Viral Haemorrhagic Septicaemia In the Great Lakes Region

Management and Science Needs Workshop Proceedings

Prepared for

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September 18, 2008

Citation: **Abraham, D. and L. Greig.** 2008. Viral Haemorrhagic Septicaemia in the Great Lakes Region Management and Science Needs Workshop Proceedings. Prepared for the International Joint Commission, the Ontario Ministry of Natural Resources and the Great Lakes Fishery Commission. Prepared by ESSA Technologies, Richmond Hill, Ontario. 11 pp.

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Executive Summary

Viral Haemorrhagic Septicaemia (VHS) is a highly contagious pathogen of fresh- and saltwater fish that has been found in all of the Great Lakes except Superior and in related watercourses. Since it was first identified in the Great Lakes Basin, a number of large-scale kills of wild fish have occurred. VHS is not an isolated threat: it is representative of a variety of aquatic diseases that could be introduced into the Great Lakes Basin with potentially dire consequences. To manage VHS and other emerging aquatic diseases, science must provide managers with the best possible information about these diseases. Workshop participants agreed on a short-list of science needs as follows:

Validating Quantitative PCR Testing – The only accepted diagnostic test for VHS is cell culture, which can detect viable (infective) virus in the sample, but takes 28 days. A polymerase chain reaction (PCR) test can be done in 1 day and is 10,000 times more sensitive than cell culture, making it more suitable for the rapid, high volume testing that is needed. However, a positive result indicates only that the fish was exposed to VHS, not that it is carrying viable virus. Validating the quantitative PCR test and getting it approved for use as the primary diagnostic tool would improve efficiency, enable higher volume through-put analysis and provide a solid basis on which to make management decisions that inevitably affect people's lives and livelihoods. In the interim, PCR can be used to screen large numbers of samples quickly, with those testing positive sent for cell culture testing.

Improved diagnostic infrastructure and efficiency – More laboratories that can conduct diagnostic testing for pathogens are needed (e.g., 3 or 4 more), as is the ability to diagnose infections by a wider range of pathogens is also needed (i.e., more diagnostic tests). Participants recognized that infrastructure needs can't be met in the near term; at a minimum, more staff for existing facilities would help, and more funding for PCR screening to determine which samples should be sent along for cell culture. Immediate diagnostic efficiencies might be possible by co-ordinating efforts among existing labs. Additionally, designing and incorporating robotics into the diagnostic process would enable higher volume analysis for all pathogens of interest.

Biological studies and treatment – There is a need to learn more about the mechanisms of transmission (vectors/pathways) for VHS and other aquatic diseases. Controlled experiments to determine the best disinfection protocols (e.g., for hatcheries, boats, etc.) are also needed.

Decision Analysis – There is an immediate need to conduct a decision analysis (risk assessment) based on the current state of science around VHS and other aquatic pathogens. A decision analysis would help clarify and prioritize uncertainties about the risks associated with specific aquatic pathogens. The results of a decision analysis would provide input into cost-benefit analyses and other socio-economic analyses. A decision support tool based on these analyses is needed to help managers decide when and how to respond to aquatic disease threats and to provide a clearer understanding of science needs. The best case scenario would be for all jurisdictions to agree that a decision analysis needs to be done and for all to collaborate on the same one.

More and better surveillance/monitoring - Surveillance/monitoring can help determine the extent of the disease distributions in the Great Lakes region and provide a better understanding of their long-term impacts on fish populations. Statistically valid surveillance protocols based on clear management goals must be developed to enable more confident conclusions to be reached. Current levels of sampling are inadequate and not always methodically executed. Good sampling protocols will mean collecting more samples from more locations and from more fish species. Increased funding will be required to meet this need.

1. Introduction

Since its first appearance in the Great Lakes in 2005, Viral Haemorrhagic Septicaemia (VHS) has been detected in a variety of freshwater fish in Canadian and American waters. VHS is considered by many nations and international organizations to be one of the most important viral pathogens of finfish (Office International des Epizooties 2007, *in* USGS 2008). However, VHS is not an isolated threat: it is representative of a large number of aquatic pathogens that have been, or could be, introduced into the Great Lakes Basin with potentially dire consequences. Given the potential impacts of VHS and other pathogens on aquatic ecosystems within and beyond the Great Lakes basin, the need to bring together the Great Lakes science and management community to identify knowledge gaps and form a coordinated response strategy was recognized.

To address this need, representatives from the Ontario Ministry of Natural Resources (OMNR), the Great Lakes Fishery Commission (GLFC), and the International Joint Commission's Council of Great Lakes Research Managers (CGLRM) held a 1.5 day workshop on March 12-13, 2008 in Toronto, Ontario. Funding for the workshop came from the OMNR Canada-Ontario Agreement, the GLFC, and the CGLRM, with additional contributions from Environment Canada and the Great Lakes Regional Research Information Network (GLRRIN). ESSA Technologies Ltd. was engaged to facilitate the workshop. A full list of participants is presented in Appendix A.

The objectives of the workshop were to:

1. Share information on current research and management efforts directed at VHS;
2. Identify critical gaps in knowledge and infrastructure needed to guide preventative and post-introduction actions to manage emerging aquatic diseases, including VHS;
3. Identify strategies to address these gaps; and
4. Lay the groundwork for dealing with VHS and other emerging aquatic diseases in a coordinated way.

This report summarizes the results of workshop discussions in the following sections:

- Section 2 defines and bounds the problem;
- Section 3 outlines management objectives and needs;
- Section 4 outlines the science needs to support management decision-making;
- Section 5 identifies priorities for management and science; and
- Section 6 summarizes next steps.

2. Problem Definition and Bounding

2.1 What VHS is

VHS is a highly contagious pathogen of fresh- and saltwater fish that may cause internal haemorrhaging and death in susceptible species. The virus first appeared in the Great Lakes in 2005, when mortalities occurred in the Bay of Quinte (Lake Ontario) and Lake St. Clair. Recent analysis of archived fish from Lake St. Clair, however, confirmed the presence of the virus there as early as 2003. VHS has now been reported in all of the Great Lakes except Superior and in related watercourses; a number of large-scale kills of wild fish have occurred.

2.2 Why we are Concerned

Understanding the risks associated with VHS is complicated by the complexity and dynamics of aquatic systems. It is also complicated by a lack of knowledge about the long-term implications of infection for fish populations and for aquatic ecosystems as a whole.

The current state of knowledge about VHS suggests that the virus could have very serious consequences for infected fish populations. Many fish in an infected population would die in the short term, especially the young, but some fish would likely survive and develop antibodies that protect them for some time into the future. For these fish, post-outbreak effects may include reduced growth and poorer condition (e.g., yellow perch). Populations that were self-sustaining prior to VHS infection might recover. However, VHS is just one of many stressors in aquatic systems. Despite significant uncertainty about long term individual and combined effects, in aggregate, VHS plus other pathogens could clearly have very serious long-term consequences for fish populations.

Another compelling argument for taking management action on VHS is that, unlike many other viral aquatic pathogens, VHS affects a large number of species. In the Great Lakes region, VHS has so far been confirmed in 25 fish species, including game and commercial food fish (e.g., walleye), bait species (e.g., emerald shiner) and native species (e.g., lake trout). Fish from a variety of trophic levels and thermal zones are susceptible to infection. As such, VHS has the potential to result in significant ecological, economic, and social/cultural impacts in the Great Lakes region. Potential impacts include:

- More large-scale fish kills;
- Reduced numbers of spawning fish;
- Reduced recruitment to new year classes;
- Ecosystem effects such as altered energy flow and food web dynamics;
- Disruption of wild egg collections for hatcheries;
- Disruption of forage collections for hatcheries;
- Significant losses for fish culture and wild fish transfers, including baitfish; and
- Decreased value of recreational fishery and lost income for charter boats and commercial fishers.

Finally, because VHS is only one of many aquatic pathogens that have been, or could be, introduced into the Great Lakes Basin, it provides a focal point for research and the development of tools and management strategies needed to respond to similar emerging diseases.

3. Management Objectives and Needs

The first objective of the workshop was met with a series of presentations, followed by question/answer discussions. Presentations covered a diverse range of topics relating to VHS and other aquatic diseases, including current management strategies and the state of scientific knowledge in Canada and the US (see Appendix B).

The next step in the process was to identify needs to effectively manage the introduction and spread of VHS and other emerging aquatic diseases in the Great Lakes basin. This information was then used to guide discussions about the science needed to support those management needs and the setting of priorities to ensure the most urgent needs get addressed first.

3.1 Management Objectives

Management objectives for VHS and other emerging diseases include: 1) identifying potential threats, 2) limiting the occurrence of infections to acceptable levels, 3) managing the spread of the virus, and 4) communicating information on risks and responses to the public and stakeholders. To meet these objectives managers must understand the broad socio-economic context, the cost of reducing the occurrence of infection and disease as well as the acceptable level of additive mortality associated with a pathogen.

3.2 Management Needs

In brief, the management needs identified by participants were:

- Better assessment of the risks associated with VHS and other emerging aquatic pathogens;
- Developing better detection tools to focus management efforts;
- Increasing laboratory capacity;
- Building management capacity for the future;
- Better understanding of management objectives in all jurisdictions;
- Improving capacity to manage the transport of biota between water bodies; and
- Improving management information availability.

Risk Assessment
There is a need to more clearly explain the risks of infection and spread to stakeholders and funders, and why action is necessary. Risk is, in part, a function of human behaviours and management. It must therefore be considered in context with management structure and human behaviour. A formal biological and socioeconomic risk assessment could help clarify the implications of infection, although the current lack of scientific information about VHS and other aquatic diseases would likely limit its reliability in the near term.

Improved Detection Tools
Detection tools that provide rapid and accurate results and enable high volume through-put testing are needed to permit a more focused management response to VHS and other aquatic pathogens. The detection protocol currently in use for VHS is cell culture and it takes 28 days to process a sample. A positive cell culture test means that viable (infective) VHS is present in the sample. Alternatively, a quantitative polymerase chain reaction (PCR) test can produce results in 1 day and is 10,000 times more sensitive than cell culture. As such, the PCR test has the potential to enable the rapid, accurate and high volume testing that is needed. However, a positive PCR result means only that a fish has been exposed to VHS not that it is carrying a form of the virus capable of causing further infection. The sensitivity differences between these tests means that a fish identified by PCR as having been exposed to VHS, could show no sign of the virus in the cell culture. This poses a significant management problem: the cell culture method is not as sensitive as the PCR method, yet the designation of water bodies as “clean” or “infected” are based on this test, as are decisions to allow the movement of fish between water bodies. A diagnostic validation for the PCR test is currently being developed, but it is estimated that it won’t be ready for another 2 years. Until then, the only accepted test for VHS is cell culture; however, in the interim PCR testing can be used as an effective first-level screening tool for managers, with samples testing positive sent on for cell culture testing.

Increased Laboratory Capacity
The number of laboratories that can test for aquatic pathogen diagnostics is relatively small and many lack the capacity to process large numbers of samples at once. The range of pathogens for which tests are

available is also relatively small. These capacity limitations, along with the long test times described in the previous section, can result in a bottleneck that seriously impacts management's ability to respond quickly to emerging threats.

Capacity Building
Over the long term, our ability to manage emerging aquatic diseases will depend on building scientific capacity in the next generation of researchers and managers through training courses and internships.

Jurisdictional Challenge
There is a mosaic of jurisdictions around the Great Lakes, including federal (Canada and US), provincial, state, and tribal. This multi-jurisdictional framework complicates the management of aquatic invasive species, including VHS and other emerging diseases. Different jurisdictions tend to have different legislation, different objectives and different policies. Even where policies are similar between different jurisdictions, the implementation of those policies tends to differ. A more explicit understanding of the management objectives in all jurisdictions was identified as a management need.

Information Availability
More timely access to information is needed to enable better management of aquatic diseases in the Great Lakes region (e.g., a trans-jurisdictional real-time database of information about outbreaks). This management need would likely require instituting rules that mandate timely reporting.

3.3 Facilitating an Informed Decision-Making Process

Clearly articulating the problem and program needs to address VHS and similar emerging diseases in the Great Lakes region is a critical step towards initiating an adaptive management process driven by open communications between scientists and managers. A clear understanding of the serious nature of this problem should prompt investment to support the science required to enable effective management (e.g., surveillance/monitoring, developing testing and disinfection protocols, etc.). This problem is exacerbated by a lack of knowledge about the pathology and etiology of VHS in the Great Lakes region. Without a good understanding of transmission vectors and pathways, and how VHS will affect aquatic ecosystems over the long term, it is difficult to make a compelling case to stakeholders, legislatures, and funders about the need for management and research – a classic "Catch-22". The concerns and recommendations documented at this workshop should be clearly communicated to resource managers and acted upon so that these key knowledge gaps can be filled and informed management action taken.

The multiple jurisdictions around the Great Lakes all have different priorities and ways of implementing policy. A co-ordinated, bi-national approach to the VHS problem is needed (e.g., a bi-national contingency fund for monitoring) to leverage resources and gain economies of scale.

4. Science and Information Objectives and Needs

The second objective of the workshop was to identify the science required to support the management needs identified by participants. The goal of science is to provide the information needed to respond to and manage emerging diseases. The science needs identified by participants were:

- Improving detection tools and laboratory testing capacity;
- Biological/epidemiological studies;
- Decision analysis;
- Ecological modelling;

- Surveillance/monitoring;
- Information availability; and
- Evidence-based diagnostics for treatment.

The most pressing science needs identified were improved detection tools and increased laboratory capacity. There is a need to improve the speed and sensitivity of testing and increase capacity for processing large numbers of samples. Validation of the quantitative PCR testing protocol needs to be completed as soon as possible. More laboratory facilities are also required to increase capacity to identify VHS and other emerging pathogens. Without these improvements, the implementation of statistically meaningful surveillance/monitoring strategies for VHS and other aquatic pathogens will be difficult, if not impossible. As a result, scientists will be severely limited in their ability to provide resource managers with quick and accurate information on new aquatic pathogen threats.

4.1 Other science needs

Biological/epidemiological studies
Research on VHS is needed to better understand the origin and development of the disease (pathogenesis), the host-pathogen interaction, mechanisms of transmission (vectors/pathways), the status of exposed fish, and the life span of VHS in wild fish. Other science needs include

- Determining of the relationships between fish densities and disease transmission. This research is needed to understand why and when outbreaks occur and to determine if controlling fish population densities is a feasible way of reducing the risk of outbreaks. The results of this work could better inform management of facilities where fish are confined.
- Understanding the dynamics of VHS reservoirs in natural systems (e.g., sediments). Can viable virus re-enter fish populations from these reservoirs? What are the factors that affect virulence?
- Developing methods for separating mortality due to VHS from natural mortality in affected populations.
- Understanding how inland fish populations are responding to VHS and other emerging diseases; a qualitative difference between inland and Great Lakes populations is expected.

In the short term, a thorough understanding of transmission pathways is needed to develop management approaches to limit the spread of VHS. Over the longer term, there is a need to develop strategies to prevent the introduction and spread of emerging aquatic diseases and to better manage pathogens already present. For example, a better understanding of whether or not ballast water plays a role in the transmission of VHS is needed.

Decision analysis
There are potentially many emerging aquatic diseases that could seriously affect fish populations in the Great Lakes region. A decision support tool is needed to help managers decide when and how to respond to disease threats. That is, when can a disease be allowed to run its course and when is intervention warranted? There is also a need to explicitly identify and rank the values to be used in a decision analysis. Whose values matter? Which fisheries matter? What are the consequences associated with and without management activities?

Ecological modelling
A framework for modelling pathogen introduction, spread, and ecological impact is needed (e.g., inoculation pressure threshold). The ability to predict the next “top 10” aquatic diseases would provide a

"heads up" and improve management response and efficacy. Additionally, a better understanding of the interactions among stressors would help predict when populations will become vulnerable.

Surveillance/monitoring
A comprehensive ecosystem approach to monitoring the spread of VHS and other pathogens is needed. Statistically valid sampling surveillance protocols must be developed. Monitoring data must represent the demographics (age, sex) of sampled populations and come from multiple species. A good sampling protocol can:

- Enable early detection of the virus;
- Better delineate zones of infection and identify "hot spots" to help focus management actions;
- Provide insights into long term population impacts (resistance, presence of antibodies, initial mortality, morbidity);
- Measure how anglers respond to changes in fish populations and management regulations;
- Determine if VHS is affecting growth, condition and fecundity; and
- Provide input for risk assessment and other modelling efforts (e.g., outbreak probability models, cost-benefit analyses, etc.).

Information availability
The capacity to share information about VHS across jurisdictions was identified as both a management need and a science need (e.g., an information clearinghouse). Examples include observations of outbreaks, kills, or the arrival of new pathogens as well as information on things like operational costs from recreational and commercial fishers that are needed for bio-economic modelling and trade-off analyses.

Evidence-based diagnostics for treatment
For example, to determine the best treatments for disinfecting recreational boats, testing is needed to measure how effective each treatment is at killing the virus. The development of effective methods for disinfecting eggs would also help manage transmission of VHS from adults to offspring. A science-based protocol for clearing VHS from infected hatcheries also needs to be developed. The European experience may provide some guidance.

5. Setting Priorities

In order to manage VHS and other emerging aquatic diseases, science must provide managers with the best possible information available. A compelling argument must be made, to all affected jurisdictions, to support the need for scientific study of VHS and other emerging aquatic diseases. A priority objective of the workshop was to develop a strong, concise message for policy makers and resource managers about the ecological and economic risks associated with aquatic pathogens and the importance of supporting further research and infrastructure development. Additionally, fish are managed for people; there is a need to clearly articulate to stakeholders how aquatic disease outbreaks may affect human stakeholders associated with fish and fishing.

Workshop participants agreed on a short-list of science priorities as follows.

Validating quantitative PCR testing
Validating the quantitative PCR test and getting it approved for use as the primary diagnostic tool would improve testing efficiency, enable higher volume through-put, and provide a more solid basis for management decisions that inevitably affect people's lives and livelihoods.

Improving diagnostic infrastructure and efficiency
Increasing the number of diagnostic laboratories (e.g., 3 or 4 more) and the range of tests they conduct would significantly improve our ability to detect, monitor, and understand aquatic diseases and to develop effective management approaches. Participants recognized that infrastructure needs can't be met in the near term; at a minimum, what's needed are more staff for existing facilities and increased funding for PCR screening to determine which samples should be tested using cell culture. Immediate diagnostic efficiencies might be possible by coordinating efforts among existing labs. Additionally, designing and incorporating robotics into the diagnostic process would enable higher volume analysis for all pathogens of interest.

Biological studies and treatment
Research is needed to improve our understanding of VHS transmission, spread, and ecological impacts. Also needed are controlled experiments to determine the best disinfection protocols (e.g., for eggs, boats, etc.).

Decision Analysis
There is an immediate need to conduct a decision analysis (risk assessment) based on the current state of science around VHS and other aquatic pathogens. The best case scenario would be for all jurisdictions to agree that a decision analysis needs to be done and for all to collaborate on the same one.

There are many uncertainties associated with the VHS infestation of the Great Lakes region; decision analysis would clarify and prioritize those uncertainties and it would also provide a clearer understanding of the science needs. Decision analysis would also help clarify why we need to continue to impose controls on the movement of biota, water and boats among water bodies. The results of a decision analysis would also provide input into cost-benefit analysis and other socio-economic analyses. As new information about VHS is obtained through research, the decision analysis could be re-visited and revised to reflect the new state of knowledge.

More and better surveillance/monitoring
Surveillance protocols that allow scientists to make statistically valid inferences about things like the distribution and rate of spread of pathogens must be developed. These protocols must be guided by clear management objectives and key information needs. Current levels of sampling are inadequate and not always methodically executed. Good sampling protocols will mean collecting more samples from more locations and from more fish species. More funding is going to be required in order to meet this need.

Monitoring data must represent the demographics (age, sex) of sampled populations and come from multiple species. Monitoring/surveillance will help determine the extent of the VHS infestation in the Great Lakes region and provide a better understanding of the long-term population impacts (resistance, morbidity effects, etc.) of the virus. Sampling for mortality at the population level could be combined with current programs that sample for stock assessment. There is also a need to identify the threat posed by VHS to species at risk and to species that might become at risk as a result of susceptibility to the virus.

6. Recommendations and Next Steps

In order to meet the management and science needs identified at the workshop, participants made a number of recommendations and identified some next steps.

The approach to managing VHS in the Great Lakes region must be multi-jurisdictional. The findings of this workshop should be presented to the Great Lakes Panel for Aquatic Nuisance Species (Great Lakes Commission, Ann Arbor, Michigan). This multi-jurisdictional and multi-stakeholder group may be in the best position to keep the process moving forward. In particular, it is recommended that the Panel oversee a decision analysis process that includes outreach and policy components.

Buy-in at the federal level in the U.S. is also needed. Workshop findings should be presented to the Aquatic Nuisance Species Task Force, an intergovernmental organization in the U.S. dedicated to preventing and controlling aquatic nuisance species. A recommendation to participate in the decision analysis process described above should also be presented to the Task Force, along with a list of resources (both US and Canadian) that have decision analysis capability. A list of resources capable of fulfilling the other primary science needs should also be developed and presented to the Task Force.

Decision analysis is a critical and cost-effective tool for improving the state of science around VHS and other emerging aquatic diseases; it will help clarify management and research priorities. An existing decision analysis by the Canada Fish Inspection Agency should be critically reviewed. Decision analysis expertise also exists at the University of Michigan (Quantitative Fisheries Center), the Ontario Ministry of Natural Resources, the Canadian Aquatic Invasive Species Network (Great Lakes Institute for Environmental Research, Windsor), and ESSA Technologies Ltd.

It is important to build on existing knowledge of VHS and other aquatic diseases (e.g., existing databases). There is a need to identify and document the work that is currently under way or has been completed and to focus on filling identified gaps in this knowledge. The Council of Great Lakes Research Manager's Great Lakes St. Lawrence Research Inventory (http://ri.ijc.org) could be used for this purpose.

A coordinated plan to follow up on this workshop and to seek funding for the priority actions identified needs to be developed. It will be important to ensure that new financial appropriations are applied where they will have the most impact; this will require some flexibility, so funds can be directed to focus on new pathogens as needed. Establishing links with and combining efforts with other jurisdictions working on invasive aquatic species (e.g., the Mississippi Interstate Cooperative Resource Association and the Great Lakes Regional Research Information Network) is also recommended.

It is important to explain to stakeholders and funders why VHS and other emerging aquatic diseases must be managed, and what needs to be done to achieve that objective. The message needs to be consistent, and sent to people at as many levels and through as many channels as possible. For example, a line of communication should be established with Great Lakes basin user groups. A political advocate / champion for the VHS issue should be identified. Additionally, a VHS/emerging diseases Ad Hoc Committee should be struck to work with the Great Lakes Fishery Commission's Fish Health Committee.

Participants also agreed that it would be valuable to maintain the engagement of the participants at the workshop. Each agency should have one contact point to streamline communications.

7. References

USGS. 2008. Molecular Epidemiology of Viral Hemorrhagic Septicemia Virus in the Great Lakes Region. URL: http://wfrc.usgs.gov/pubs/factsheetpdf/vhsfs2011108.pdf. Accessed March 27, 2008.

Appendix A: Workshop Participants

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Appendix B: Workshop Agenda

Developing Science Strategies to Address VHS and Similar Emerging Diseases in the Great Lakes Basin.

March 12 & 13, 2008

Environment Canada – Dufferin Campus, Toronto ON

Workshop Agenda

Wednesday March 12

9:00 – 9:35AM	Welcome and Introductions	
9:35 – 10:25AM	Status of VHS in the Great Lakes Basin	
	• Known Distribution and Outbreaks	Beth Wright
	• Genetics	Kyle Garver
10:25 – 10:40AM	Break	
10:40 – 11:25AM	Status of VHS in the Great Lakes Basin – continued	
	• Emerging and Re-surging Diseases of the Great Lakes: Etiology and Challenges	Mohamed Faisal
	• Summary of Current Management Activities	Brian Grantham
11:25 – 12:15PM	Results of Recent Meetings	
	• GSI/GLPF Study of non-native microbes	Jim Casey
	• CFIA Biosecurity Workshop	Grace Karreman
	• Cleveland Workshop on Ballast Water	Phil Moy
12:15 – 1:15PM	Lunch	
1:15 – 1:25PM	Charge to Sub-Groups	
1:25 – 3:00PM	Sub-Group Discussions	
	1. Science & Infrastructure Gaps	
	2. Management Needs	
3:00 – 3:20PM	Break	
3:20 – 3:50PM	Sub-Group Discussions – continued	
3:50 – 4:30PM	Sub-Group Reports to Plenary	
4:30 – 5:00PM	Sub-Group Discussions	
	1. Prioritize Science Needs	
	2. Prioritize Management Needs	

Thursday March 13

8:30 – 9:45AM	Sub-Group Discussions - continued
9:45 – 10:15AM	Sub-Group Reports to Plenary
10:15 – 10:40AM	Break
10:40 – 11:45AM	Moving Forward (Plenary Discussion)
	• opportunities for collaboration
	• opportunities for sharing capabilities / infrastructure
	• approaches for addressing high priority needs
	• possible funding sources
11:45 – 12:00PM	Next Steps

Sponsored by:
International Joint Commission – Council of Great Lakes Research Managers, Ontario Ministry of Natural Resources – Canada Ontario Agreement, Great Lakes Fishery Commission, Environment Canada, and the Great Lakes Regional Research Information Network (www.GLRRIN.info)