Great Lakes Basinwide Botulism Coordination Workshop

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June 24- 25, 2008

Detroit Metro Airport Marriott Hotel
Romulus, MI

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Great Lakes Basinwide Botulism Coordination Workshop
Final Report

June 24-25, 2008

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Workshop Overview

The Great Lakes, which include Lakes Erie, Huron, Michigan, Ontario, and Superior, make up the largest freshwater system in the world. They cover more than 94,000 square miles and provide about 20 percent of the world's surface freshwater supply. Impacts to this valuable resource have the potential to affect industry, public health, fish and wildlife populations, and the ecosystem at every level.

Botulism is a current cause for concern in the ecological health of this unique region, since it is implicated in numerous fish and bird mortalities. The *botulinum* neurotoxin is secreted during normal metabolism of *Clostridium botulinum.* This spore forming bacteria is associated with a paralytic illness in humans caused by improperly canned foods; however, it also occurs naturally in the soils as well as the sediments of lakes and rivers. The spores can survive for years until conditions optimal for vegetative growth prevail—generally including an oxygen-depleted, nutrient-rich environment. Various strains of the *C. botulinum* bacteria are able to produce seven types of toxins (types A-G). In the Great Lakes area, Types A and B are most commonly implicated in human botulism cases, while Types C, D, and E cause illness in mammals, amphibians, birds, and fish brought on by food web interactions. Type E is the strain implicated in the current Great Lakes region outbreaks.

The avian form of botulism has been recognized as a cause of paralysis and mortality in bird populations since the turn of the twentieth century. Suspected incidences of Type E botulism in the Great Lakes began to appear in the 1960s with documented mortalities in 1963. Isolated botulism outbreaks occurred over the next several decades, but beginning in 1998, yearly die-offs exhibited alarming severity in the lower Great Lakes and appeared again in Lake Michigan in 2006. Although several hypotheses exist, the exact mechanism causing this increased resurgence remains unknown.

With the growing threat of Type E botulism and its noticeable effects on a wide range of species (some already endangered and unnecessary losses of which cannot be afforded), the need was apparent for action to respond to this threat plaguing the precious Great Lakes ecosystem. The Great Lakes Basinwide Botulism Coordination Workshop was planned by U.S. EPA's Great Lakes National Program Office and Sea Grant, with support provided by the Great Lakes Interagency Task Force Regional Work Group, to identify management actions for controlling botulism that could potentially mitigate the impacts of these outbreaks. The workshop was created as an invitational meeting of leading botulism researchers and agency representatives in order to foster collaboration, increase awareness, and generate new ideas. The aim was for participants at this meeting to develop and assess possible management actions drawing from current knowledge of the botulism issue in the Great Lakes, while building from the information discussed during Sea Grant's prior workshops; these prior workshops significantly enhanced similar Great Lakes botulism research efforts, and have also enhanced public outreach and education, understanding of the local ecosystems, efficiency in case identification, and delineations of roles of invasive and native species.

Although additional attention to the problem of botulism in the Great Lakes is required, the botulism workshops have and continue to (1) refocus researchers and local, state, and federal agencies on the problem; and (2) redirect efforts as needed and where recommended as appropriate.

The purpose of this year's coordination workshop was to jump-start development of botulism management and control options by convening top botulism researchers to share current knowledge and to brainstorm with key state and federal agency representatives. The agenda included discussions of relevant research, lessons learned from recent outbreaks, potential mitigation strategies, and ideas for collaboration.

Workshop Proceedings

The 2008 Great Lakes Basinwide Botulism Coordination Workshop was held June 24-25, 2008, in Detroit, Michigan. This workshop was supported by the Great Lakes Interagency Task Force Regional Working Group, the U.S. EPA's Great Lakes National Program Office, and Sea Grant.

The two-day workshop consisted of presentations, panels, and facilitated discussions. Topics included the history of botulism outbreaks, overviews of current research and existing management practices, public outreach and education, needs, and recommendations. Presenters and panelists were provided with the following suggested guidance in the creation of their presentations in order to ensure adequate coverage of the topic:

Speaker Guidance

- Overview of state of knowledge/update on current activities.
- Identify any known or suspected linkages to aquatic invasive species and/or breaking the vector as it relates to speaker's research.
- Identify research/resource needs (financial, informational, staff, etc.).
- Identify any management outcomes that may result from research.
- Identify how research and outcomes are currently communicated or coordinated with other researchers or management agencies.

Panelist Guidance

- Overview of botulism in panelist's state or province
- Communication and coordination
- Identification of needs

An overview and general abstracts of the presentations for each day of the workshop are included below; complete presentations are provided in Appendix B.

Day 1, Tuesday, June 24th

The workshop opened with a welcome address from Bill Bolen and Beth Murphy, both of the U.S. EPA's Great Lakes National Program Office, before technical sessions began.

Mechanism and History of Type E Botulism in the Great Lakes Basin

Eric Obert, Pennsylvania Sea Grant Extension, and Thomas Cooley, Michigan Department of Natural Resources – Wildlife Disease Laboratory, delivered the first set of technical presentations on the mechanism and history of botulism in the Great Lakes.

> *Mechanism and History of Type E Botulism in the Lower Great Lakes*
> *Eric Obert, Director*
> *Pennsylvania Sea Grant Extension*
> *Clostridium botulinum*, a spore forming bacteria, is known to cause avian botulism and has been known as a major cause of mortality among migratory birds since the early 1900s. Spores of Types C and E are found naturally in anaerobic habitats, especially that of aquatic sediments, although Type C is generally found in the western United States. Type E botulism is a major cause for concern in the Great Lakes region for fish-eating birds, as it has been increasing in

recent years. Progressive symptoms of both Types C and E in birds include inability to fly, paralysis of limbs, paralysis of the eyelid and neck (often leading to drowning of water birds), and respiratory failure. The bacterium thrives in the conditions of a decaying carcass releasing *botulinum* toxin that may be ingested by maggots, which may be ingested by other predatory birds. The first reports of a large-scale outbreak of Type E botulism appeared in 1998 in Lake Erie, when many dead channel catfish washed up on Presque Isle Beaches following a warm winter with record low snowfalls. In the months following this incident, many sick and dying gulls were noted in the area and along the Canadian shoreline. This trend has continued, and today, Type E botulism has been found in fish and water birds in each of the Great Lakes. Commonly, Type E botulism outbreaks are episodic, correlating with seasons; they appear under conditions of low lake levels, increased presence of invasive species, and *Cladophora* algal blooms.

Type E Botulism in Michigan: A Historical Review
Thomas Cooley, Wildlife Disease Biologist
Michigan Department of Natural Resources
This presentation included a comprehensive timeline of events highlighting the outbreaks of Type E botulism throughout Michigan. The first waterfowl die-off attributed to botulism in Michigan occurred in 1941 in the Lake Erie marshes near Monroe, MI. Type C *botulinum* toxin was identified in nearly 1,000 dead ducks and shorebirds. The first Type E botulism outbreak in waterfowl in North America occurred in 1963. Prior to this event, Type E botulism had not been identified in wild birds. An estimated 7,720 birds died during this outbreak, which extended nearly the entire length of the Lake Michigan shoreline of the Lower Peninsula. Significant die-off of water birds and fish also occurred in 1964, 1965, 1976, 1981, 1983, 2006, and 2007. These events have occurred on the shorelines of each of the Great Lakes in Michigan. A link has been proposed to *Cladophora* algal blooms that have occurred throughout the Great Lakes which can produce toxins similar to that of Type E botulism; however, further studies are needed to delineate suspected links.

Questions and comments following these presentations highlighted the following:

- Fish mortality does not necessarily correlate with bird mortality and may result from different cause(s); toxins can be affected by dialysis; and with proper supportive care, birds are able to recover from botulism.

- Are the recent botulism outbreaks linked to the *Cladophora* algal blooms? Although further research is needed to delineate the link between zebra and quagga mussels and botulism outbreaks, it does not appear that these mussels are susceptible to the toxin because they lack a true nervous system.

- Circulation models on Lake Michigan need to be completed to correlate with bird mortality patterns.

Food Web and Invasive Species Links

The second topic of discussion for this day regarded local food webs and invasive species. Presenters from this panel were Harvey Bootsma, University of Wisconsin, Milwaukee; Lynda Corkum, University of Windsor; and Dan Molloy, New York State Museum. Dr. Bootsma proposed, through benthic studies, possible food web interactions that end in avian botulism cases in which non-native invasive species—specifically dreissinid mussels and round gobies—play a major role in transmission. He also suggested

that the decay of material following large *Cladophora* blooms may contribute by depleting dissolved oxygen and creating a nutrient-rich environment for *C. botulinum* growth.

> *Algae, Mussels, and Botulism in Lake Michigan*
> *Harvey Bootsma, Great Lakes WATER Institute*
> *University of Wisconsin, Milwaukee*
> Botulism outbreaks are of increasing concern in the Great Lakes region due to the increased mortality of indigenous waterfowl and fish species. One recently proposed mechanism for Great Lakes botulism outbreaks suggests that excessive growth of the filamentous green algae, *Cladophora* sp., creates optimal conditions for increased *C. botulinum* growth by promoting high organic / low oxygen conditions in the benthos. Invasive dreissenid mussels in the Great Lakes contribute to this cycle by filtering the bacteria out of the water and sediment. When the invasive round goby and other bottom dwelling fish eat dreissenids, they ingest the bacterial released Type E *botulinum* toxin. The toxin may then be transferred to predatory fish and other birds that consume these gobies. This presentation described data and modeling results that indicate the potential for anoxia in mussel beds, based on mussel respiration rates and near-bottom turbulence. Also included in the presentation were stable isotope data indicating that gobies do not necessarily rely on mussels as a major food source, suggesting there may be other trophic pathways through which the toxin is ingested by gobies. Possible next steps in understanding transmission routes are: further studies of nearshore food web dynamics, better data on benthic dissolved oxygen concentrations in mussel / *Cladophora* beds, and studies comparing the western and eastern shores of Lake Michigan to account for a noticeably smaller incidence of botulism on the western shores of the lake.

Mr. Bootsma concluded his presentation by asserting the following needs:

- A better understanding of benthic oxygen dynamics, including the roles of *Cladophora,* mussels and turbulence
- A better understanding of the near-shore food web
- Studies on conditions along the western shores of Lake Michigan—apparently, botulism outbreaks are not occurring there as elsewhere in the Great Lakes

Dr. Corkum presented a possible control strategy for the round goby (*Neogobius melanostomus)*, a highly prolific invasive species in the Great Lakes that may be contributing to the increased number of botulism outbreaks. This strategy involves a pheromone trap to catch both reproductive and non-reproductive females, both of which appear to be attracted to the male-secreted sex pheromone.

> *Progress Towards a Control Strategy for Round Goby*, Neogobius melanostomus
> *Lynda Corkum, Associate dean of Science*
> *University of Windsor, Department of Biological Sciences*
> The round goby (*Neogobius melanostromus)* is an invasive species of bottom dwelling fish first discovered in the Great Lakes in 1990 in the St. Claire River. The round goby originates in the Black and Caspian Seas of Eastern Europe and is believed to have arrived in the ballast water of vessels entering the Great Lakes. Round gobies have been able to rapidly proliferate throughout the Great Lakes because they can spawn several times in one season and are known to aggressively protect their nests and surrounding waters. They are potentially impacting the local ecosystems through predation of the eggs and young of native species, competition for food and habitat, predation on native benthos, and vector mediation of avian botulism. Eradication of the round goby has been suggested, but the feasibility of this is unknown. Suppression may be the

answer to locally deplete the density in critical habitats. To ensure effective population suppression, the breeding habits and olfactory responses to pheromones of reproductive females and males were studied. It was discovered that a pheromone release in the urine of reproductive males can attract both reproductive and non-reproductive females. The next step will be to identify the key steroid in order to develop an effective pheromone trap of reproductive females that will lead to selective and benign control.

Dan Molloy followed with a presentation regarding another highly invasive species, *Dreissena* spp., which have become a burden in the Great Lakes and may play a role in increasing botulism outbreaks. He suggested a highly specific microorganism, *Pseudomonas fluorescens* strain CL145A, as a more efficient, safe, and environmentally friendly alternative method for controlling zebra mussels. The current method of control of these mussels in pipes in infested facilities involves primarily chlorine.

Biological Control of Zebra and Quagga Mussels: Potential Use of Novel Microbial Agent
Daniel P. Molloy, Director
Cambridge Field Research Laboratory, New York State Museum
Dreissena spp., zebra and quagga mussels, are invasive and extremely prolific invaders of the waters of the Great Lakes. The primary method for controlling these mussels in pipes within infested facilities is chlorine application over weeks or months. This results in carcinogen (trihalomethane and dioxin) formation in receiving waters, such as lakes and rivers. The use of a selective novel microbial agent against these invasive mussels could serve as a safe, effective, and environmentally benign alternative. In the 1980s Molloy's lab assisted in the commercial development of the bacterium, *Bacillus thuringiensis israelensis,* for control of another aquatic pest, black fly larvae, and this encouraged him to investigate a similar approach to deal with zebra and quagga mussels. A large-scale laboratory screening trial at his lab revealed that a naturally occurring bacterium, *Pseudomonas fluorescens* strain CL145A, was highly lethal to these mussels because of a natural byproduct within its cells, and lab trials showed high kill rates regardless of mussel size. In contrast, at dosages resulting in high mussel mortality, no bacteria-induced mortality was recorded among any of the non-target species tested, including native bivalves. Because mussel death results from a lethal, yet selective, natural compound within the bacterial cells, mussels die from intoxication, rather than infection. Thus, dead bacterial cells kill the mussels as well as live cells do. Techniques have already been developed to kill the bacterial cells while still insuring their lethality to the mussels. Testing to date has been for control of these mussels in pipes. Future studies will test the efficacy of treatments in open water environments, and thus assess whether this bacterium could be used to control dreissenids in lakes. If successful and should dreissenids be clearly shown to play a role in botulism outbreaks, this bacterium might be useful to control these mussels in areas where these outbreaks are occurring.

Comments from this presentation included suggestions to look into how mussel die-offs affect botulism growth, and the possible use of a widespread method of zebra mussel eradication.

PCR Assay

Following a discussion of the morning presentations and a short break, the sessions continued with Rod Getchell from Cornell University, who presented his work on advances in the area of botulism research. In order to increase efficiency and quality of research and sample diagnosis, a molecular polymerase chain reaction (PCR) assay was developed. The sample DNA is isolated from tissue and then a multi-step procedure will simultaneously detect and quantify the presence of the botulism type E toxin gene (bontE)

per gram of tissue. This assay is a novel approach in the field of botulism research. Previous testing methods included ELISA, mouse bioassays, and sample culture, all of which add time, expense, and error.

A Quantitative PCR Assay for Clostridium botulinum *Type E*
Rod Getchell, Research Associate
Cornell University, Department of Microbiology and Immunology
Since 1999, the number and extent of recurring botulism outbreaks have increased. In order to (1) learn more about the cause of botulism emergence and spread throughout the Great Lakes and (2) increase awareness of Type E botulism in the fish-eating birds of the Great Lakes region, need was evident for a faster, safer, and more affordable method to screen samples for presence of the toxin. A molecular assay was designed to quickly and efficiently quantify *C. botulinum* Type E in each sample. This would facilitate understanding of species susceptibility to *C. botulinum* and help identify fish carrying Type E toxin that are associated with waterfowl mortality. The procedure involves determining DNA concentrations in fish or bird intestinal contents and livers. A Polymerase Chain Reaction (PCR) assay then establishes whether the *C. botulinum* Type E toxin gene is present. To further delineate concentration, this material can be isolated and run through a quantitative (real-time) PCR (QPCR) to provide numbers of *C. botulinum* Type E per gram of tissue. Thus far, interassay repeatability testing is showing accurate results. Plasmid standard creation is underway to further validate results. Current activities related to the botulism bioassay include testing cultured fish with QPCR during known botulism outbreaks, providing plasmid standards and assistance for diagnostic work in this area, and continuing validation work in the molecular assay.

Impacts to Fish

In the next session, Rich Moccia, University of Guelph, and Gary Whelan, Michigan Department of Natural Resources, presented on impacts to the fish populations from recent botulism outbreaks. Dr. Moccia's group discussed the ecotoxicology and epidemiology of a botulism outbreak on fish.

Ecotoxicology of Botulinum Poisoning in Great Lakes Fish and Birds
Richard D. Moccia, Interim Associate Vice-President (Research) Agri-food and Partnerships
University of Guelph, Department of Animal and Poultry Science
Since 1999, tens of thousands of mortalities of fish-eating water birds throughout the Great Lakes region have been attributed to increased outbreaks of Type E botulism. Among the most highly affected are loons, mergansers, grebes, ducks, and gulls. Delineation of the toxin pathway in birds that feed exclusively on live fish continues. Correlation between the fish botulism outbreaks and the avian mortality patterns is somewhat uncertain. This study regarding the intoxication pathway indicated the following:

- Each species of fish tested showed a unique set of clinical signs.
- Intoxication may cause physical changes that create a selective prey situation for larger fish and birds.
- Of the species tested, perch seemed highly resistant to the effects of Type E toxin, while round goby were especially susceptible.
- *C. botulinum* spores were unable to germinate in rainbow trout.
- Significance to human health of fish carrying the toxin is low.

The main conclusion is that live fish can be a significant vector for toxin transfer through trophic levels. Further research endeavors and agency programs should include expansion of the fish

information database, expansion of public awareness, establishment of a surveillance program, and creation of a centralized database.

During the presentation it was noted that risk to human health from fish carrying the toxin is unlikely; however, research shows that fish may be an important vector to the transmission of botulism through trophic levels. Dr. Moccia recommended that the next steps in research should include expanding a searchable fish database and researching the contribution of mudpuppies in the transmission cycle. The results could lead to rallied public support, establishment of an epidemiologic surveillance program, creation of an affected bird retrieval and diagnosis program, and a centralized database and records program.

Gary Whelan discussed the implications of botulism in fish species. He noted the effects on the lake sturgeon populations in the Great Lakes and that gobies have become their preferred prey. He considers botulism an ecosystem symptom requiring much more attention than traditional disease control, and believes that fish population density in a given area may influence a botulism outbreak. Benthification and looking further into the roles of the current aquatic invasive species are key processes that must be addressed to adequately respond to this ecosystem problem.

Implication of Type E Botulism on Fish Populations
Gary Whelan
Michigan Department of Natural Resources, Fisheries Division
Undoubtedly, increased botulism outbreaks within the Great Lakes region are affecting many key species in local ecosystems. Any mortality in the lake sturgeon population is of concern. Already a threatened species sensitive to local ecosystem changes, lake sturgeon are also susceptible to botulism infections during outbreaks. Other key species affected by Type E botulism infection include large and smallmouth bass, yellow perch, mudpuppies, channel catfish, carp, and round gobies. Evidence suggests that this is a propagating epidemic, and that more than traditional disease control and response strategies will be required to decrease future outbreaks. It is suggested that botulism is more a symptom of ecosystem disruption and should be treated as such. To treat this ecosystem symptom, several conditions must be addressed, including benthification of the lake bottom, the presence of aquatic invasive species, and human ecosystem interaction.

Moderator Amy DeWeerd, U.S. Fish and Wildlife Service (USFWS), welcomed attendees back from lunch for the afternoon sessions, the first of which addressed the effects on bird populations in and around the Great Lakes region.

Impacts to Birds

Chip Weseloh of the Canadian Wildlife Service discussed colonial waterbird species in Eastern Lake Ontario. He has evaluated the overall population health of several bird species by examining several conditions in their habitats and assessing how the recent outbreaks of botulism have affected them.

Impacts of Exposure to Type E Botulism on the Health of Colonial Waterbird Populations in Eastern Lake Ontario
Chip Weseloh, Wildlife Toxicology
Canadian Wildlife Serve, Environment Canada
Since 1999, Type E botulism has caused an estimated 70,000 waterbird deaths in and around the Great Lakes. Although botulism is a naturally occurring bacterium in lake and river sediments,

its released toxins are causing increased mortality and outbreaks in the region. This recent study was conducted to answer the following questions.

- Given current conditions, will botulism outbreaks occur regularly?
- What is the relationship between botulism-induced mortality and waterbird population health?

These questions and others were answered through surveys of mortality data of colonial waterbirds associated with Type E botulism outbreaks in eastern Lake Ontario. Study results indicate a seasonal mortality distribution with botulism-associated deaths. Populations of herring and great black-backed gulls are declining in the area as the incidence of botulism increases. Further studies should be conducted to monitor the health of indicator species such as the herring gull, to evaluate the role of botulism vs. other stressors on population decline, and to identify the routes of exposure to Type E botulism.

Jack Dingledine, USFWS, looked at one species of shorebird, the piping plover—a federally listed endangered species susceptible to the recent botulism outbreaks. He has studied their migratory, dietary, and reproductive habits over the past several years and suggested that the decreased distribution of the plover could increase their susceptibility to outbreaks in specific areas. Evidence indicates that early season outbreaks have affected reproductively active adults and chicks.

The Great Lakes Piping Plover and the Threat of Type E Botulism
Jack Dingledine, Region 3 Piping Plover Coordinator
U.S. Fish and Wildlife Service
The piping plover has been considered an endangered species in the Great Lakes regions since 1986, when the species reached a scant 17 remaining breeding pairs due to hunting, habitat loss, and recent Type E botulism outbreaks. After piping plovers arrive in the region in early spring to nest and feed along the beaches of the Great Lakes, they are very susceptible to botulism infection. In 2007, 63 breeding pairs of the piping plover were present—seemingly concentrated along the northern Lake Michigan shoreline where outbreaks of botulism have been known to occur. Studies on the piping plover have found that they regularly ingest carrion-associated maggots known to carry Type E botulism. Early-season outbreaks of disease impact reproductively active adults and chicks. The decrease in the population increases the potential impact of a major outbreak of botulism on the remaining population.

Mr. Dingledine made the following recommendations during his presentation:

- Conduct daily patrols of the piping plover nesting areas to note potential risks of outbreak and to remove and bury carcasses.
- Investigate the feasibility of grooming beaches where *Cladophora* mats are present.
- Evaluate the feasibility of administering anti-toxin to sick plovers or other species to increase survivability.

Education and Outreach Efforts

The second presentations of the afternoon by Helen Domske, New York Sea Grant, and Mark Breederland, Michigan Sea Grant, highlighted current and past education and outreach efforts in the Great Lakes Region to increase awareness of the problem. Efforts currently include utilizing media outlets to spark public attention and increase awareness. Education programs also are underway aimed at local professional and sport fishermen to train them in spotting and understanding the situation. Several related actions were presented, including the development of a network of experts; SOPs for reporting, sampling, and analysis; identification of potential funding agencies; universal disposal guidelines that address public concerns; and conducting surveys to measure the perceived impact.

Botulism in the Lower Great Lakes: Education and Outreach Efforts
Helen M. Domske, Coastal Education Specialist and Sr. Extension Associate
New York Sea Grant
Concern has grown regarding recent botulism outbreaks causing die-offs of fish and waterfowl. These outbreaks began in 1999 in the Lake Erie basin and have since spread throughout each of the Great Lakes. Area residents, anglers, and environmentalists sought assistance and information to deal with the problem. Early workshops were held to develop research priorities for addressing the outbreaks, as well to resolve questions and concerns of the key stakeholders on topics such as links to human health, fish carrying the toxin, native or invasive bacteria in the area, safety in procedures to handle sick or dead fish or birds, and conditions that may have sparked recent outbreaks. Early research endeavors looked at the following areas: (1) mussels and other potential toxin sources, (2) better diagnostics, (3) population effects, (4) spore distribution, (5) synergistic effects of contributing factors to increased outbreak incidence, (6) local food web interactions, and (7) human health implications. Impressive progress has been evident in many of these areas, and researchers continue to advance understanding of outbreak control. Current outreach actions include widely disseminated factsheets, newsletter articles, increased public awareness through media outlets, and information guides and presentations given to anglers and hunters.

Botulism Education and Outreach in the Upper Great Lakes
Mark Breederland, Extension Educator
Michigan Sea Grant Extension, Traverse City, Michigan

Outbreaks of Type E botulism in 2006 and 2007 and the subsequent public outcry and press coverage sparked an increased awareness in the upper Great Lakes region and calls for action. Dead or paralyzed fish eating birds were appearing along the shorelines in the hundreds. Many educational presentations occurred, and web pages were created in an effort to disseminate information to the local populations. Currently, efforts are underway to boost public awareness and coordinate efforts of Sea Grant and state, federal, tribal agencies, non-governmental organizations (NGO), and academic institutions to attack this problem. Some current issues include carcass disposal, bioassay sampling, increased ecological research needs, lakeshore size, consistent messaging in addressing the public, and volunteer activities.

During discussion, questions arose as to whether states have similar programs for West Nile Reporting for shoreline birds and whether states are utilizing non-profit groups to collect reports.

State/Provincial Panel

A state/provincial panel then shared lessons learned, anticipated projects, and identified needs in dealing with the issue of botulism outbreaks.

Lessons Learned, Anticipated Projects, and Needs Identification
Gary Whelan – Michigan Department of Natural Resources
Julie Langenberg – Wisconsin Department of Natural Resources
Ken Roblee – New York Department of Environmental Conservation
John Dungavell – Ontario Ministry of Natural Resources
Roy Domazlicky – Illinois Department of Natural Resources
A panel of representatives of state and provincial agencies from Michigan, Wisconsin, New York, Ontario, and Illinois discussed an overview of botulism in their area, communication and coordination, and needs identification as well as lessons learned and anticipated projects for their respective agencies. Highlights included Type E botulism studies specific to common loons in Wisconsin, mudpuppies as a possible part of the vector in New York, and a mortality event response plan in place in Illinois. Wisconsin has plans for increased surveillance programs beginning with the 2008 season. Ontario highlighted beach surveys completed throughout 2007 and has plans for programs to increase staff awareness, enhance collaborations to assess population impacts, and increase research capacity where funding allows.

The following key considerations emerged:

- Dead fish and bird cases should be investigated with due diligence and not assumed to have resulted from botulism without proper testing.

- A current push is underway to pool resources across state programs in order to increase efficiency.

- Experience indicates that most birds appear to die quickly after exposure and that herring gull chicks show some resistance to botulism.

Federal Panel

The final panel of the first day was the federal panel to share lessons learned, anticipated projects, and needs assessments.

Lessons Learned, Anticipated Projects, and Needs Identification
Stephen Riley – U.S. Geological Survey, Great Lakes Fishery Commission
Mike Hoff – U.S. Fish and Wildlife Service
David Blehert – U.S. Geological Survey, National Wildlife Health Center
Ken Hyde – National Park Service
Chip Weseloh – Canadian Wildlife Service, Environment Canada
Tommy Parker – U.S. Forest Service
A panel of representatives from federal agencies including the U.S. Geological Survey, U.S. Fish and Wildlife Service, National Park Service, Environment Canada, and U.S. Forest Service discussed an overview of botulism in their area, communication and coordination, and needs identification as well as lessons learned and anticipated projects for their respective agencies. Highlights included the support of research on disease in Great Lakes fish populations through the Great Lakes Fishery Research Program (visit www.glfc.org), potential for impacts in the Mississippi River basin, an upcoming botulism meeting coordinated by Bird Studies Canada as a follow-up to this workshop, and a mouse toxin neutralization test for botulism. Present and future concerns of the U.S. Fish and Wildlife Service are the population levels of already endangered species such as the piping plover, lake sturgeon, pallid sturgeon, bald eagle, common loon, and native mussel species. As a result, they are instituting recovery plans for some of these species

of concern and more aggressive approaches to zebra and quagga mussel control that includes testing of a biobullet targeted at these mussels. The USGS highlighted future research needs in the field including, the development of an in vitro, high throughput BoNT/E-specific assay, identification of toxic food web components leading to type E intoxication, prediction of population effects, and a systematic sampling approach, some of which have already begun.

The following key points were noted:

- It was suggested that the National Oceanic and Atmospheric Administration (NOAA) lake circulation models could help in estimating the time for carcasses to flow from Green Bay to the Michigan Shore.

- To calm fears about inland bodies of waters and Type E botulism, it was stressed that these waters seem to be more susceptible to Type C botulism.

- An inter-disciplinary approach to future research should focus on the relationships among Type E botulism, *Cladophora*, gobies, and dressenids.

- Special attention should be paid to botulism hotspots and determination of conditions around them.

- It would be important to compare the mortalities of Great Lakes waterbirds to bird mortalities in other similar environments, for example Allegheny National Forest.

- National resource agencies are cooperating with the National Fish and Wildlife Foundation (NFWF) to pool resources and develop a unified approach to deal with the issue of botulism in the Great Lakes.

Day 2, Wednesday, June 25th

Day 2 of the workshop opened with a welcome address from Beth Murphy, Great Lakes National Program Office, before the only presentation of the day. Additionally, some brief discussion was had regarding whether a research plan similar to the Saginaw Bay Plan should be designed to focus on: completing the botulism pathway chain, using Beach Act dollars to fund research and program endeavors, and conducting risk assessments on the area. Addressing episodic and spatial concerns also was suggested.

Human Health

Michelle Watters, Agency for Toxic Substances and Disease Registry (ATSDR), addressed human health risks and Type E botulism. Although Type E botulism does not generally result in human cases of wound botulism, handling fish or bird carcasses carefully is important where potential for botulism intoxication exists. Proper freezing, preparation, and cooking temperatures and times are essential to prevent foodborne cases of Type E botulism. She also highlighted the need for a faster, cheaper assay to detect the toxin directly.

Type E Botulism and Human Health
Michelle Watters, Medical Officer, Division of Regional Operations

Agency for Toxic Substances and Disease Registry
While the level of botulism in fish tissue is of concern for human consumption, the cooking preparation methods are of most concern as appropriate cooking temperature and time destroy the toxin. This presentation discussed general information on botulism related to human illness, particularly foodborne botulism as well as food safety tips. Of the seven types of botulism (Type A through G), types A, B, E, and F are associated with human disease. There are approximately 145 cases of botulism per year, and 15 percent of them are foodborne. Botulism is not transmissible from person to person. Symptoms of botulism generally begin 18 to 36 hours after eating a contaminated food, but they can occur as early as 6 hours or as late as 10 days. Symptoms typically include alertness without fever, double-vision, drooping eyelids, eye muscle palsies, difficulty swallowing and talking, dry mouth, symmetrical paralysis, and respiratory failure. While the current mortality rate is 3 to 5 percent, it can take weeks to months to recover. Properly cooking food and keeping cooking surfaces clean can greatly reduce the risk of food borne botulism. The bacterium is destroyed by cooking, does not grow in temperatures above 118°F, and is killed by chlorine. The spores can survive boiling up to 3 to 4 hours but are readily killed by chlorine. Maintaining temperatures above 140°F will prevent outgrowth. In addition, the spores are more heat resistant at higher pH, higher fat content, lower salt, lower sugar content, and lower oxygen. In addition, preservatives and other inhibitory substances will restrict growth.

Some food safety tips highlighted during the presentation include the following:

- Wash hands, containers, and food before preparing food
- Do not use plastic, glass, or sealed plastic bags for fermenting
- Use salt to preserve dried fish and to discourage growth of *C. botulinum*
- Ferment food at a cold temperature, ideally below 37°F
- Cook food before eating it (boil greater than 10 minutes)
- Do not feed identified sources of botulism spores (e.g., honey) to infants
- When in doubt, throw it out!

Facilitated Discussion

This presentation led to a series of discussions focused on (1) research and resource needs, (2) management actions, and (3) communication and coordination. Main points from each of these discussions are as follows.

<u>Research and Resource Needs</u>
Better understanding of botulism type E in the Great Lakes requires fulfillment of the following research needs:

- Develop a conceptual model (build off of the Great Lakes Fishery Commission (GLFC) work)
    - Tie in different ecosystem components (for example, circulation patterns, environmental factors, geography, etc.)
    - Build off of Coordinated Monitoring Programs (Lake Michigan and water quality sampling planned for 2010)
- Create a suitable control for botulism. Find answers to the following questions:
    - Can this be done without fully understanding the mechanism? How?

  - Can we create botulism as opposed to trying to catch it in the act?
  - Can we remove a suspected part of the vector in an area with known toxin levels?
  - Could we follow an experimental lake approach by implementing doses of botulism to test different control techniques?
- Perform broad correlation studies to examine the cause of outbreaks.
- Investigate pathways for toxin production and dispersal—prioritize these for discussion at future meetings.
- Determine the exact geographic locations of outbreaks, and compare conditions near-shore with those off-shore. Focus research on geographic "hot spots" such as the Sleeping Bear Dunes and Lake Erie. These could be developed into case studies for adaptive management approaches.
- Further explore the benthic environment and exposure pathways, and identify botulism-favorable environments, if possible.
- Determine additional levels of fish toxicity, for example, by measuring gene expression in spores or the toxin itself, if possible.
- Develop baseline data to enable measurement of toxin buildup in bird species. Data could be obtained by taking blood samples from birds before, during, and after outbreaks. The U.S. Department of Agriculture (USDA) could be asked to assist in this effort. Also, determine how to quantify and respond to impacts to specific species such as the piping plover, lake sturgeon, and the common loon.
- Develop better assay procedures for use in the field, particularly a cost-effective, rapid assessment technique to quantify the botulism toxin

Additional factors to consider when planning and conducting research/analysis/modeling projects include analyzing blue-green algae in addition to botulism, and considering factors such as lake-wide drifts, circulation, upwelling events, wind patterns, and timing of outbreaks. NOAA data layers could be used in conjunction with monitoring and outbreak data to help develop physical, chemical, and biological links to develop management options.

Through this discussion, it was proposed that there should be a process for prioritizing research needs:

- Assign top priority to development of a field kit/rapid assessment technique for quantification of the botulism toxin and determine funding and responsibility for development.
- Rank three or four priorities for research to maintain focus.
- Conduct research on parallel paths.

Other aspects discussed include:

- Create a manual of lessons learned, standardized collection and handling procedures, and distribute via listerv.
- Develop lessons learned.
- Increase volunteer action. For example, involve birders in monitoring.

<u>Management Actions</u>

The discussion on management actions included a brainstorming session that focused on the following questions:

- What successful management controls are currently in place?
  - Carcass removal
  - System of painting and counting of carcasses prior to removal
- What additional actions would be useful?
  - Appropriate understanding of state/county permitting and regulations
  - Assessment of alterations to the food chain to break the transmission cycle and its effect on botulism outbreaks
  - Assessment of the affect botulism control might have on other adverse impacts in the Great Lakes
- What novel approaches can be explored to prevent and mitigate further outbreaks?
  - Multi-outcome mitigation approaches
  - Nutrient management
  - *Cladophora*, round goby, and botulism control, including embankment or river control of round gobies
  - Communication with the public to foster support for proposed actions.

Other management issues and concerns raised during the discussion include:

- Decide whether a theoretical or empirical approach (top-down vs. bottom-up) would be more appropriate.
- Determine funding sources. For example, determine if botulism research funding can be linked with funding allotted to species-at-risk issues.
- Garner interest and support to ensure momentum of the projects. For example, tie into existing programs with applicable areas of interest, join agencies with common needs, and affiliate outbreaks with possible human health implications.
- Create different research workgroups, committees, etc., that focus on the topics of modeling, trophic pathways, microbial research, outbreak geography and timing, and population impacts.
- Practice surveillance for a variety of wildlife diseases and mortalities

During the discussion, questions arose as to what issues managers are currently responding. Responses included the following:

- Need for a permitting process to allow people to sample during outbreaks. For example, some states allow for removal and burial.
- Need to demonstrate that botulism has a severe impact on bird populations. For example, Great Lakes loon populations in the Midwest are at risk of extirpation in 3 to 8 years.
  - More information is needed on the basic ecology of loons. For example, determine where loons are breeding. More loons need to be banded for increased monitoring.

  - Aerial reconnaissance or research of old gill-netting records is needed to provide better population counts. Use of radar ornithology could be used to develop bird species-specific information on migration patterns.
  - Risk assessments on populations should be undertaken; especially for species of interest such as lake sturgeon, piping plovers, and common loons
- Increased communication with Council of Great Lakes Governors and Congressional liaison for Great Lakes Regional Collaboration is needed. A demonstration project involving applied science would help to generate support.
- Interested public groups and agencies should be included.

Communication and Coordination

The final discussion focused on communication and coordination—uniformly collecting and counting birds and fish, pooling resources, coordinating with Lakewide Management Plans (LaMPs), preparing an advanced plan for a possible spread of Type E botulism outside the Great Lakes region, and undertaking surveillance for a variety of diseases. The following suggestions for achieving these aims were offered:

- Develop partnership and collaboration opportunities.
  - Foster/build relationships between fishing and birding communities.
  - Organize volunteers among groups, including LaMPs, Marsh Monitoring Program (MMP) team, etc.
- Work on developing a manual of outbreak response best management practices that can be distributed to the public. A working group could be assembled to accomplish this task.
- Develop or participate in existing workshops.
  - Develop a GLFC workshop to tie together biological, chemical, and physical effects.
  - Hold an annual botulism workshop. Possibly co-locate with upcoming State of Lake Michigan Conference.
  - Attend the Beach Association annual meeting in fall (NW Indiana); and the HOW conference.
  - Attend the Flyway Councils (Mississippi and Atlantic), which meet two times per year, possibly addressing the botulism issue; the Councils have begun addressing non-game wildlife regulatory issues.
- Coordinate with other groups and agencies to gather existing data.
  - Develop standards. Some are available online in the U.S. Geological Survey (USGS) *Wildlife Disease Manual*.
  - Coordinate with the International Joint Commission's Research Inventory (www.ri.ijc.org)
  - Use the Great Lakes Regional Research Information Network (GLRRIN) database.
  - A Geographic Information System (GIS) referenced mortality database could be developed in cooperation with databases maintained by the National Wildlife Health Center (NWHC) and Canadian Cooperative Wildlife Health Center (CCWHC)
  - To help grasp the big picture, coordinate research activities with microbiologists, modelers, and benthic ecologists; and with radar studies.

    - Coordinate with state/tribal agency managers.

- Communicate issues to government and agency networks, including the Council of Great Lake Governors, Congressional representatives, LaMPs, Great Lakes Wildlife Commission (similar to GLFC to provide guidance from multiple jurisdictions), and the Midwest Fish & Wildlife health community.

This concluded the workshop activities, and guests adjourned.

Main Issues & Actions Summary

Issues listed below were identified by the attendees of the Great Lakes Basinwide Botulism Coordination Workshop held June 24th and 25th, 2008. The Botulism Coordination Workshop Steering Committee has identified the first three issues as highest priority. It is the consensus of the Steering Committee that addressing these first three issues is necessary to facilitate success of the other actions.

Issue 1: Establish a coordinating body to facilitate information exchange, outreach, and resource identification.

Action: Build on initial contacts made through the Botulism Coordination Workshop by establishing a multi-agency/stakeholder Great Lakes Botulism Coordination Network. Take advantage of existing meeting opportunities to bring workshop attendees and other interested parties together as a group or as specialized sub-committees to continue work surrounding botulism and other wildlife disease issues. Potential meetings include the 2009 State of Lake Michigan Conference in Milwaukee, Wisconsin, the 5-7 November 2008 USGS sponsored Fish Disease Ecology Workshop in Ann Arbor, Michigan, or a joint Bird Studies Canada and Canadian Wildlife Service sponsored botulism follow up workshop.

Issue 2: Centralized Data repository needed.

Action: Coordinate agencies with existing databases, such as the CCWHC and USGS-NWHC, to establish reporting requirements and develop a binational database for wildlife disease information and formalization of a reporting mechanism. Data included in this database would be for multiple species and multiple diseases and would be easily accessible by the public and participating agencies. The unification and expansion of existing databases would allow the Great Lakes to be at the forefront of data collection innovations at minimal cost.

Issue 3: Identify funding sources for high-priority projects.

Action: Botulism Network representatives to approach agencies, working groups, non-profits, or other network members regarding the development and support of key projects (see below). Efforts could include coordination of pooling of resources among Network members.

The issues listed below provide additional examples of individual projects that should be pursued once funding sources have been established.

Issue: Refinement of botulism testing method needed.

Action: Develop and disseminate a rapid and inexpensive field testing method to identify presence and concentration of botulism toxin.

Issue: Predictability of outbreaks is not understood.

Action: Create a multi layer GIS database of mortality information (species, numbers, location, etc.) overlaid with water temperature, weather and lake circulation patterns, Cladophora vegetation mat locations, etc. for use in data analysis projects aimed at predicting outbreaks.

Issue: Novel approaches to managing botulism needed.

Action: Identification of projects in 2 to 3 focus areas for implementation of on the ground cooperative management / control actions, e.g. Sleeping Bear Dunes and Eastern Basin of Lake Erie.

Issue: Population / species level impacts are unknown.

Action: Perform risk assessments on population effects to key species, such as loons and sturgeon, and species levels effects to piping plovers to help elevate the issue of botulism in agency strategic work plans and priority setting.

Issue: Standard operating procedures for carcass collection and disposal, lessons learned, and best management practices needs to be developed.

Action: Create manual for botulism outbreak response management in the Great Lakes Basin. The manual should draw from existing agency guidelines, methods, and fact sheets. In addition to a basic manual, the document should include standard operating procedures for carcass surveillance and reporting, disposal, pick up, and testing (if possible).

These issues and actions have been identified as priorities, but are not easily obtainable in the short term. It is important to note that many of these issues do not stand alone, but are supported by multiple actions addressing related issues.

Issue: Information exchange outside of botulism network.

Action: Communicate issues to congressional representatives, Council of Great Lakes Governors, and others to identify support for Network identified priorities.

Issue: Mechanism of how Type E botulism is transferred through the food chain has not been scientifically proven.

Action: Establish Research Subcommittee under Botulism Coordination Network to assess feasibility of, develop, and implement a research plan to identify how Type E botulism is transferred through the food chain. Identify key investigators (microbiologists, fishery biologists, toxicologists, etc.) and resources.

Appendix A

Workshop Invitation and Agenda

1. Botulism Coordination Workshop Invitation
2. Botulism Coordination Workshop Agenda

Appendix B

Workshop Presentations

1. Botulism Workshop Welcome
2. Mechanism and History of Type E Botulism in the Lower Great Lakes
3. History of Type E Botulism in the Upper Great Lakes
4. Algae, Mussels and Botulism in Lake Michigan
5. Progress Towards a Control Strategy for Round Goby *Neogobius melanostomus*
6. Biological Control of Zebra and Quagga Mussels
7. Botulinum Identification Assay by PCR
8. Ecotoxicology of Botulism Poisoning in Great Lakes' Fish and Birds
9. Implications of Type E Botulism on Fish Populations
10. Impacts of Type E Botulism on Colonial Waterbirds in Eastern Lake Ontario
11. The Great Lakes Piping Plover & the Threat of Type E Botulism
12. Education and Outreach in the Lower Great Lakes
13. Education and Outreach in the Upper Great Lakes
14. Wisconsin DNR Botulism Type E Update
15. New York DEC Botulism Type E Update
16. Ontario MNR Botulism Type E Update
17. Illinois DNR Botulism Type E Update
18. US Geological Survey; Great Lakes Fishery Commission Botulism Type E Update
19. US Fish and Wildlife Service Botulism Type E Update
20. US Geological Survey; National Wildlife Health Center Botulism Type E Update
21. US Forest Service Botulism Type E Update

Appendix C

Workshop Attendee List

1. Botulism Coordination Workshop Attendee List

Appendix D

References of Interest and Additional Materials

1. Botulinum and Human Health
2. Botulism in Lake Erie and Human Health Information
3. Ecology of Type E Botulism Within Dreissenid Mussel Beds
4. FAQ: Botulism in the Great Lakes
5. Type E Botulism in Canada
6. Type E Botulism in Lake Erie: Ecology and Lower Food Web Transfer
7. Inconsistencies in Current Mortality Outbreaks and Previous Type E Botulism Episodes
8. Botulism Links and References of Interest