

**Developing Decision-Support Tools to Enhance
Aquatic Connectivity in the Great Lakes Basin:
*Results of a Workshop Sponsored by the
Great Lakes Fishery Trust***
September 4-5, 2014



Reported by

Jonathon Beard
Grant Manager
Great Lakes Fishery Trust

Mark Coscarelli
Manager and Secretary
Great Lakes Fishery Trust

Molly Good
Graduate Research Associate
Department of Fisheries
and Wildlife
Michigan State University

Tammy Newcomb
Senior Water Policy Advisor
Michigan Department of
Natural Resources;
and Great Lakes Fishery Trust
SAT co-chair

The workshop was organized by a planning committee convened with input from the Great Lakes Fishery Trust Scientific Advisory Team. The members of the planning committee were:

Brian Anderson

Executive Director
Illinois Natural History Survey and Interim Science
Coordinator Upper Midwest and Great Lakes
Landscape Conservation Cooperative
U.S. Fish and Wildlife Service

Mark Coscarelli

Manager and Secretary
Great Lakes Fishery Trust

Tom Gorenflo

Director
Intertribal Fisheries Program
Chippewa Ottawa Resource Authority (CORA)
and Great Lakes Fishery Trust SAT Member

Marty Holtgren

Senior Fisheries Biologist
Little River Band of Ottawa Indians
and Great Lakes Fishery Trust SAT member

Jonathon Beard

Grant Manager
Great Lakes Fishery Trust

Molly Good

Graduate Research Associate
Department of Fisheries and Wildlife
Michigan State University

Mark Holey

Project Leader
Green Bay Fish and Wildlife Conservation Office
U.S. Fish and Wildlife Service
and Great Lakes Fishery Trust SAT member

Tammy Newcomb

Senior Water Policy Advisor Michigan
Department of Natural Resources
and Great Lakes Fishery Trust SAT co-chair

Cover Photo: Former Manton Millpond Dam site, located in the Manistee River watershed.
Photo provided at the courtesy of the Conservation Resource Alliance.

Contents

Executive Summary	3
Workshop Proceedings	6
Introduction	6
Workshop Goals and Desired Outcomes	7
Summary of Presentations	7
Evaluating Intended and Unintended Consequences of Fish Passage	15
Research Needs and Enhancing Decision-Support Tools	20
Future Initiatives	22
Appendix A: Great Lakes Fishery Trust Background	23
Mission and Vision Statement	23
Appendix B: Workshop Agenda	24
Appendix C: Workshop Attendees	26
Appendix D: Workshop Evaluation	29
Appendix E: GLFT Support of Connectivity Projects	31
References	33

Executive Summary

Interest in reconnecting riverine habitat (aquatic connectivity) through barrier removal and other fish passage projects (e.g., bypass channels) continues to increase, and funding sources are becoming more readily available in Michigan and other Great Lakes states. The most common barriers to aquatic connectivity are dams and road-stream crossings that prevent natural stream function and organism passage. Dams and road-stream crossings each present unique issues for resource managers as they seek to achieve multiple, sometimes conflicting, environmental outcomes.

Within the Great Lakes basin, researchers conservatively estimate that more than 7,000 dams and 265,000 road-crossings may serve as barriers to migratory fish (Januchowski-Hartley et al 2013). The resource management community has reached general consensus that removing barriers to aquatic organism passage above the lowermost barrier is a priority to enhance ecosystem health. This includes dams upstream of the lowermost barrier and almost all road-stream crossings, which rarely serve as an effective barrier to invasive species, but can impede success of native and desirable nonnative species. Given the number of road-stream crossings that may serve as barriers to fish passage and the desire for aquatic connectivity, the resource management community has identified the need to develop decision-support tools to prioritize connectivity projects within and among watersheds and deploy scarce resources more strategically.

The Great Lakes Fishery Trust (GLFT) sponsored an aquatic connectivity workshop on September 4 and 5, 2014, in Lansing, Michigan. The goal was to identify types of decision-support tools that resource managers and practitioners (those who conduct barrier removal projects) need and would use to guide decisions on where to improve fish passage or remove a dam in the Great Lakes basin.

Over 50 workshop participants representing 23 entities—including state (3), federal (3), and tribal (4) agencies; utilities (2); binational coordination organizations (2); universities (4); county road commission (1); and nonprofit organizations (4)—discussed their information needs and process used when developing, evaluating, and implementing aquatic connectivity projects and reviewed existing decision-support tools. This discussion helped identify research needs and information gaps as well as ways to enhance existing tools to support more effective and efficient decision making. During the first part of the workshop, resource managers and practitioners discussed their processes and information needs for evaluating aquatic connectivity projects. The second part of the workshop featured presentations by researchers regarding currently available support tools and, based on what they heard in the first part of the workshop, tools could be developed or modified to meet the needs of the manager and practitioner community.

Managers and Practitioners

Managers and practitioners were asked to respond to a series of questions about how they currently approach aquatic connectivity projects; the extent of their involvement; what information they use and need to make decisions; challenges they experience when evaluating or implementing a connectivity project; and how a decision-support tool would enable them to make more effective or efficient decisions. While each organization approaches aquatic connectivity projects from a unique perspective, participants identified common information needs, challenges, and ways that decision-support tools could support their work.

Participants identified the types of information needed to develop and evaluate connectivity projects, which can be generalized into five categories: identifying information, structural features, ecosystem dynamics, sociocultural factors, and economic factors.

The workshop identified a number of challenges faced by managers and practitioners. These challenges fall within three primary issues:

- Accessing available and reliable data and information needed to develop and execute projects. For example, while some of the basic information needed exists, there is no consensus spatial database from which resource managers and practitioners can use as a foundation for consistency in beginning or considering projects.
- Balancing management goals and evaluating potential tradeoffs among alternative management scenarios, such as weighing benefits from enhancing the amount of habitat available to desirable species against risks of invasive species infestation.
- Funding and managing complex connectivity projects, which frequently require funding from multiple sources with unique requirements and restrictions.

To address these challenges, participants identified key information needs and processes to guide effective, holistic informed decision making. The following solutions were identified:

- Enhance the availability of existing information by aggregating data into simple and accessible tools using data sets that stakeholders agree on.
- Update relevant data sets that are known to be out of date or incomplete, such as the Michigan Natural Features Inventory's database of endangered and threatened species.
- Conduct new research and data collection to fill knowledge gaps. Examples include designing structures to allow for selective fish passage, completing watershed inventories, determining meaningful economic outcomes for inclusion, and working to incorporate the various types of information into stakeholder support processes.

Managers and practitioners were supportive of decision-support tools that would help them address these challenges. Functions they would like to see in a decision-support tool include:

- Access to information needed to develop, evaluate, and implement aquatic connectivity projects from an ecosystem health perspective at both watershed and basin scales.
- Output that supports efforts to prioritize connectivity projects and deploy resources more strategically.
- A suite of approaches to evaluate management alternatives, recognizing that options surrounding connectivity projects can have unique social, economic, and biological outcomes.

Researchers Developing Decision-Support Tools

Four teams of researchers from universities, state and federal agencies, and nonprofit organizations on the forefront of decision-support tool development for the Great Lakes basin presented on the second day of the workshop. The researchers were asked to review the tools they are developing to aid decision making regarding resource management, and respond to the issues discussed by managers and practitioners with the goal of identifying ways to enhance the development of tools to meet the needs of those engaged in connectivity projects.

The decision-support tools currently available meet many needs of managers and practitioners as they evaluate and implement aquatic connectivity projects. As presenters noted, these tools could be augmented to include additional information and data sets that would assist resource managers in making more efficient and effective decisions. Furthermore, the tools have the potential to assist with developing consensus goals regarding aquatic connectivity, evaluating alternative management scenarios, and tracking progress over time.

Research Needs and Enhancing Decision-Support Tools

Over the course of the workshop, participants identified the information they need to improve fish passage or dam removal in Great Lakes tributaries and reviewed the status of existing decision-support tools. This discussion helped identify research needs and information gaps as well as the types of decision-support tools that would enable managers and practitioners to make more effective and efficient decisions when evaluating and executing aquatic connectivity project. In addition to the tools that are under development and provide promise for partially or wholly meeting the needs of the resource managers and practitioners, priority needs include the following:

- Development of a desktop barrier removal decision support tool (or supporting modules) to allow managers and regulatory agencies to evaluate potential social-cultural, biological, and ecological trade-offs of removal projects within and among watersheds.
- Supporting modules include but are not limited to:
 - *Development of a river spatial habitat quality index for key species of interest (e.g., game species, species of greatest conservation need) that could be used in a decision-support tool.*
 - *Development of an economic benefits framework and/or module that evaluates connectivity projects for multiple perspectives (such as property values, recreation/tourism, ecosystem system services and others).*
- Field inventories that comprehensively identify road-stream crossings and other barriers at the watershed scale for watersheds identified as high priority in planning documents or other management documents.
- An economic assessment comparing the lifespan and cost of properly and improperly placed road-stream crossing structures that would inform placement of design alternatives.

Workshop Conclusion

At the conclusion of the workshop, participants were encouraged to complete an evaluation to help the planning committee assess whether workshop goals were achieved. Overall, participants felt the workshop was well executed, enhanced understanding of issues associated with aquatic connectivity, helped define research and information gaps, and identified the types of decision-support tools for further development. Some workshop participants suggested that additional time for breakout groups would have allowed for more meaningful engagement and additional tangible outcomes for decision-support tool direction.

Workshop Proceedings

Introduction

In the Great Lakes basin, there is continued interest among the public and resource managers to reconnect tributary habitat (aquatic connectivity) with barrier removal and other fish passage projects (e.g., bypass channels). The most common barriers to aquatic connectivity are dams and road-stream crossings that prevent natural stream function and organism passage. Dams and road-stream crossings each present unique issues for resource managers as they seek to achieve multiple, sometimes conflicting, environmental outcomes.

Within the Great Lakes basin, researchers conservatively estimate there are more than 7,000 dams and 265,000 road-crossings that may serve as barriers to migratory fish (Januchowski-Hartley et al. 2013). The resource management community has reached general consensus that removing barriers to aquatic

Within the Great Lakes basin, researchers conservatively estimate there are more than 7,000 dams and 265,000 road-crossings that may serve as barriers to migratory fish.

- Januchowski-Hartley et al. 2013

organism passage upstream of the lowermost barrier to the Great Lakes is a priority to enhance fish community dynamics and benefit instream habitat. This includes dams upstream of the last barrier and almost all road-stream crossings, which rarely serve as an effective barrier to invasive species but can impede success of native and desirable non-native species. Given the number of road-stream crossings that serve as barriers to fish passage and the desire for aquatic connectivity, the resource management community has identified the need to develop decision-support tools to prioritize connectivity projects within and among watersheds and deploy funding resources more strategically.

The last or lowermost downstream barriers in a watershed present a more complex challenge. In

addition to the growing interest in river connectivity projects, dams within the Great Lakes basin are aging, many to a point of obsolescence. This is prompting communities and stakeholder groups to evaluate the potential benefits and risks of dam removal. Enhanced connectivity is expected to increase long-term sustainable natural reproduction for many desirable species, including those now supported by hatchery production, as well as native species not supported through hatchery production. Additionally, barrier removals can enhance habitat quality by improving abiotic factors—such as dissolved oxygen levels and temperature—that are altered by impoundments. However, barrier removals also have the potential to increase rates of disease and chemical contaminant transfer into upstream areas, and increase the availability of habitat for sea lamprey and other invasive species, all of which present consequences for the fishery and resource management costs. Given existing technologies, consensus has not yet emerged regarding an ideal management approach to the lowermost barriers, which prevent passage of both desirable and invasive species. Decision-support tools have the potential to provide a consistent platform of baseline information and to evaluate benefits and risks associated with alternative management scenarios to make more effective and informed decisions (McLaughlin et al. 2013). Decision-support tools also have the potential to serve the resource management community by aggregating relevant information needed to evaluate—and potentially implement—connectivity projects. For example, an informational geospatial support tool developed using generally accepted data sets that addresses information needs of multiple local, state, and federal agencies, as well as nongovernmental organizations, would streamline project development and decrease conflicting interpretations of data.

The GLFT has invested over \$5.3 million in projects that advance fish passage technology, aquatic

connectivity through barrier removals of both dams and road-stream crossings, and the development of geographic information system (GIS) tools to enhance decision making (Appendix E). In addition, numerous other state and federal funding programs are targeting fish passage in the basin, such as the Great Lakes Restoration Initiative and Michigan Department of Natural Resources' Dam and Fish Habitat Grant Programs.

Recognizing the interest in aquatic connectivity and the challenges faced by the management community, the GLFT convened a workshop to discuss these topics further to identify research needs and discuss opportunities to support enhanced decision making through the development and use of decision-support tools.

Workshop Goals and Desired Outcomes

The workshop was organized by a planning committee convened with input from the GLFT Scientific Advisory Team (SAT). The primary goal for the workshop was to identify types of decision-support tools that resource managers and regulators need and would use to guide decisions on where to improve fish passage or remove a dam in the Great Lakes basin.

The workshop intended to help attendees:

- Gain insight from managers and practitioners regarding sociocultural, biological, and economic information they need to determine how to improve fish passage or remove a dam in Great Lakes tributaries
- Be informed by researchers about the status of decision-support tools that are available to meet the information needs of managers and stakeholders
- Identify a) types of decision-support tools for further development and b) gaps in biological, sociocultural, and economic information pertaining to fish passage and dam removal that would further inform management and regulatory decision making

- Ultimately, the SAT would use the information gained from these outcomes to guide the development of a request for proposals that would direct future investment of GLFT funds through its Ecosystem Health and Sustainable Fish Populations grant programs.

Participants representing state, federal, and tribal biologists and regulators, utility staff, academia, and nonprofit organizations were invited to attend and present at the workshop.

Summary of Presentations

The workshop was held over two half-day sessions. Representatives of management agencies and practitioners directly involved with planning and executing barrier removal projects presented as teams on the first day. The presentation teams were developed to give perspectives from state, federal, tribal, and local municipal agencies and non-profit organizations. Eleven presentation teams shared their knowledge and experience regarding aquatic connectivity issues. During the evening of the first day, attendees viewed a presentation on unintended outcomes of barrier removal and held a discussion around the salient points. On the second day, presentations were provided by research teams involved in developing relevant habitat models with the potential to evaluate and inform connectivity project prioritization, development, and selection. The research teams were selected from ongoing project teams with relevancy to aquatic connectivity in the Great Lakes basin. In order to capture the variety of issues and information needs associated with aquatic connectivity projects, teams were selected to represent a diverse range of interests.

Managers and Practitioners

To enhance the consistency of the information presented, managers and practitioners were asked to respond to a series of questions about how they approach aquatic connectivity projects; the extent of their involvement; what information they use and need to make decisions; challenges they experience when executing a removal project; and how a decision-support tool would enable them to make more

effective or efficient decisions. The following is a brief summary of the presentations from the manager and practitioner teams followed by presenter responses to questions regarding information needs, challenges, and opportunities for decision-support tools are summarized collectively.

State of Michigan Agencies

Representatives of State of Michigan agencies discussed how the state approaches aquatic connectivity and barrier removal projects. The presenters were Chris Freiburger, Habitat Management Unit, Fisheries Division, Department of Natural Resources (MDNR); Joe Rathbun, Nonpoint Source Unit Monitoring Coordinator, Water Resource Division, Michigan Department of Environmental Quality (MDEQ); and Coreen Strzalka, Drainage Coordinator, Hydraulic Unit, Michigan Department of Transportation (MDOT).

In Michigan, state agencies are involved in potential barrier removals in many capacities, including providing grants for dam removals and road-stream crossing improvements; serving on grant program review committees; providing technical support for design and analysis; conducting various surveys and studies (e.g., geomorphic, biological, and chemical studies); overseeing and participating in the development of various barrier inventories; educating residents and other stakeholders; and reviewing various permits associated with removal projects. The agencies are involved in different aspects of connectivity projects and approach the projects from different perspectives but collaborate when evaluating or advancing barrier removal projects.

The MDNR and MDEQ use the MESBOAC method of installing culverts at road-stream crossings to provide for more natural stream function and enable aquatic organism passage. Several of the elements are also considered by MDOT as well. MESBOAC includes the following elements:

- M**atch culvert width to bankfull width
- E**xtend culvert length through road prism
- S**et culvert slope to stream slope
- B**ury the culvert
- O**ffset multiple culverts
- A**lign with the stream channel
- C**onsider headcuts

State of Wisconsin Agencies

Bobbi Jo Fischer, Environmental Analysis and Review Specialist for the Wisconsin Department of Natural Resources (WDNR), discussed how the State of Wisconsin approaches barrier removals. Fischer noted that Wisconsin state agencies have a similar role as Michigan's agencies in aquatic connectivity projects; however, the WDNR includes functions of the both the MDNR and MDEQ. The state provides technical support, training and serves in a permitting capacity. The WDNR and Wisconsin Department of Transportation (WDOT) work collaboratively through connectivity teams through a cooperative agreement (under review) that establishes a two-step process, which gives preliminary comments and final concurrence on road-stream crossing projects.

Fischer highlighted that the State of Wisconsin takes a proactive approach to maintaining and enhancing aquatic connectivity by updating the permitting process for county and local roads such that the design addresses aquatic organism passage and enables more natural stream function. Under the requirements, road-stream crossing, structures should be as wide as bankfull width and may not impound water. The size and placement of the structure should mimic depth, width, and velocity in the natural stream channel. Placement of structures should be flat for low gradient streams and low enough to allow streambed material to deposit in the bottom of the culvert or add streambed material.

U.S. Fish and Wildlife Service

Andrea Ania, Fish Passage Biologist, and Jessica Barber, Sea Lamprey Barrier Coordinator for the USFWS, discussed the agency's role in aquatic connectivity and sea lamprey control. The USFWS has multiple programs that advance habitat restoration and aquatic connectivity, while the sea lamprey control program is often faced with needing to retain or add barriers to control sea lamprey populations. Agency staff balance both program goals to enhance aquatic connectivity for desirable species while working to prevent and control invasive species. The USFWS is involved in many potential barrier removal projects by providing grant funding, technical support, and determinations regarding the potential lamprey impacts of these projects.

The presenters noted that there are nearly 200 tributaries in the Great Lakes basin currently treated for sea lamprey, which are suppressed using chemical treatments and alternative controls, including the installation and maintenance of barriers. Over the years, the agency has shifted its focus from barrier installation to a greater emphasis on maintaining existing lowermost barriers, many of which are aging. The presenters noted that the increased interest in barrier removals for aquatic connectivity coupled with their aging condition threatens the efficacy of the sea lamprey control program, given the potential for opening access to new spawning habitat.

Chippewa Ottawa Resource Authority Representative

Mark Ebener, Fisheries Assessment Biologist for the Inter-Tribal Fisheries and Assessment Program of the Chippewa Ottawa Resource Authority (CORA), presented information regarding research on aquatic connectivity and sea lamprey controls. The 1985 and 2000 Consent Decrees established fishing rights for the five CORA member tribes in Lakes Michigan, Huron, and Superior. The Consent Decrees include total allowable catches for lake trout that account for sea lamprey predation. To date, CORA members are not able to harvest some lake trout and

some lake whitefish at levels identified in the Consent Decrees because of estimated fish mortality from sea lamprey. As a result, CORA member tribes have a significant interest in both lamprey control and restoration of native species.

Ebener discussed the relationship between sea lamprey control and restoration of native species, particularly lake sturgeon. Information from the Great Lakes Fishery Commission shows that streams that produce relatively high levels of sea lamprey are also those particularly well suited for sturgeon restoration. He reviewed data simulations that project the impact of lamprey control on sturgeon populations under different management scenarios. He suggested that these simulations could be important elements to include in an aquatic connectivity decision-support tool by helping evaluate tradeoffs between various management scenarios.

Representatives of other tribal natural-resource organizations noted that each tribe has a unique perspective on, and interest in, barrier removals, aquatic connectivity, sea lamprey control, and sturgeon restoration.

Nongovernmental Organizations

Amy Beyer, Executive Director of the Conservation Resource Alliance (CRA), and Brad Jensen, Executive Director of Huron Pines, discussed aquatic connectivity from the perspective of non-profit organizations actively involved with river and stream restoration projects in Northern Michigan. Both organizations have established themselves as leaders within the state and their service regions for aquatic connectivity and environmental restoration projects. The CRA and Huron Pines approach aquatic connectivity projects within a context of broader ecosystem health at the watershed scale. The two organizations have jointly supported the www.northernmichiganstreams.org website, which includes a field-verified inventory of road-stream crossings and streambank erosion sites in many northern Michigan watersheds. The inventory includes a low, medium, or high ranking system for

road-stream crossings that may prevent aquatic organism passage. This publicly available inventory serves as a foundation for strategic decision making by stakeholder groups to determine priority projects. They noted that while the inventory can inform site selection, operational factors can influence which sites are selected for restoration. Beyer and Jensen highlighted that economies of scale can be achieved by bundling sites within a subwatershed or region. This approach may make it more efficient to conduct a holistic restoration of a longer river reach or subwatershed than focusing on the highest-ranked restoration sites, which may be dispersed throughout a region. Community support and project readi-



The Sucker Creek – Black River road-stream crossing in Alcona County, Michigan. Restoration funded in part by the GLFT. Photo provided at the courtesy of Huron Pines.

ness are significant considerations when prioritizing restoration sites and both organizations frequently partner with local groups such as road commissions when executing projects.

Rural Road Crossings Stakeholders

Lisa Dutcher, a road-stream crossing consultant for the Oceana County Road Commission, and Bob Stuber, Fisheries Biologist for the U.S. Forest Service (USFS) discussed how their organizations approach

aquatic connectivity and road-stream crossings. A significant portion of Oceana County is part of the Manistee National Forest, which has the agencies to partner on many projects.

Oceana County

Dutcher discussed road-stream crossings and aquatic connectivity from the perspective of a county road commission that has established itself as a leader in designing and constructing crossings with an ecological filter on its decision making. County road commissions, like many state and local agencies, are experiencing fiscal constraints. Under these conditions, local jurisdictions may not design a site to provide natural stream flow because it can

The Northern Michigan Streams website includes a field-verified inventory of road-stream crossings and streambank erosion sites in many northern Michigan watersheds.

www.northernmichiganstreams.org

increase total project costs. Dutcher noted, however, that poorly designed road-stream crossings, such as those that use undersized culverts or don't match bank width, are more likely to fail and have a decreased lifespan, which can increase total costs over time. Dutcher noted that Oceana County has augmented its local financing of road-stream crossing replacements by using designs that provide fish passage and obtaining grant funding from fish habitat restoration programs.

To assist with asset management, Oceana County uses RoadSoft software developed by Michigan Technological University and MDOT. The software was recently updated to include a road-stream crossing module that identifies waterways, the type of crossing structure, age, and other features. Dutcher suggested that as local road management agencies complete their inventories using RoadSoft, the information becomes available to other organizations and may be available for possible inclusion in a decision-support tool.

United States Forest Service

Stuber discussed the USFS' involvement in, and approach to, aquatic connectivity projects. The USFS is a land management agency that partners with other local, state and federal agencies, tribes, and nongovernmental organizations to manage habitat through a watershed approach. The agency emphasizes aquatic organism passage and ecosystem connectivity while also managing invasive species, such as sea lamprey. Stuber noted that resource managers frequently evaluate and manage conflicting priorities such as connectivity versus invasive species

“How can we get the most ecological impact for the money we are spending?”

- Amy Beyer, Executive Director,
Conservation Resource Alliance

control and stressed the importance of stakeholder collaboration when evaluating potential barrier removal projects. Aquatic connectivity projects that occur within a national forest qualify as a federal action and require an Environmental Assessment under NEPA. Through this review, an interdisciplinary approach is used to evaluate environmental impacts on endangered, threatened, invasive, resident, and anadromous species; as well as social and cultural impacts. The review also requires opportunities for public comment.

Implementing Aquatic Connectivity Projects: Challenges and Opportunities for Enhanced Decision Making

In preparation for their presentation, managers and practitioners were asked to respond to a series of questions regarding their approach to aquatic connectivity projects. The purpose of this approach was to identify consistent challenges and opportunities they face and to inform the development of decision-support tools for development, evaluation, and implementation of aquatic connectivity projects. Questions posed to presenters include:

- What information do you need when evaluating, developing, or implementing an aquatic connectivity project?
- What are the challenges associated with aquatic connectivity projects?
- What information would help you make more effective or efficient decisions?
- What would you like to see in a decision-support tool and how would you use it?

In responding to the questions, many of the presentation teams discussed similar themes.

What information do you need when evaluating, developing, or implementing an aquatic connectivity project?

Workshop participants discussed the types of data and information needed to evaluate, develop, and implement aquatic connectivity projects. The types of information used by managers and practitioners can be generalized into the following categories:

- Identifying information (location, project type)
- Structural features (barrier type, design, function, etc.)
- Ecosystem dynamics (physical, biological, chemical factors, native and invasive species implications, etc.)
- Sociocultural factors (stakeholder support; historic significance, etc.)
- Economic factors (effects on property values, tourism, alternative management scenario costs)

Aquatic Connectivity Project Information Needs

Identifying Information

- What type of barrier is it (road-stream crossings, low head dam, weir, etc.)?
- Where is the project located (latitude/longitude)?

Ecosystem Dynamics

Physical Attributes

- What is the longitudinal profile of the stream?
- What is the bankfull width?
- What is the rate of flow (e.g., cubic feet per second)?
- How many river miles would be reconnected?
- What is the quality of the habitat that would be connected?
- How much sediment is contained behind the barrier?
- Are there contaminated sediments and any associated hazards with removal?
- If an impoundment is being removed, where is the stream channel expected to form?

Biological Attributes

- What species is the project intended to benefit? To what extent will they benefit?
- Is the site a known first or second sea lamprey barrier?
- Are sea lamprey currently in the watershed?
- What is the potential for infestation if the barrier is removed?
- If infested, what is the estimated rate of larval sea lamprey production?
- Are there native lamprey present upstream?
- What are the potential impacts of aquatic invasive species other than sea lamprey?
- Are there endangered and/or threatened species present? If so how would the project affect them?
- What are the specific benefits/detriments to the resident or migratory fish community?

Structural Features

- What type of structure is currently in place?
- What is the condition of the structure?
- Does the existing structure pose any safety risks?
- What is the life expectancy of the existing structure?
- What are the design alternatives to meet project objectives (e.g., selective passage, complete passage, invasive species management)?
- Was the structure designed with fish passage in mind?

Sociocultural Factors

- Who are the stakeholders and what are their levels of support?
- Is the project a priority in an existing watershed inventory or assessment?
- What are the intended social benefits?
- Is the site registered with the State Historic Preservation Office (SHPO) or a regional historic preservation office (RHPO)?
- Have stakeholders conducted a risk-benefit analysis? If so, what are the risks and benefits?
- Would the project affect tourism?
- What is the benefit to recreation such as fishing or boating?

Economic Factors

- How cost effective (relative to other sites) is the project?
- What will the project cost?
- What are the costs to treat additional upstream habitat with lampricide?
- Would the removal enhancing natural reproduction thereby decreasing fish stocking requirements and cost?
- How would the project affect property values?

What are the challenges associated with aquatic connectivity projects?

Presenters discussed challenges they face when approaching barrier removals projects. Broadly, these challenges include the following themes of (1) balancing management goals; (2) availability and reliability of data and information; and (3) funding and project implementation.

Balancing Management Goals

Throughout the workshop, participants discussed challenges associated with balancing multiple, sometimes competing, management objectives. Foremost in the discussion was the balance between invasive species control and improving the sustainability of target species by enhancing aquatic connectivity. Presenters also discussed differing goals of single-species versus holistic ecosystem management approaches. Some presenters suggested that there could be additional emphasis placed on management of all native and desirable nonnative fish species as well as nonfish species, such as mussels and herptiles. Presenters who execute on-the-ground restoration projects highlighted that projects are frequently implemented from a holistic perspective, yet funding opportunities and technical support are sometimes more focused on fisheries management. While these participants were especially appreciative for funding and support provided for fish passage, they identified a gap in funding and technical assistance for other components such as community planning, public relations, pre- and post-restoration monitoring, and restoration for nonfish species that are included when advancing restoration projects.

Presenters noted that a primary challenge for resource managers is evaluating tradeoffs among management alternatives—something that could be improved through a decision-support tool. Additionally, participants noted that the Great Lakes management community has not yet collectively established consensus goals regarding aquatic connectivity. Participants suggested that establishing these goals would help alleviate tensions among conflicting management priorities. Within the con-

text of specific connectivity projects, participants noted that early and fully inclusive stakeholder involvement can help overcome these challenges.

Availability and Reliability of Data and Information

Participants noted the challenges of obtaining all of the necessary information to evaluate and implement barrier removal projects. Many data sources are incomplete either in geographic scope or inclusiveness. For example, databases identifying dams in Michigan are known to be incomplete; and watershed inventories have not been completed for all regions. Additionally, participants discussed challenges presented by using different data sets to review potential projects (e.g., differing dam databases). Workshop participants noted the value of agreeing on data sources used for evaluation such that researchers developing data models, practitioners who implement removal projects and managers reviewing potential removal projects have a common source of information.

Funding and Project Implementation

Participants identified the number of road-stream crossings and dams within the basin relative to available funding as a challenge to overall efforts to enhance aquatic connectivity. Additionally, participants discussed the aging condition of dams within the basin, many of which are nearing obsolescence, which is likely to put additional pressure on available funding sources in the future.

The cost of large-scale removals is significant and often requires funding from a multitude of sources. For instance, the removal of the Boardman Dam, the second in a series of four dams on the Boardman River, has an estimated removal cost of over \$10 million (Beyer 2014). Project partners have raised funds from a variety of state and federal sources as well as local and private foundations. Presenters noted that administration of project funds can be one of the most challenging aspects of managing a removal project. This is because each funding source has unique restrictions, program require-

ments, disbursement schedules, and reporting that must be tracked in detail. Successful project managers are required to secure a portfolio of investments that, collectively, can complete a restoration project. Presenters suggested that more flexible funding enables practitioners to complete more work, more efficiently. Additionally, some practitioners noted that it is generally more difficult to raise funds for certain tasks including pre- and post-monitoring; engineering and geotechnical analysis; as well as project planning, community engagement, and public relations.

What information would help you make more effective or efficient decisions?

Presenters were asked to discuss what information would enable them to make more effective and efficient decisions when evaluating and executing barrier removal projects. Many of the presentation teams identified similar information needs or desires that can be generalized into the categories (1) enhancing the availability of existing information; (2) updating relevant data sets; and (3) conducting new research or data collection.

Enhancing the Availability of Existing Information

Participants discussed the need to collect and aggregate relevant information that already exists (potential data and information to include are identified on page 12). Making this information available in an easily accessible and integrated manner would streamline assessments of potential connectivity projects. Priority should also be given to data sets that resource managers generally embrace and agree

Building consensus around underlying data and information used to evaluate potential removals is expected to help resource managers who may have varying management goals evaluate alternative scenarios more empirically.

on. In areas where differing data sets exist or consensus has not emerged, efforts that resolve data issues (integrity or validity) and build consensus among stakeholders would be encouraged. Building consensus around underlying data and information used

to evaluate potential removals is expected to help resource managers who may have varying management goals evaluate alternative scenarios more empirically.

Updating Relevant Data Sets

Participants discussed the need to update relevant data sets more frequently to help ensure that accurate information is available and being used. For example, participants noted that the Michigan Natural Features Inventory (MNFI) maintains a database with information on threatened and endangered species that is widely used and generally, the most complete and comprehensive source available. However, participants noted that the MNFI could be enhanced and supported by including updated information.

New Research/Data Collection

Participants identified a number of areas where additional research or data collection would help managers and practitioners evaluate and execute connectivity projects. A significant focus was placed on issues related to lowest-most barriers that help control invasive species. Participants suggested that additional research needs to be conducted to design barriers that enable selective fish passage—particularly for nonjumping species—while preventing aquatic invasive species. Additionally, participants suggested that additional studies should be completed to assess the potential of sea lamprey production in watersheds currently protected by a barrier. Furthermore, participants suggested that additional research on the impact of barriers on all native and desirable nonnative (as well as invasive) species would enable resource managers to make more effective decisions when evaluating tradeoffs among management alternatives. Participants suggested that research should be conducted to advance alternative methods to control invasive species while minimizing the negative effects on native species.

Participants also suggested that better information about post-removal stream function would help resource managers implement barrier removal projects. For instance, additional information regarding the sediment yield at a dam site, channel evolution in a former reservoir, long-term channel stability, and downstream transport and deposition following a removal would be extremely valuable when removing a dam.

What would you like to see in a decision-support tool and how would you use it?

Presenters were asked to respond to a series of questions to help identify the most useful outcomes from a decision-support tool. Through discussion, participants identified a number of functions a decision-support tool should serve, which include (1) providing access to information needed to develop, evaluate, and implement aquatic connectivity projects from an ecosystem perspective; (2) supporting efforts to prioritize connectivity projects and deploy resources more strategically; and (3) helping resource managers evaluate management alternatives. Participants emphasized the importance of developing tools that allow users to weigh decision points independently using their own decision criteria rather than with predetermined weights.

Participants also identified the lack of consensus goals among connectivity stakeholders and suggested that a decision-support tool could help inform the development of goals, as well as track progress toward those goals.

Evaluating Intended and Unintended Consequences of Fish Passage

Dr. Robert McLaughlin, Associate Professor, Department of Integrative Biology, University of Guelph, presented at an evening reception on unintended consequences and tradeoffs with fish passage. McLaughlin suggested that barriers should be considered a management tool that is not inherently good or bad, but has a set of consequences. He suggested that questions of whether to place or remove a barrier should be evaluated by whether the management objectives (i.e., intended consequences) are being achieved and whether there are unintended consequences.

McLaughlin also discussed risk perception of sea lamprey and suggested that the public and local managers sometimes perceive lamprey risks to be lower than they are. He attributes this perception to the success of lamprey control programs over the last 50 years, which has led people to forget the impact lam-

prey historically had on the fishery, resulting in emphasizing perceived side effects of dams and greater need for fish passage.

He reviewed common consequence of barriers that can create tradeoffs and uncertainty for management scenarios, including:

- **Delays:** Fish passage structures can cause delays in movement of fish within systems. Given the seasonal nature of systems, these delays are expected to yield consequences.
- **Fallback:** Downstream migration of fish following a successful passage.
- **Ecological traps:** Fishways can create ecological traps, which are created by human alterations to the ecosystem and result in animals selecting a habitat where they will have a lower Darwinian success. Ecological traps result when attractive forces entice fish to move up a fishway; there is unidirectional movement upstream (fish cannot return downstream); conditions above the dam have a conditions resulting in lower fitness rates; and conditions below the dam have better conditions resulting in higher fitness rates.
- **Selective passage:** From a Darwinian perspective, fishways are selective not only of species but also phenotypes and genotypes that can affect the evolutionary trajectory of species. In some instances, species that have evolved in systems with fishways may face challenges if a barrier is removed completely. Some of these evolutionary changes that result from fishways and barriers may lead to adaptations that reduces long-term production of the species.
- **Species interactions at dam sites:** Dams frequently increase population levels immediately below the structure, resulting in hotspots for predation, disease transfer and can increase competition within and among species (interspecific and intraspecific competition).
- **Introductions:** Barrier removals can cause introductions into a system, including invasive species, genotypes, diseases, and contaminants.

McLaughlin suggested that these factors should be evaluated and could be incorporated into decision-support tools to enhance decision making. Additionally, he highlighted the need for improved communication among management agencies and other stakeholders when addressing aquatic connectivity projects as it pertains to the primary management goals and objectives.

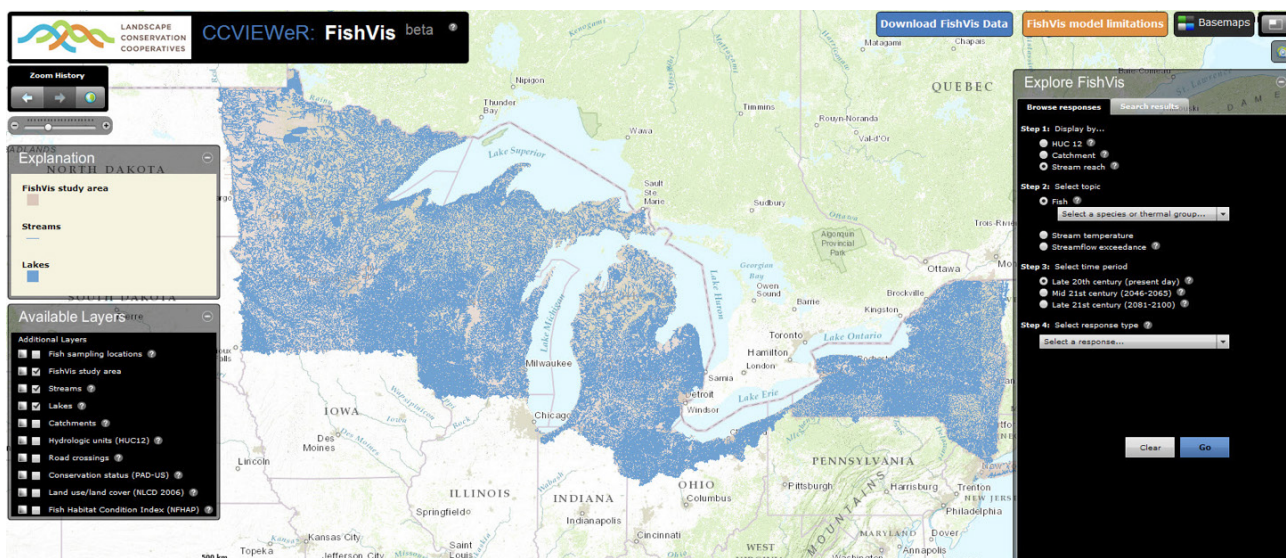
Researchers Developing Decision-Support Tools

The second day of the workshop included presentations from four research teams on the forefront of developing tools to support enhanced decision making regarding resource management in the Great Lakes basin. The researchers were asked to review the tools they are developing and respond to the issues discussed by managers and practitioners, with the goal of identifying ways to enhance the development of tools to meet the needs of those engaged in connectivity projects.

Enhancing Decision Making for Managing Fluvial Habitats: Current Status and Future Opportunities with FishVis

Jana Stewart, a geographer from the U.S. Geological Survey at the Wisconsin Water Science Center, and Dr. Dana Infante, Assistant Professor in the Department of Fisheries and Wildlife at Michigan State University (MSU), discussed FishVis—a Web-based

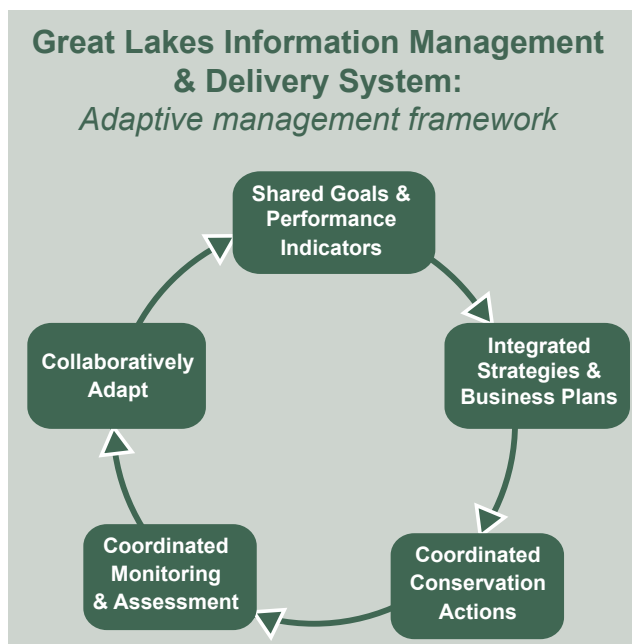
decision-support mapper intended to enhance decision making for managing fluvial habitats and the responses of fish species in the presence of climate change. The FishVis project is part of a collaborative effort between MSU, the U.S. Geological Survey, the Wisconsin and Michigan Departments of Natural Resources, and the U.S. Fish and Wildlife Service. Funding for the project is being provided by the Upper Midwest and Great Lakes Landscape Conservation Cooperative and the U.S. Geological Survey. Stewart and Infante presented FishVis as a user-friendly and easily accessible Web-based tool that resource managers can readily utilize for a multitude of purposes. The tool enables users to obtain information such as landscape characteristics, fish species present, stream temperatures, and flow measurements to develop assessments of current resources and projections of future trends. FishVis includes predictive models that estimate the occurrence and/or distribution of 13 common cold, cool, and warm water fish species in streams across the Great Lakes basin, under anticipated changing climate conditions. Infante highlighted that FishVis is designed to allow for integration of more data, such as the location of dams. With the integration of additional data sets, she expects FishVis will continue to become more valuable in assisting resource managers evaluate and execute barrier removal projects, as well as enhance strategic decision making regarding aquatic connectivity in the basin, both within the context of climate change.



Screen shot of the FishVis Mapper provided at the courtesy of Dr. Dana Infante and Jana Stewart. The FishVis tool is available online at: <http://wimcloud.usgs.gov/apps/FishVisDev/FishVis.html#>

Great Lakes Information Management and Delivery System (IMDS)

Dr. Patrick Doran, the Director of Science for the Michigan chapter of the Nature Conservancy, discussed the Great Lakes Information Management Delivery System (IMDS). The IMDS is a Web-based platform designed to support adaptive management processes and issue-specific strategic plans, such as those dealing with connectivity issues. In his presentation, Doran cited the IMDS as a potential way to define priorities, track progress, and enhance collaboration and adaptation among the many stakeholder groups involved in large-scale management decisions. Doran provided an overview of the IMDS and highlighted that it is composed of six complimentary modules: (1) the knowledge network (sharing knowledge to increase understanding); (2) data catalog (sharing data to advance knowledge); (3) dynamic maps (sharing online maps to provide a sense of place); (4) decision tools (sharing models and tools to address complex problems); (5) assessment and adaptation (sharing goals and progress to ensure accountability); and (6) project tracking (sharing ideas and experiences to coordinate actions). Currently, Doran and his team are working with an IMDS prototype that is fully functioning, and they will soon launch a demo of the platform. According to Doran, the IMDS has been gaining interest from state, feder-



The Great Lakes Information Management & Delivery System adaptive management framework image provided at the courtesy of Dr. Patrick Doran. The IMDS is available online at: <http://greatlakesinform.org>

al, and binational agencies and could serve as a way to encourage stakeholders to engage in more collaborative and adaptive management in the future.

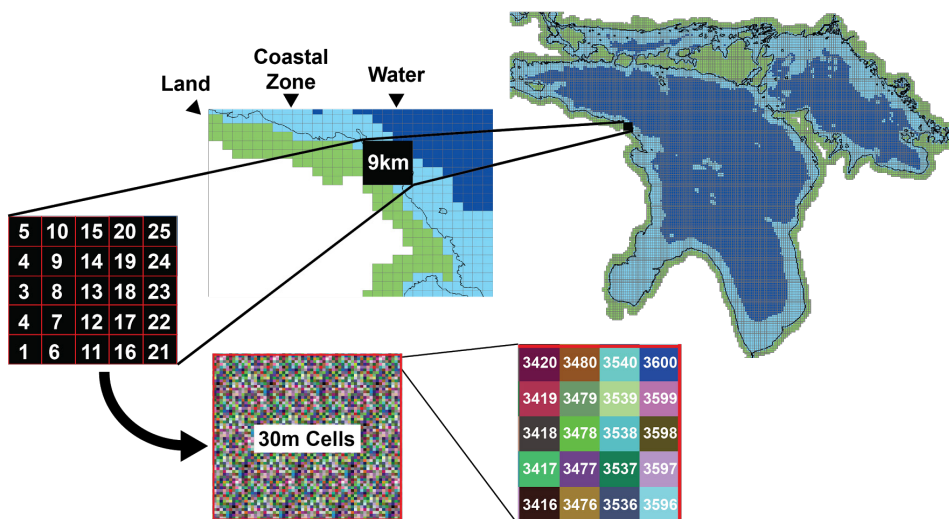
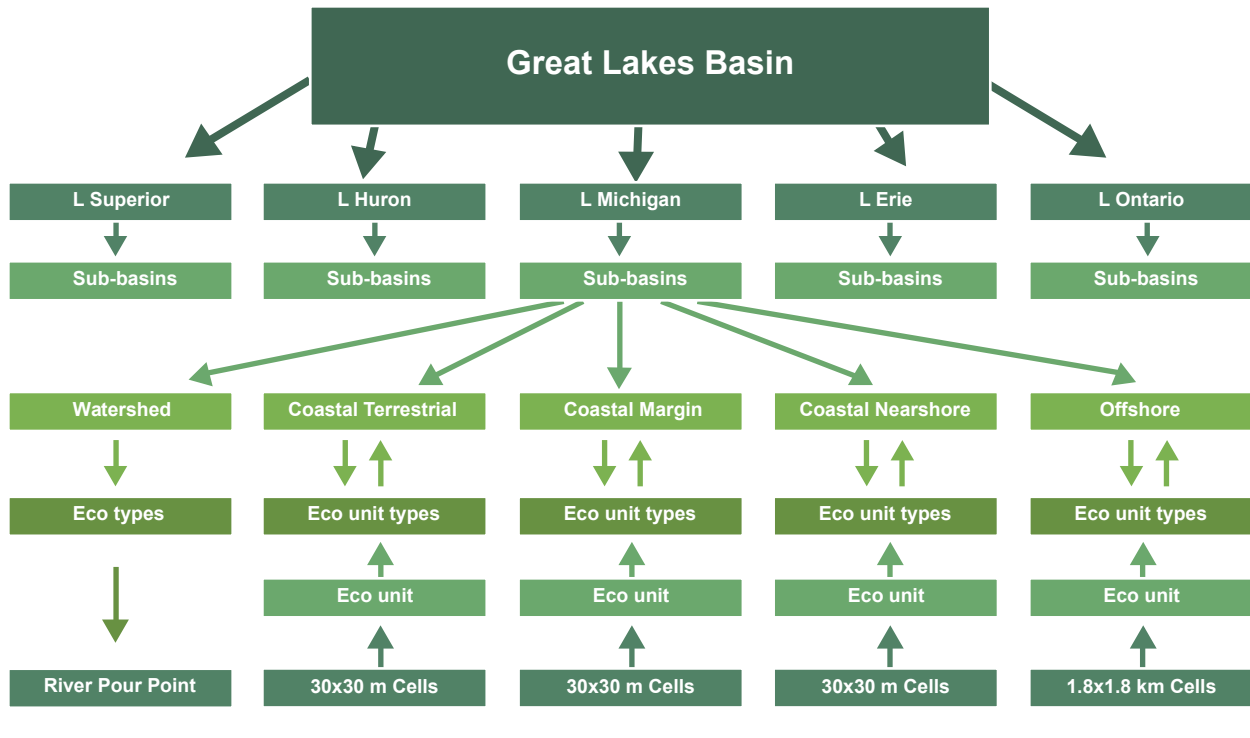
Decision Support—Application of the Great Lakes Aquatic Habitat Framework (GLAHF) to Meet the Needs of Great Lakes Managers

Dr. Catherine Riseng, an aquatic ecologist and researcher at the University of Michigan, discussed the Great Lakes Aquatic Habitat Framework (GLAHF), funded in part by the Great Lakes Fishery Trust. The GLAHF is an aquatic habitat database and hierarchical classification framework that organizes and integrates habitat components and landscape features to address local, lakewide, and basinwide restoration and management concerns. The GLAHF is intended to serve as an up-to-date geodatabase that includes information from Great Lakes coasts and nearshore waters, large river mouths, and open water habitats. The internal structure of GLAHF is complex and composed of many hierarchical categories known as zones. The zones are established by various science advisory groups and classified based on certain biological information. Riseng noted that the GLAHF includes information for the entire Great Lakes basin including Canadian waters. Thus, the GLAHF functions effectively as a decision-support tool, in which managers can use the data nested within the framework to answer a variety of physical, chemical, and biological questions. Riseng anticipates that the GLAHF will be available to users in fall of 2014.

Riseng discussed a grant her team received from the University of Michigan Water Center, Graham Sustainability Institute, titled Assessing Information Needs and Developing Tools for Great Lakes Ecosystem Management. Through that project, the investigators will acquire and compile data on Great Lakes tributaries to be utilized in GLAHF. Additionally, Riseng and other collaborators reviewed existing decision-support tools relevant to the Great Lakes. Their findings are available in the *Review of Great Lakes Web-based Geospatial Information Tools* report. The grant also provided funding to host two binational workshops for resource managers and other interested groups to discuss these tools and develop the foundation of a decision-support tool for determining fish habitat suitability. The first workshop was held on July 29, 2014, the second was held on October 15, 2014.

Great Lakes Aquatic Habitat Framework: Hierarchical Spatial Classification Framework

The Great Lakes Aquatic Habitat Framework (GLAHF), funded in part by the Great Lakes Fishery Trust, is an aquatic habitat database and hierarchical classification framework that organizes and integrates habitat components and landscape features to address local, lakewide, and basinwide restoration and management concerns. The internal structure of the GLAHF is complex and composed of many hierarchical categories known as zones. Managers can use the data nested within the framework to answer a variety of physical, chemical, and biological questions.



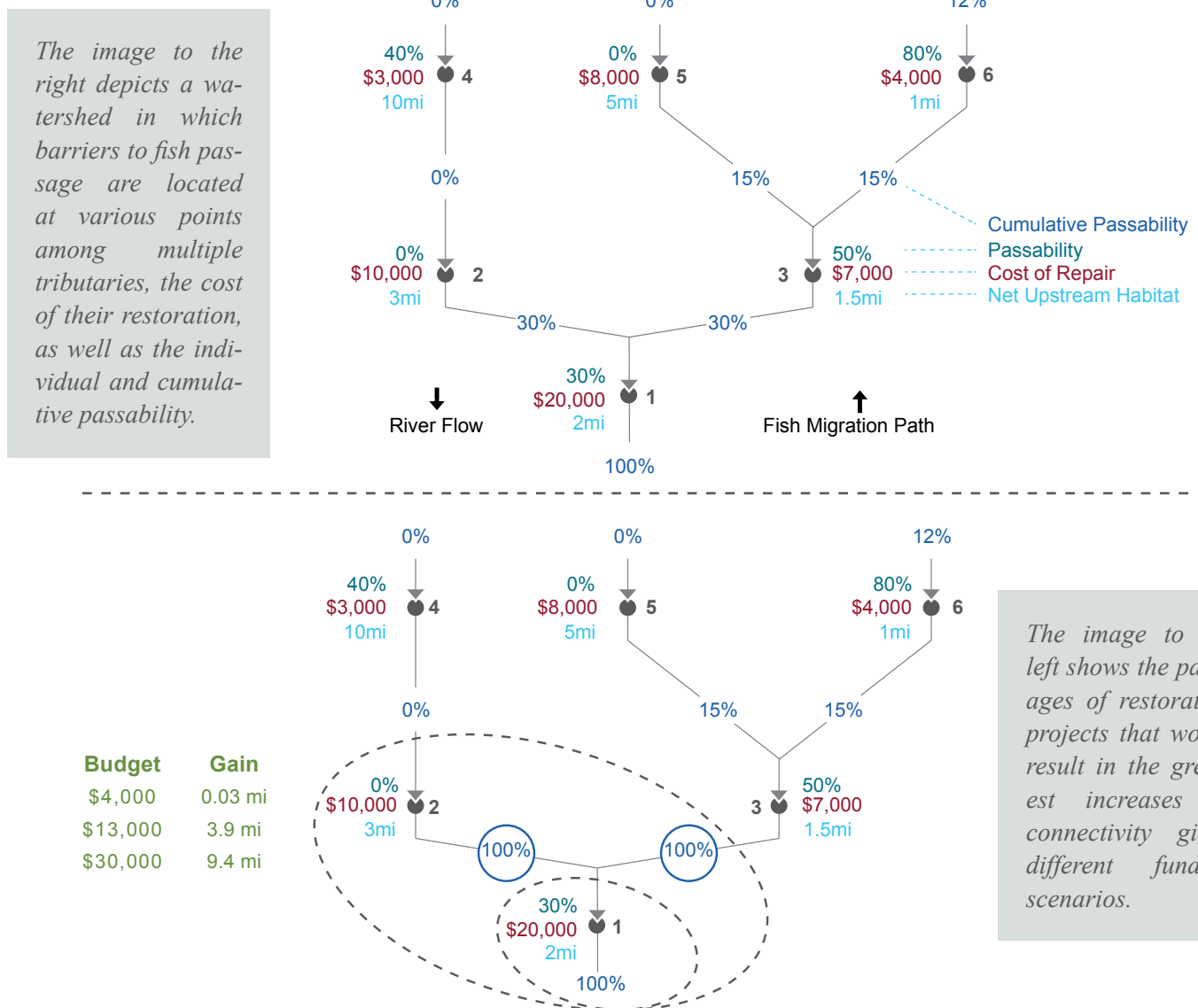
Great Lakes Aquatic Habitat Framework figures provided at the courtesy of Dr. Catherine Riseng. Additional information is available online at: <http://ifr.snre.umich.edu/projects/glafh>

Optimization Models to Support Barrier Removal Decisions for Nation's Migratory Fishes in Great Lakes Tributaries

Dr. Tom Neeson, a postdoctoral researcher in the Center for Limnology at the University of Wisconsin-Madison, and Dr. Matt Diebel, an aquatic ecologist with the Wisconsin Department of Natural Resources, their work to quantify the number of potential barriers and develop data models to help prioritize connectivity projects. Neeson began the presentation by discussing the number of existing and potential barriers in the Great Lakes basin. Conservatively, they estimate that there are more than 7,000 dams and 265,000 road crossings that may serve as barriers to migratory fish.

The Fish Passage Prioritization Problem

Decision-support tools can assist resource managers by identifying a suite of projects that would result in the greatest connectivity gains, given various levels of funding.



Figures provided at the courtesy of Dr. Tom Neeson. Additional information about the University of Wisconsin Center for Limnology's Optimization Model is available in Volume 112 of the Proceedings of the National Academy of Sciences (Neeson et al 2015).

Neeson noted that decisions regarding barrier removals are complicated and should weigh costs and benefits. The decision points regarding a potential removal can include both benefits of a barrier (such as preventing invasive species movement, or containing contaminated sediments) and negative impacts of maintaining a structure (such as blocking passage of native species, or risking human safety due to structural integrity). Fundamentally, he explained, these decisions include spatial elements that create unique challenges for resource managers, since the benefits/costs of each removal project are affected by other barriers distributed throughout a watershed. Neeson proposed to simplify this decision-making process through the use of a decision-support tool intended to assist in the prioritization of fish passage projects across the Great Lakes basin. In development of this support tool, Neeson and collaborators have begun to build basinwide data sets and integrate them into an optimization model. The team envisions this model will serve as an interface for people to access data to assist in decision-making. For example, Neeson explained that this model could help managers determine priority barrier removal projects across the basin and identify suites of projects that would enhance cumulative passability, given a particular amount of funding available. In other words, the model can help answer the question of which barrier removal project will yield the greatest benefits, given scarce resources.

Diebel continued the presentation and explained the importance of utilizing quality data in the optimization model discussed by Neeson. Diebel stated the goal of the optimization model, at its most basic level, is to produce good outputs that lead to good decisions. Thus, part of the model development process will be a personal, quantitative, and critical evaluation of the data to be used in the model. Diebel discussed the results of his model that used light detection and ranging or LiDar data to develop Dig-

ital Elevation Models (DEMs) that help determine whether a potential barrier (such as a road-stream crossing) is likely to impede aquatic connectivity. He has been able to use this method of remote sensing technology to assess characteristics of dams and road-stream crossings, such as the elevation above and below the potential barrier, to predict its likelihood of impeding passage. The results of the model have been verified through limited field surveys. Diebel's hope is that this methodology will help enhance the reliability and usefulness of the optimization model.

Existing Tools and Opportunities for Enhancement

The decision-support tools currently available or in development may meet many needs of managers and practitioners as they evaluate and implement aquatic connectivity projects. As presenters noted, these tools could be augmented to include additional information and data sets that would assist resource managers make more efficient and effective decisions. Furthermore, the tools have the potential to assist with the development of consensus goals regarding aquatic connectivity, evaluation of alternative management scenarios, and tracking of progress over time.

Research Needs and Enhancing Decision-Support Tools

Over the course of the workshop, participants identified the information they need to improve fish passage or dam removal in Great Lakes tributaries and reviewed the status of existing decision-support tools. This discussion helped identify research needs and information gaps as well as the types of decision-support tools that would enable managers and practitioners to make more effective and efficient decisions when evaluating and executing an aquatic connectivity project.

Information Gaps

A summary of the information gaps identified by participants is provided below:

- While many watershed inventories have been completed, many areas of Michigan and the Great Lakes basin have not been assessed. Completing inventories that comprehensively identify road-stream crossings and other barriers and collect information on the connectivity status of the site would support enhanced decision making. To the extent possible, inventories should involve local stakeholders and use a consistent methodology to allow for better comparisons among watersheds. Additionally, an assessment of the existing inventories should be prepared that identifies watersheds with and without comprehensive road-crossing inventories.
- Underlying data sets that may be incomplete should be updated as appropriate. For example, practitioners noted that the Michigan Natural Features Inventory (MNFI) maintains a database of endangered and threatened species, which is a valuable resource as they evaluate projects. It was noted that the MNFI database would benefit from more frequent updates.
- During the workshop, it was suggested that improperly placed road-crossing structures are more likely to fail during severe storm events. Participants suggested that an economic assessment comparing the lifespan and cost of properly and improperly placed structures would inform discussions regarding design alternatives.
- Currently, when reviewing connectivity projects, project teams and funders frequently use the number of river-miles as a proxy to help determine the relative priority of a potential project. While using river-miles restored is generally a good indicator it does not take into account the quality of the habitat that would be connected. Enhanced methods to evaluate and quantify habitat quality would support decision making.
- Developing estimates of sea lamprey production potential upstream from known barriers would enable resource managers to better evaluate tradeoffs of removing or keeping a barrier and help estimate potential lampricide treatment costs.
- Practitioners who conduct large-scale removal projects noted that funds administration and project management (coordinating multiple funding sources and project requirements) presents one of the greatest challenges when removing a dam. Additional tools could be developed to simplify project management.
- Throughout the workshop, participants discussed tradeoffs among management alternatives. Continued research on alternative methods of aquatic invasive species control that have a lower impact on desirable species would advance management goals.
- The workshop planning committee asked participants to discuss the sociocultural and economic factors that influence decisions regarding connectivity projects. Practitioners discussed project readiness as a factor they consider when determining which projects they will seek to advance. Elements of readiness include availability of funding, stakeholder support, and capable project managers. Additional research is needed to better identify these factors and determine how they could be incorporated into a decision-support tool.

“Readiness is everything.”

- Amy Beyer, Executive Director,
Conservation Resource Alliance

- What was noted as lacking throughout the entire workshop is information pertaining to economic benefit not only from enhanced connectivity, but also from an ecosystem services perspective. If economic benefits could be more clearly articulated, there would be a better balance for discussion regarding costs and benefits.
- Over the course of the workshop, it became clear that the Great Lakes fishery management community has not yet developed consensus goals regarding aquatic connectivity and invasive species control. This could help alleviate tensions among sometimes conflicting management priorities and help guide funding. Rigorous decision-support tools could be useful to help develop these goals and track progress over time.

Additionally, resource managers reiterated the need to develop design alternatives to enable selective fish passage, particularly for nonjumping species, while preventing passage of aquatic invasive species at barriers. However, this research was identified as being separate from research that would advance the development of decision-support tools. Furthermore, some priorities identified during the workshop may be best addressed by organizations other than the GLFT. The GLFT will evaluate these priorities within the context of its strategic plan and funding policies to determine priorities to address through future funding opportunities.

Enhancing Decision-Support Tools

Workshop participants identified the primary functions that decision-support tools could provide to add value for resource managers. These primary functions are (1) providing a central source of information to develop, evaluate, and implement aquatic connectivity projects; (2) supporting efforts to prioritize connectivity projects to deploy resources more strategically; and (3) help resource managers evaluate management alternatives. To the extent possible, decision-support tools that use data sets upon which stakeholders agree as being accurate and valid will be more valuable than those that do not. Additionally, decision-support tools that allow individual users the ability to manipulate inputs or weights for decision criteria will be more fully embraced by the management community. The tools reviewed by the researchers on the second day of the workshop include many of these elements and can serve as the basis to develop more robust decision-support tools that would continue to enable resource managers to make more efficient and effective decisions.

Decision-support tools that allow individual users the ability to manipulate inputs or weights for decision criteria will be more fully embraced by the management community.

Future Initiatives

The GLFT would like to thank the planning committee, participants, and presenters of the workshop for their efforts to identify research needs and information gaps to support enhanced decision making when evaluating and executing aquatic connectivity projects. The participants represented a group of people on the forefront of aquatic connectivity within Michigan and the Great Lakes basin that brought a wealth of experience to the topic. The research needs and potential applications of decision-support tools identified during the workshop will assist resource managers and researchers develop and refine tools.

The GLFT will review the workshop proceedings document to help define funding priorities and solicit proposals that address the research needs and information gaps and support enhancements to existing decision-support tools. The GLFT emphasizes collaborative projects that leverage partnerships among researchers, managers, and practitioners to achieve the most meaningful results.

Appendix A:

Great Lakes Fishery Trust Background

The Great Lakes Fishery Trust (GLFT) was created in 1996 as a result of a settlement agreement to mitigate the unavoidable fish losses from the operation of the Ludington Pumped Storage Plant (LPSP), a hydroelectric facility located on Lake Michigan near Ludington, Michigan, which is co-owned by Consumers Energy and DTE Energy utilities. Grant funds awarded under the agreement give preference to Lake Michigan projects. Since its inception, the GLFT has granted over \$60 million with a focus on the following activities:

- Research directed at increasing the benefits associated with Great Lakes fishery resources
- Rehabilitation of lake trout, lake sturgeon, and other fish populations
- Protection and enhancement of fisheries habitat, including Great Lakes wetlands
- Public education concerning the Great Lakes fisheries
- Provide public access to the Great Lakes fisheries
- Acquisition of property for the above purposes

As provided in the settlement agreement, the GLFT was established as a private, nonprofit corporation directed by a board of trustees comprised of representatives from the Michigan Department of Natural Resources (MDNR), the Office of the Michigan Attorney General, the Michigan National Wildlife Federation, Grand Traverse Band of Ottawa and Chippewa Indians, the Michigan United Conservation Clubs, and the U.S. Fish and Wildlife Service (USFWS). Using funds derived from the settlement, the GLFT contracts administrative and management support services through Public Sector Consultants Inc., a firm based in Lansing, Michigan.

Mission and Vision Statement

The GLFT's mission is to provide funding to enhance, protect, and rehabilitate the Great Lakes fishery. The GLFT manages its resources to compensate for the lost use and enjoyment of the Lake Michigan fishery resulting from the operation of the LPSP. The GLFT envisions the Great Lakes as supporting a sustainable and diverse fishery that meets the needs of the Great Lakes community in terms of a healthy environment, wholesome food, recreation, employment, commerce, and preservation of its cultural heritage. The GLFT will dedicate its assets to fostering realization of this vision, particularly for Lake Michigan. The GLFT's guiding principle is to consider the total environment, recognizing the connections in the chemical, physical, and biological processes of the Great Lakes ecosystem as well as the human uses and values associated with this magnificent resource. The GLFT recognizes that public understanding of, and involvement in, Great Lakes fishery management is essential to successfully attaining its objectives.

Appendix B: Workshop Agenda



Aquatic Connectivity Workshop

September 4–5, 2014

Henry Center | 3535 Forest Road, Lansing, Michigan 48910

Workshop Overview

The Great Lakes Fishery Trust is hosting an Aquatic Connectivity Workshop, which will convene resource managers, practitioners, and researchers on the forefront of fish passage and invasive species management as it relates to dam and barrier removals. The workshop will include presentations from local, state, federal, and tribal agency representatives, non-governmental entities, and academic organizations. Attendees will identify what kinds of decision support tools managers need and would find useful to make decisions on where to improve fish passage or remove a dam in the Great Lakes basin.

Workshop Goal and Outcomes

Identify types of decision support tools that resource managers and regulators need and would use to guide decisions on where to improve fish passage or remove a dam in the Great Lakes basin.

Desired Workshop Outcomes

- Attendees will learn from managers and stakeholders what sociocultural, biological, and economic information they need to determine how to improve fish passage or remove a dam in Great Lakes tributaries.
- Attendees will learn from researchers the status of decision support tools that are available to meet the information needs of managers and stakeholders.
- Managers and researchers will jointly identify a) types of decision support tools for further development and b) gaps in biological, sociocultural, and economic information pertaining to fish passage and dam removal that would further inform management and regulatory decision making.
- A proceedings document will be developed that summarizes the workshop results.

Potential Outputs of Decision Support Tool(s)

- General information to help decision-makers evaluate a potential removal project
- Identification of likely constraints (e.g., a potential removal may expand the amount of available habitat to lamprey) using a red-yellow-green rating system
- Various levels of analysis—lake basin, regional/state, watershed, site-specific

Agenda

Day 1/September 4, 2014

Noon–1:00PM	Registration	
1:00–1:10PM	Welcome and Introduction	Newcomb/Coscarelli
1:10–1:40PM	Michigan State Agencies <ul style="list-style-type: none"> • Department of Environmental Quality • Department of Natural Resources • Department of Transportation 	Joe Rathbun (confirmed) Chris Freiburger (confirmed) Coreen Strzalka (confirmed)
1:40–2:10PM	Wisconsin State Agencies <ul style="list-style-type: none"> • Wisconsin environmental regulator 	Bobbi Jo Fischer (confirmed)
2:10–2:40PM	U.S. Fish and Wildlife Service <ul style="list-style-type: none"> • Sea Lamprey Barrier Coordinator • Fish Passage Biologist 	Jessica Barber (confirmed) Andrea Ania (confirmed)
2:40–3:00PM	Break	
3:00–3:30PM	Tribal Representatives <ul style="list-style-type: none"> • Chippewa Ottawa Resource Authority 	Mark Ebener (confirmed)
3:30–4:00PM	Non-governmental Organizations <ul style="list-style-type: none"> • Conservation Resource Alliance • Huron Pines 	Amy Beyer (confirmed) Brad Jensen (confirmed)
4:00–4:30PM	Road Crossings Stakeholders <ul style="list-style-type: none"> • Oceana County Road Commission • U.S. Forest Service 	Lisa Dutcher (confirmed) Bob Stuber (confirmed)
4:30–5:00PM	Wrap-up	Newcomb/Coscarelli
5:30–7:30PM	Evening Reception: University Club/Henry Center	Presentation from Rob McLaughlin (confirmed)

Day 2/September 5, 2014

7:45–8:30AM	Continental Breakfast	
8:30–8:45AM	Welcome and Introduction	Newcomb/Coscarelli
8:45–9:15AM	Michigan State University U.S. Geological Survey	Dana Infante (confirmed) Jana Stewart (confirmed)
9:15–9:45AM	The Nature Conservancy	Patrick Doran (confirmed)
9:45–10:00AM	Break	
10:00–10:30AM	University of Michigan	Catherine Riseng (confirmed)
10:30–11:00AM	University of Wisconsin Wisconsin Department of Natural Resources	Tom Neeson (confirmed) Matt Diebel (confirmed)
11:00 AM–noon	Discussion: Next Steps	Newcomb/Coscarelli

Appendix C: Workshop Attendees

Brian Anderson

Illinois Natural History Survey
1816 South Oak St., MC652
Champaign, IL 61820
217-333-6830
bda@illinois.edu

Andrea Ania

U.S. Fish & Wildlife Service
Alpena FWCO
480 West Fletcher Street
Alpena, MI 49707
989-356-5102 ext. 1020
Andrea_Ania@fws.gov

Jessica Barber

U.S. Fish & Wildlife Service
Marquette Biological Station
3090 Wright St.
Marquette, MI 49855
906-226-1241
jessica_barber@fws.gov

Jon Beard

Great Lakes Fishery Trust
230 N. Washington Sq., Ste. 300
Lansing, MI 48933
517-371-7468
jbeard@glft.org

Amy Beyer

Conservation Resource Alliance
10850 Traverse Hwy.
Ste. 1180
Traverse City, MI 49684
231-946-6817
amy@rivercare.org

Heather Braun

Great Lakes Commission
2805 S. Industrial Hwy.
Ste. 100
Ann Arbor, MI 48104
734-971-9135
hbraun@glc.org

Mark Brouder

U.S. Fish and Wildlife Service
2800 Lake Shore Dr. East
Ashland, WI 54806
715-682-6185 ext. 11
mark_brouder@fws.gov

Dale Burkett

Great Lakes
Fishery Commission
2100 Commonwealth Blvd.
Ste. 100
Ann Arbor, MI 48105
734-662-3209
dburkett@glfc.org

Bryan Burroughs

Trout Unlimited
P.O. Box 442
DeWitt, MI 48820
517-599-5238
bryanburroughs@michigantu.org

Sandra Clark

Michigan Department of Natural
Resources
P.O. Box 30740
Lansing, MI 48909
517-373-6362
clarkss@michigan.gov

Mark Coscarelli

Great Lakes Fishery Trust
230 N. Washington Sq., Ste. 300
Lansing, MI 48933
517-371-7468
mcoscarelli@glft.org

Gary Dawson

Consumers Energy
1 Energy Plaza
Jackson, MI 49201
517-788-2432
gary.dawson@cmsenergy.com

John Dettmers

Great Lakes Fishery Commission
2100 Commonwealth Blvd.
Ste. 100
Ann Arbor, MI 48105
734-662-3209
jdettmers@glfc.org

Matt Diebel

University of Wisconsin-Madison
Center for Limnology
680 N. Park St.
Madison, WI 53704
608-224-7151
Matthew.Diebel@Wisconsin.gov

Kevin Donner

Little Traverse Bay Bands of Odawa
Indians
7500 Odawa Cir.
Harbor Springs, MI 49740
231-242-1672
kdonner@lbbodawa-nsn.gov

Patrick Doran

The Nature Conservancy
101 E. Grand River Ave.
Lansing, MI 48906
517-980-4815
pdoran@tnc.org

Lisa Dutcher

Oceana County Road Commission
3501 W. Polk Rd.
Hart, MI 49420
231-873-4226
ldutcher@oceanacrc.org

Mark Ebener

Chippewa Ottawa Resource
Authority
179 West 3 Mile Rd.
Sault Sainte Marie, MI 49783
906-632-0072
mebener@lighthouse.net

Bobbi Jo Fischer

Wisconsin Department of Natural Resources
DNR Wautoma Service Center
427 E. Tower Dr., Ste. 100
Wautoma, WI 54982
920-787-3015
Bobbi.Fischer@wisconsin.gov

Jim Francis

Michigan Department of Natural Resources
525 W. Allegan St.
Lansing, MI 48933
517-284-6244
francisj@michigan.gov

Chris Freiburger

Michigan Department of Natural Resources
Executive Division
P.O. Box 30028
Lansing, MI 48909
517-284-5824
freiburgerc@michigan.gov

Jim Galloway

U.S. Army Corps of Engineers
P.O. Box 1027
Detroit, MI 48231
313-226-6760
jim.e.galloway@usace.army.mil

Molly Good

Michigan State University
13 Natural Resources Bldg.
East Lansing, MI 48824
517-353-3048
goodmoll@msu.edu

Tom Gorenflo

Chippewa Ottawa Resource Authority
Albert LeBlanc Bldg.
179 W. 3 Mile Rd.
Sault Sainte Marie, MI 49783
906-632-0043
tgorenflo@sault.com

Todd Grischke

Michigan Department of Natural Resources
P.O. Box 30446
Lansing, MI 48909
517-284-5826
GrischkeT@michigan.gov

Mark Holey

U.S. Fish and Wildlife Service
2662 Scott Tower Dr.
New Franken, WI 54229
920-866-1717
mark_holey@fws.gov

Marty Holtgren

Little River Band of Ottawa Indians
375 River St.
Manistee, MI 49660
231-398-2193
mholtgren@lrboi.com

Dana Infante

Michigan State University
334 E. Natural Resources Bldg.
East Lansing, MI 48824
734-663-3554 ext. 115
infanted@anr.msu.edu

Brad Jensen

Huron Pines
4241 Old US 27 S., Ste. 2
Gaylord, MI 49735
989-348-9319
brad@huronpines.org

Todd Kalish

Michigan Department of Natural Resources
970 Emerson Rd.
Traverse City, MI 49696
231-922-5280
kalisht@michigan.gov

Byron Lane

Michigan Department of Environmental Quality
P.O. Box 30473
Lansing, MI 48909
517-281-6821
laneb@michigan.gov

Rob McLaughlin

University of Guelph
Science Complex
Guelph, Ontario, CN
N1G 2W1
519-824-4120 ext. 52756
rlmclaug@uoguelph.ca

Andrew Muir

Great Lakes Fishery Commission
2100 Commonwealth Blvd.
Ste. 100
Ann Arbor, MI 48105
734-662-3209
amuir@glfc.org

Tom Neeson

University of Wisconsin-Madison
Center for Limnology
680 N. Park St.
Madison, WI 53704
608-262-3088
neeson@wisc.edu

Tammy Newcomb

Michigan Department of Natural Resources
P.O. Box 30046
Lansing, MI 48909
517-284-5832
newcombt@michigan.gov

Stephanie Ogren

Little River Band of Ottawa Indians
159 Brickyard Rd.
Manistee, MI 49660
231-723-1594
sogren@lrboi.com

Erik Olsen

Grand Traverse Band of Ottawa and Chippewa Indians
2605 NW Bay Shore Dr.
Fisheries Management Building
Suttons Bay, MI 49682
231-534-7364
erik.olsen@gtbindians.com

Carl Platz

U.S. Army Corps of Engineers
307 S. Harbor Dr.
P.O. Box 629
Grand Haven, MI 49417
616-842-5510 ext. 25521
Carl.A.Platz@usace.army.mil

Brad Potter
Upper Midwest & Great Lakes
Landscape Conservation Cooperative
2651 Coolidge Rd., Ste. 101
East Lansing, MI 48823
517-351-4213
Bradly_Potter@fws.gov

Joe Rathbun
Michigan Department of
Environmental Quality
525 West Allegan St.
P.O. Box 30473
Lansing, MI 48909
517-284-5517
RATHBUNJ@michigan.gov

Catherine Riseng
University of Michigan
1st Floor Wolverine Tower
3003 S. State Street
Ann Arbor, MI 48109
734-763-9422
criseng@umich.edu

John Rogner
Upper Midwest & Great Lakes
Landscape Conservation Cooperative
1250 S. Grove Ave., # 103
Barrington, IL 60010
847-381-2253 ext. 12
John_Rogner@fws.gov

Phil Schneeberger
Michigan Department of
Natural Resources
484 Cherry Creek Rd.
Marquette, MI 49855
906-249-1611
SchneebergerP@michigan.gov

Matt Shackelford
DTE Energy
7940 Livernois Ave.
Detroit, MI 48210
313-897-1021
shackelfordm@dteenergy.com

Jana Stewart
U.S. Geological Survey
Wisconsin Water Science Center
8505 Research Way
Middleton, WI 53562
608-821-3855
jsstewart@usgs.gov

Coreen Strzalka
Michigan Department
of Transportation
State Transportation Building
425 W. Ottawa St.
P.O. Box 30050
Lansing, MI 48909
517-373-3397
StrzalkaC@michigan.gov

Rob Stuber
U.S. Forest Service
Huron-Manistee
National Forests
1755 S. Mitchell St.
Cadillac, MI 49601
231-775-2421
rstuber@fs.fed.us

Kevin Wehrly
MDNR Institute for Fisheries
Research
1109 N. University Ave.
212 Museums Annex Bldg.
Ann Arbor, MI 48109
734-663-3554 ext. 120
wehrlyk@michigan.gov

Jay Wesley
Michigan Department of
Natural Resources
970 Emerson Rd.
Traverse City, MI 49696
269-685-6851 ext. 117
WesleyJ@michigan.gov

Rick Westerhof
U.S. Fish and Wildlife Service
2661 Scott Tower Rd.
New Franken, WI 54229
231-582-3553
rick_westerhof@fws.gov

Gary Whelan
Michigan Department of Natural
Resources
P.O. Box 30446
Lansing, MI 48909
517-284-5830
whelang@michigan.gov

Appendix D: Workshop Evaluation

Workshop Evaluation

A postworkshop evaluation was distributed to all 54 workshop participants in paper form. Twenty-nine participants returned the evaluations (54 percent of the total) anonymously with their responses to ten basic statements or questions regarding the goals, objectives, execution, and intended outcomes of the workshop and the role the GLFT can provide in future workshops and resource development. Some respondents also contributed written comments to two additional questions regarding the usefulness of this workshop and suggested workshop improvements. A summary of these responses, grouped in themes, is provided below:

Workshop Execution

Overall, most of the respondents agreed that the workshop was successful in achieving the intended goals and objectives. More than 70 percent of respondents either strongly agreed or agreed with seven out of the ten basic statements or questions regarding workshop goals and objectives. For example, 90 percent of respondents said that the workshop fostered communication among researchers, managers, and nongovernment entities active in barrier removals, invasive species management, and data models. Additionally, 90 percent of respondents also said they left the workshop feeling they had gained valuable insight into connectivity issues. Only 41 percent of evaluation participants gained “a more detailed understanding of the GLFT’s role relative to fisheries habitat protection and restoration in the Great Lakes.” Though not the focus of this workshop, the GLFT could have more clearly articulated its role as an organization that advances habitat protection and restoration through research and on-the-ground restoration projects. In their written comments, a few of the participants noted the Michigan State University Henry Center as a fantastic facility for this type of workshop, though one person disliked the seating arrangements. In general, respondents appeared to be satisfied with this workshop and many of them provided their congratulations on a job well done.

Workshop Format

From the start, the format of this workshop was uniquely designed to facilitate discussion about aquatic connectivity and fish passage among various stakeholder groups. Many of the evaluation participants acknowledged this workshop format to be helpful in bridging communication gaps, but improvements could be made for future workshops. For example, many participants suggested that the Day 2 presenters (scientists and researchers) could have better responded to questions raised and data needs identified by the Day 1 presenters (managers and regulators) if there was a greater length of time between the presentations. One participant recommended future presentations be submitted a week or two in advance to give everyone ample time to prepare a tailored talk. Overall, a number of the Day 1 and Day 2 presenters said they would have preferred more discussion time, perhaps in small breakout groups, to talk about other aquatic connectivity issues, such as the impact(s) of invasive species and costs of barrier removal. Though improvements can be made for future workshops, it is clear that most respondents acknowledged and appreciated the efforts behind creating this new workshop format.

Workshop Invitees

Respondents generally felt there was a diverse representation of stakeholders in attendance at this workshop. They enjoyed the opportunity to network and interact with a variety of stakeholders including managers, scientists and researchers, regulators, etc. A couple of the respondents appeared to be especially pleased by the inclusion of representatives of tribal natural resource organizations in this workshop. Two evaluation participants suggested extending an invitation to representatives from the Michigan Association of County Drain Commissioners for the next workshop.

Next Steps

While most evaluation participants were pleased with the results of this workshop, some of them were curious about the immediate outcomes of this workshop or what to do next. According to the evaluations, future workshops are encouraged.

Summary of Workshop Evaluation Completed by Workshop Participants

AQUATIC CONNECTIVITY WORKSHOP

A Workshop Sponsored by the Great Lakes Fishery Trust

Twenty-nine evaluations were returned. Below are the evaluation instructions and a figure compiling evaluation questions, including the number of responses that fell into each of the five categories.

Instructions: The Great Lakes Fishery Trust would appreciate your evaluation of the Aquatic Connectivity Workshop. Below are several statements or questions; we would like you to indicate the level with which you agree, disagree, or feel neutral towards the statement. Please provide any other comments you may have on the bottom of the form. Your opinions on the success of the workshop are important to us and we appreciate you taking the time to complete the evaluation. Thank you again for a productive workshop.

Please rate each of the following items on a scale of one to five (**1 = Strongly agree; 2 = Agree; 3 = Neutral; 4 = Disagree; 5 = Strongly disagree**).

	1	2	3	4	5	no answer
The workshop fostered communication among researchers, managers, and nongovernment entities active in barrier removals, invasive species management, and data models.	14	12 (90% agree)		1	2	
The workshop adequately identified the primary information needs of managers and existing assessment tools that can provide decision support when evaluating a potential removal.	1	20 (72% agree)	5	2	1	
Your knowledge of decision factors relating to barrier removals and fish passage has increased.	10	12 (76% agree)	4	3		
The workshop adequately identified information gaps/research needs that need to be filled to develop a tool(s) to guide decisions on improvement of fish passage or dam removal in the Great Lakes basin.	3	16 (66% agree)	7	2	1	
The workshop adequately identified the primary technical challenges managers face when evaluating a potential barrier removal.	7	14 (72% agree)	4	2	1	1
You have gained a more detailed understanding of the Great Lakes Fishery Trust's role relative to fisheries habitat protection and restoration in the Great Lakes.	3	9 (41% agree)	9	6	1	1
The results of this workshop will help you and your agency in evaluating potential barrier removals.	3	14 (59% agree)	8	3		1
You would attend another workshop sponsored by the Great Lakes Fishery Trust.	20	7 (93% agree)			2	
The organization, methods, and procedures of the workshop encouraged participants to contribute to the discussions.	10	12 (76% agree)	5	1	1	
You left the workshop feeling you gained valuable insight.	12	14 (90% agree)		3		

Appendix E:

GLFT Support of Connectivity Projects

.....

Since its inception in 1996, the GLFT has invested over \$5.3 million in projects to enhance aquatic connectivity and inform decision making. The GLFT has provided funding support to a range of projects that include on-the-ground restoration through large and small scale barrier removals, community planning, development of geographic information systems (GIS), and research to advance connectivity goals. The following is a list of selected projects supported by the GLFT. More information about projects supported by the GLFT is available online at <https://glft.org/projects>.

GLFT Grant Number	Project Title	Grant Recipient	Project Manager	Grant Award
2014.1497	Stream and Wetland Restoration in Ulaop Creek Milwaukee Estuary AOC	Ozaukee County	Matt Aho	\$154,923
2014.1490	Pucker Street Dam Removal	Niles City	Marcy Colclough	\$200,000
2014.1472	Boardman River - Dam Removal #2	Conservation Resource Alliance	Amy Beyer	\$400,000
2013.1350	Kids Creek Restoration Project	The Watershed Center Grand Traverse Bay	Sarah U'Ren	\$100,000
2013.1348	Dam Removal and Fish Passage Restoration in Mineral Springs Creek	Ozaukee County	Andrew Struck	\$49,987
2013.1346	Culvert Removals - Brayton Creek at Cleveland Road	Oceana County Road Commission	Lisa Dutcher	\$75,000
2013.1343	Menomonee River Fish Barrier Removal Project	Milwaukee Metropolitan Sewage District	Kevin Shafer	\$25,000
2013.1342	Reconnecting Black River Tributaries with Lake Huron	Huron Pines	Samuel Prentice	\$115,224
2013.1302	Behavior of Juvenile Lake Sturgeon Stocked Above a Hydropower Dam	Michigan Department of Natural Resources	Ed Baker	\$472,362
2012.1262	Coastal Lake Huron Tributary Restoration	Huron Pines	Brad Jensen	\$58,370
2012.1261	Reconnecting Lake Huron Fish with Rifle River Tributaries	Huron Pines	Brad Jensen	\$116,000
2012.1260	Carlton Creek Culvert Removal	Oceana County Road Commission	Lisa Dutcher	\$85,000
2011.1206	Great Lakes Aquatic Habitat Framework	The Regents of the University of Michigan	Catherine Riseng	\$527,229
2011.1200	Lake Sturgeon Metapopulation Structure in a Complex River-Lake Ecosystem	Great Lakes Fishery Commission	Charles Krueger	\$359,929
2010.1165	Beginning the Removal of the Boardman River Dams: Removing/Restoring Brown Bridge Dam	City of Traverse City	Ben Bifoss	\$1,000,000
2010.1162	Evaluating the Success of New Rock Ramp Fish Passages and Prioritization of Tributaries for Barrier Removals in the Saginaw Bay Watershed	Central Michigan University	Tracy Galarowicz/ Brent Murry	\$257,430
2008.1023	Jordan River Electrical Weir Removal Project	Conservation Resource Alliance	Kimberly Balke	\$25,000
2008.986	Fate of the Boardman River Dams	Rotary Camps and Services	Marsha Smith	\$141,573

GLFT Grant Number	Project Title	Grant Recipient	Project Manager	Grant Award
2007.972	Mortality and Recruitment Mechanisms Affecting Early Life Stages of Lake Sturgeon Population in Lake Michigan	University of Alaska Fairbanks	Trent Sutton	\$104,026
2007.855	Dair Creek Fish Passage Project	Conservation Resource Alliance	Amy Beyer	\$50,000
2006.776	Fate of the Boardman River Dams	Northwestern Michigan College	Marguerite Cotto	\$334,427
2005.693	Evaluation and Synthesis of Methods for Identifying and Quantifying Critical Fisheries Habitat for Great Lakes Lower Riverine and Nearshore Zones	Great Lakes Fishery Commission	Barb Staples	\$31,544
2005.650	Great Lakes Aquatic Nonindigenous Species Information System (GLANSIS)	National Oceanic and Atmospheric Administration	David Reid	\$33,937
2004.563	Nearshore Habitat Mapping of Grand Traverse Bay	Grand Traverse Band of Ottawa and Chippewa Indians	Brett Fessell	\$24,280
2003.417	Great Lakes Basin Lake Sturgeon GIS Database Web Page	U.S. Fish and Wildlife Service	Emily Zollweg	\$34,872
2003.415	Potential for Lake Sturgeon Habitat Rehabilitation in Green Bay Tributaries of Lake Michigan	Purdue University	Trent Sutton	\$33,375
2001.220	Big Rapids Dam Removal Communications Project	City of Big Rapids	Cindy Plautz	\$16,159
2000.58	Big Rapids Dam Removal and Riverwalk Construction Project	City of Big Rapids	Cindy Plautz	\$350,000
1999.33	Building a Prototype Fishway for Lake Sturgeon	University of Massachusetts	Boyd Kynard	\$133,452
N/A	Enhancing Lake Sturgeon Passage at Hydroelectric Facilities in the Great Lakes	2011 GLFT Sponsored Workshop	2011 GLFT Sponsored Workshop	2011 GLFT Sponsored Workshop
Total				\$5,309,099

References

Beyer, Amy. March 5, 2014. Written communication to Jonathon Beard, Grant Manager, Great Lakes Fishery Trust.

Januchowski-Hartley, Stephanie R. Peter B. McIntyre, Matthew Diebel, Patrick J. Doran, Dana M. Infante, Christine Joseph, and J. David Allan. 2013. Restoring aquatic ecosystem connectivity requires expanding inventories of both dams and road crossings. *Frontiers in Ecology and the Environment* 11: 211–2517. <http://dx.doi.org/10.1890/120168>

McLaughlin, Robert, Eric Smyth, Theodore Castro-Santos, Michael Jones, Marten Koops, Thomas Pratt, and Luis-Antonio Velez-Espino. 2013. Unintended consequences and trade-offs of fish passage. *Fish and Fisheries* 14: 580–604.

Neeson, Thomas, Michael Ferris, Matthew Diebel, Patrick Doran, Jesse O’Hanley, and Peter McIntyre. 2015. Enhancing ecosystem restoration efficiency through spatial and temporal coordination. *Proceedings of the National Academy of Sciences of the United States of America* 112: 6236–6241. <http://www.pnas.org/content/112/19/6236.short>