

Task	Description
1.0 Identify and summarize existing wetland services assessment tools used nationally	• Summarize the literature to date on the linkage between wetlands ecological processes and the goods and services they produce. • Summarize the literature to date on the data intensive monetized evaluation of wetland goods and services. • Identify measurement endpoints important to state, local and tribal end-user and develop list of potential rapid assessment surrogates of these measures that are appropriate for Level 2 benefit assessment • Propose how existing wetland ecological assessments metrics relate to wetland goods and services.
2.0. Case study wetland ecological assessment.	• For this effort, I will use one riverine wetland important to the Bozeman Community as case studies: the urban system of Story Mill Wetlands. • I will conduct a rapid assessment of wetland functions using existing tools (Hauer et al. 2002, Berglund and McEldowney 2008).
3.0 Build theoretical foundations for the rapid economic assessment.	• I will use the Community of Bozeman as the benefactors of these wetlands services. • Establish a benefit rapid assessment conceptual model and identify assumptions, limitations, and potential uncertainties. • Identify commonalities and connections between existing wetland condition/function assessment and conceptual service attributes. • Suggest how benefit rapid assessment conceptual model can be applied case study wetland.
4.0 Outreach and Implement	• Present conceptual model to wetland and ecological economics societies through white papers and policy briefs. • Present a research seminar on the project that is open to faculty, students and the general public on the MSU campus IOE Rough Cut Series and to the City of Bozeman programs related to Story Mill Regional Park • Conduct outreach through presentations at local, and regional meetings.
5.0 Project Management	• Constant communication and internal task and budget management within the team on program progress and support. • Scheduled communication between project team and CRAEA.

The following is considered outside of the page limit for the proposal.

2. Human Subjects

There will be no human subjects in this study.

3. Itemized Budget and Justifications

Expenditures	Year 1
William Kleindl, PI (Salary and Benefits)	
Richard Ready, Co-PI (Salary and Benefits)	
Supplies/Expendables	
Publication Expense	
Travel and Conference Fees	
Total	

Total Project Cost: Of the **total cost**, **Salaries, Wages and Benefits are :** these include effort for the PI-William Kleindl who is an Assistant Research Professor in LRES and is not subject to the summer salary restrictions; Co-PI Richard Ready who is budgeted for 10 hours of summer salary. **Supplies/Expendables are :** This fee is set aside to purchase necessary equipment and computer software for wetland assessment. **Publication Expenses :** fees are set aside to cover expenses for the necessary white paper, policy brief publications. **Domestic Travel is** : travel funds are reserved for conference costs.

4. Proposal Timeline

The following are timeline is tightly linked to the detailed tasks above. It is imperative that each milestone on time to ensure successful completion of the project. These will be closely managed by the PI.

Task	Spring 2017	Summer 2017	Fall 2017
1.0 Identify and summarize existing wetland services assessment tools used nationally.			
2.0. Case study wetland ecological assessment.			
3.0 Build theoretical foundations for the rapid economic assessment.			
4.0 Outreach and Implement			
5.0 Project Management			

5. Staff Expertise/Qualifications

The project will be led by Drs. William Kleindl and Richard Ready from Montana State University (MSU). Short biographies of each are presented below:

William Kleindl (PI) is a socioecologist specializing on aquatic systems, with a B.A. in Botany (UW Madison 1987), an MS in Urban Stream Ecology (UW Seattle 1995), and a Ph.D. in Systems Ecology (UM Missoula 2014). I am currently an assistant researcher professor in LRES. I have extensive experience in the development and implementation of ecological assessment tools for decision makers. In the early 90s, I developed such tools for the Puget Sound Lowlands, in the mid-90s I developed these in Alaska and regions in the lower 48, in the 2000s for the Jicarilla Apache and large mining projects in Alaska, and recently developed a watershed scale assessment tool for Glacier

National Park. In my research facility position at LRES, I connect wetland structure and function with ecological service while teaching the 2015 LRES Capstone course and in the 2016 Capstone course, we continued to specifically address this question as it applied to the Story Mill Wetlands in the City of Bozeman. Through NSF macrosystems, I am advancing socioecological theory at region scales. The objective of my career has been to provide straightforward analysis of ecological data to facilitate a translation for management application. The following is my CV:

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Land Resources and Environmental Sciences
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PROFESSIONAL PREPARATION

University of Wisconsin	Madison, WI	Botany	B.A. 1987
University of Washington	Seattle, WA	Aquatic Ecology	M.S. 1995
University of Montana	Missoula, MT	System Ecology	Ph.D. 2014
University of Montana	Missoula, MT	Postdoctoral Scholar	2015
Montana State University	Bozeman, MT	Postdoctoral Researcher Macrosystems	2016

APPOINTMENTS

(Academic)

Current Research Professor, Land Resource and Environmental Science, Montana State University
2016 Postdoctoral Researcher, Macrosystems, Stoy Lab, Montana State University
2014-2016 Postdoctoral Scholar, Institute of the Environment, University of Montana
2009-2014 Research Assistant, Institute of the Environment, University of Montana
1992-1995 Research Assistant, Institute of Environmental Studies, University of Washington

(Private Consulting)

2006-Current President, Naiad Aquatic Consultants, LLC, Bozeman, MT
1997-2006 Project Manager and Aquatic Ecologists, Parametrix, Seattle, WA
1995-1997 Aquatic Ecologists, L.C. Lee and Associates, Seattle, WA

PUBLICATIONS/PRODUCTS

Five most closely related

Kleindl, W.J., Rains, M.C., Marshall, L.A. and Hauer, F.R., (2015). Fire and flood expand the floodplain shifting habitat mosaic concept. Freshwater Science, 34(4), p.1366.

Kleindl, W.J., S. L. Powell, and F. R. Hauer. (2015). Effect of thematic map misclassification on landscape multi-metric assessment. Ecological Monitoring and Assessment. 187-321. DOI 10.1007/s10661-015-4546-y

Kleindl, W. J., F. R. Hauer, B. Ellis, S. Kimball, K. Kunkel, P. Matson, C. Muhlfeld, J. Oyler, E. Porter, C. Servheen, and K. Smucker. (2015). A multi-metric watershed condition model for Glacier National Park. Natural Resource Report NPS/GLAC/NRR—2015/944. National Park Service, Fort Collins, Colorado.

Kleindl, W.J., M.C. Rains, and F.R. Hauer. (2010). HGM is a rapid assessment: Clearing the confusion. Wetland Science and Practice 27:17–22.

Stein, E.D., M. Brinson, M.C. Rains, **W.J. Kleindl,** and F.R. Hauer. (2009). Wetland assessment alphabet soup: How to choose (or not choose) the right assessment method. Wetland Science and Practice 26:20–24.

Five other significant Socio-Ecological Structure and Function Products

Rains, M.C., K.C. Rains, **W.J. Kleindl,** S. Landry, T.L. Crisman, A. Brown, and L. van Maurik. (2011). Wetland Inventory and Evaluation, St. Lucie County, Florida. Prepared for St. Lucie County, Fort Pierce, Florida.

Kleindl, W.J., M. C. Rains, F. R. Hauer, J. Doskocil, and J. White. (2009). Jicarilla Rapid Assessment of Functions (JRAF): A Protocol for the Rapid Assessment of Functions on Riverine Floodplains in the San Juan River System. Jicarilla Apache Nation. Natural Resources Department. Dulce, New Mexico.

Kleindl, W.J. and D. Smith. (2004). Prioritizing Natural Resource Capital Improvement Products: Drainage Needs Report Protocols. Snohomish County Public Works Department Surface Water Management Division.

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Lee, L.C., M. Brinson, **W.J. Kleindl**, M. Whited, M. Gilbert, W.L. Nutter, M.C. Rains, D. Whigham, D. Dewald. (1997). Operational draft Guidebook to HGM Functional Assessments in Temporary and Seasonal Depressional Waters/Wetlands in the Prairie Pothole Region of North America. Prepared for the Natural Resources Conservation Service, Washington, D.C.

SYNERGISTIC ACTIVITIES

Academic and Professional Curricular Activities: Professor: LRES Capstone 2015 – Distinguishing between ecosystem services and function; Professor: LRES Capstone 2016 – Assessing and managing ecosystem services of Story Mill Wetlands for the City of Bozeman; Professor: On-line Wetland Ecology and Management (2016), Professor: Beginning an On-line Wetland Ecology and Management for Regional Practitioners (2017), Montana State University; Lead Instructor, Wetland Science Certification Program, University of Washington Extension, Seattle, WA (2001-2005); Instructor, National Wetland Science Training Cooperative, Seattle, WA (1995-1997).

Workshops Presentations: Structure and function assessment at site to watershed to sub regional scales. Multi-metric assessment ecosystem condition of Glacier National Park, West Glacier, MT (2015), Hydrogeomorphic Approach to Assessing Wetland Function (HGM) for the Jicarilla Apache Natural Resource Department, Durango, CO (2005 and 2007); HGM Santa Margarita Watershed, CA (1997); HGM Discontinuous Permafrost Fairbanks, AK (1997).

Public Curricular Activities: Montana Outdoor Science School (MOSS) board member (2010-2012); Bozeman's Conservation Network organizer (Greendrinks) (2012-current).

Leadership: Bozeman, MT Wetland Review Board (2009-2010); Project manager and owner operator of Naiad Aquatic Consulting (2006 – Current).

Ph.D. Thesis Advisor and Post-Doc Sponsors: F. Richard Hauer, University of Montana. Paul Stoy, Montana State University.

Certifications: Professional Wetland Scientist (Cert # 1695) Society of Wetland Science

Richard Ready (Co-PI) is an environmental economist, with a B.A. in Natural Resources (Cornell University 1981), and an MA and PhD in Agricultural and Resource Economics (University of Wisconsin, 1985 and 1988 respectively). He is currently a Professor in the Department of Agricultural Economics and Economics at MSU Bozeman, and Associate Director of the Montana Institute on Ecosystems. His research program focuses on the economic valuation of environmental goods and services that are not traded in markets. He has conducted research valuing ecosystem services including outdoor recreation, aesthetics, biodiversity, and water quality. His research has been supported by the US Army Corps of Engineers, the EPA, USDA, and the NSF. He is currently serving on the EPA Science Advisory Board Environmental Economics Advisory Committee. The following is Dr. Ready's CV:

Richard C. Ready
Professor of Economics
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Education:

B.S.	Natural Resources	Cornell University, 1981
M.A.	Agricultural and Resource Economics	University of Wisconsin, Madison, 1985
Ph.D.	Agricultural and Resource Economics	University of Wisconsin, Madison, 1988

Employment:

2015-present	Professor of Economics, Department of Agricultural Economics and Economics, Montana State University
2016-present	Associate Director, Montana Institute on Ecosystems, Montana State University
2000-2015	Assistant Professor, Associate Professor, Professor, Department of Agricultural Economics, Pennsylvania State University
1996-2000	Visiting Professor and Researcher, Department of Economics and Sociology, Norwegian University of Life Sciences
1989-1996	Assistant Professor, Department of Agricultural Economics, University of Kentucky

Selected Publications:

Mills, D., A. Jones, K. Carney, A. St. Juliana, R. Ready, A. Crimmins, J. Martinich, K. Shouse, B. DeAngelo, and E. Monier. Quantifying and Monetizing the Potential Climate Change Policy Impacts on Terrestrial Ecosystem Carbon Storage and Wildfires in the United States. *Climatic Change* 2014. Doi:10.1007/s10584-014-1118-z.

Lane, D., R. Jones, D. Mills, C. Wobus, R.C. Ready, R.W. Buddemeier, E. English, J. Martinich, K. Shouse, and H. Hosterman. Climate Change Impacts on Freshwater Fish, Coral Reefs, and Related Ecosystem Services in the United States. *Climatic Change* 2014. doi:10.1007/s10584-014-1107-2.

Yoo, James, and Richard Ready. Preference Heterogeneity for Renewable Energy Technology. *Energy Economics* 42(2014):101-114.

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Ready, Richard C., Patricia A. Champ, and Jennifer L. Lawton. Using Respondent Uncertainty to Mitigate Hypothetical Bias in a Stated Choice Experiment. *Land Economics*. 82(May 2010):363-381.

Ready, Richard C., Ann Fisher, Dennis Guignet, Richard Stedman and Junchao Wang. A Pilot Test of a New Stated Preference Valuation Method: Continuous Attribute-Based Stated Choice. *Ecological Economics,* 59(20 September 2006):247-255

Bateman, Ian J., Philip Cooper, Stavros Georgiou, Ståle Navrud, Gregory L. Poe, Richard C. Ready, Pere Riera, Mandy Ryan, and Christian A. Vossler. Economic Valuation of Remote Mountain Lakes. *Aquatic Sciences,* 67(September 2005):274-291.

Ready, Richard C., Willard Delavan, and Donald Epp. A Comparison of Revealed, Stated, and Actual Behavior in Response to a Change in Fishing Quality. *Human Dimensions of Wildlife,* 10(Jan/Feb 2005):39-52.

Selected Recent Research Grants:

Biological and Social Impacts of Aquatic Invasive Species in the Great Lakes: Development of Scenarios through Expert Judgement and Assessment of Impacts on Recreational Angling. Great Lakes Fishery Commission. (PI)

Center for Green Infrastructure and Stormwater Management. US EPA STAR. (Co-PI).

Predicting the Cumulative and Ecological Impacts of Pests and Pathogens in the Forest of Eastern United States. USDA. (Co-PI)

Center for Green Infrastructure and Stormwater Management. US EPA Star Grant. (Co-PI)

Hydrologic Forecasting for Characterization of Non-linear Response of Freshwater Wetlands to Climatic and Land Use Change in the Susquehanna River Basin. US EPA STAR Grant Program. (Co-PI)

Member, EPA Science Advisory Board Environmental Economics Advisory Committee

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