



## Botulism Outbreaks

### Overall Assessment

**Trend:** Undetermined

**Rationale:** Avian mortality estimates vary greatly due to fluctuations in anthropogenic and environmental factors as well as inconsistencies in data collection and monitoring.

### Lake-by-Lake Assessment

#### Lake Superior

**Trend:** No Change

**Rationale:** Avian mortality estimates due to *Clostridium botulinum* type E are infrequent and small in scale.

#### Lake Michigan

**Trend:** Undetermined

**Rationale:** Avian mortality estimates fluctuate substantially between years during which records were provided.

#### Lake Huron

**Trend:** Undetermined

**Rationale:** Avian mortality estimates were recorded for the United States in the 1960s and either no outbreaks or monitoring has occurred since that time. Canadian estimates exist as of 1998 but are skewed due to insufficient monitoring.

#### Lake Erie

**Trend:** Undetermined

**Rationale:** Avian mortality estimates are consistently in the thousands for the United States during 2000 to 2008, however, no recorded data exists before or after this time frame. Canadian estimates are considerably lower during these same years.

#### Lake Ontario

**Trend:** Undetermined

**Rationale:** Avian mortality estimates for recorded years show numbers in the hundreds and thousands for both the United States and Canada. Existing data is less than 10 years for both countries and monitoring discontinued in 2010 due to budgetary constraints.

### Purpose

- To estimate the number of bird mortalities (by species) in the Great Lakes related to *Clostridium botulinum* type E (avian botulism)
- To infer the effects of invasive species and seasonality on incidence of botulism outbreaks
- The Botulism Outbreaks indicator is used in the Great Lakes indicators suite as an Impact indicator in the Fish and Wildlife top level reporting category and demonstrates how the state of the environment can impact fish and wildlife species

### Ecosystem Objective

The goal is to ultimately reduce or, if possible, eliminate the number of bird, fish and other species mortalities due to the toxin produced by active bacterium spores of *Clostridium botulinum* type E. The favorable conditions through

which the toxin is released and has the potential to move through the food chain, may be the result of various environmental and anthropogenic factors. The Great Lakes Regional Collaboration recommends in the GLRC Strategy to Restore and Protect the Great Lakes that further “research [is needed] to clarify sources and transport of biotoxins (i.e., botulism) through the foodweb.”

This indicator supports the Great Lakes Water Quality Agreement objectives under Annex 1 addressing microbial agents that can affect human health, Annex 2 listing impairment of beneficial uses and Annex 17 delineating “research need to support the achievement of the goals of this Agreement” (GLWQA 1987). Lakewide Management Plan managers also consider outbreaks of Type E botulism to be a significant ongoing and emerging issue and recommend further research.

## **Ecological Condition**

### Background

The type E strain of *Clostridium botulinum* is one of seven different types of botulism bacteria. This strain in particular is responsible for vast mortalities of water birds in the Great Lakes region and in other parts of the United States, generally during the late summer through fall seasons.

Botulism is a neuromuscular disease that can affect a variety of species from invertebrates, amphibians and reptiles to fish and birds. Some species are more susceptible to contracting the toxin than others primarily due to their eating habits. For instance, a diving duck may ingest the botulism toxin through consumption of mussels that have strained the active toxin-producing bacteria from their environment (Fig 1). It is through the food chain that many water birds may then contract botulism, in turn acting as a highly visible indicator of the toxin’s presence in the environment.

Birds that have ingested the toxin will often display outward signs of paralysis before dying, including an inability to fly, to utilize their neck muscles and hold the head erect (known as limberneck) and unresponsive inner eyelids. Generally the birds will drown before reaching shore, however, those that do reach land tend to die soon afterward of respiratory failure (Locke and Friend 1989). The severity of poisoning depends upon the amount of toxin ingested and the species of bird, however the incubation period is generally 12 hours and mortality can occur anytime within a three-day period (personal communication with Steven Riley 2011; Gross 1971).

Dormant spores of the botulism bacterium are naturally abundant in sediments, soils and even the intestinal tracts of live, healthy animals and are endemic to the Great Lakes region. Under certain conditions, namely an anoxic environment with suitable nutrients and favorable temperatures and pH, these dormant spores reach the vegetative or active growth stage and begin producing the botulism toxin (Brand et al. 1988). The spores are resistant to extreme temperatures and desiccations, and so are capable of remaining in the ecosystem for long periods of time (Domske 2003).

### Status of type E botulism

Avian mortalities are currently our primary indicator for the presence of active toxin-producing type E botulism in the environment. Monitoring programs are generally run through state/federal agencies and universities or concerned citizens send in reports. Due to budgetary constraints both past and present as well as differences in data collection procedures and analysis, the number of avian mortalities estimated for each of the Great Lakes is not always representative of the far-ranging effects of the toxin in both Canada and the United States.

Total estimated avian mortalities for U.S. Great Lakes states were aggregated using data from the USGS National

Wildlife Health Center's wildlife mortality database and from the State of Michigan's Department of Natural Resources. Represented are only the years during which data were collected and estimates provided. The data is limited in that it does not encompass all the mortality events that have occurred for both reported and non-reported years. However, despite the limitations in established reporting mechanisms the data illustrates that at least 116,265 avian mortalities have occurred on the United States side since the 1960s (Fig 2). It's important to note that not all of these birds were tested for botulism, however, a subset of birds from these locations tested positive for the toxin in those years.

Canadian data is also limited due to a lack of consistent reporting mechanisms. Estimates for avian mortalities attributed to type E botulism have only been monitored since 1998 and because of differences in data collection and analysis these numbers are likely not representative of actual mortality events in the lakes. The notable increase in estimated mortalities in 2004 is the result of further monitoring efforts by the Canadian Wildlife Service in Lake Ontario. Funding for this monitoring was again reduced in 2010 and we once again see a decline in the number of mortalities (Fig 3).

### *Lake Superior*

While Lake Superior is not traditionally associated with type E botulism outbreaks and is not included in the lake-by-lake graphical assessment (Fig. 4), there have been recorded instances according to records kept by Michigan Department of Natural Resources. In 1967, 39 gull and three common loon mortalities were reported. Similarly the subsequent year, 19 gulls, nine loons and one unknown species of duck succumbed to botulism intoxication. Then, no cases were reported until 1981 when 13 common loons found on the coast of southeast Lake Superior at Whitefish Point in Chippewa County tested positive for type E botulism (Cooley 2011). No other known cases of type E botulism events have been monitored or reported and all reports have been on the U.S. side of the Great Lakes. However, knowing that incidents have occurred in the past demonstrates a need for further understanding of the presence of the toxin in the Lakes.

### *Lake Michigan*

Reports for type E botulism outbreaks date back as far as 1963 and 1964, with massive mortalities estimated at 7,725 and 12,650 water birds respectively. A variety of bird species were impacted, but most commonly found among the mortalities were loons, gulls, grebes and ducks. The number of water bird deaths was likely due to the major alewife population crash resulting in large numbers of alewives washing up on shore and decaying. Scientists confirmed their suspicions after examining deceased gulls and loons to determine that alewives were the dominant food item showing up in their gizzards (Fay 1966). Prior to these incidences, no known wild bird die-offs had occurred due to type E botulism in North America. In 1965 and 1966 water bird die-offs continued to occur, but no estimates were determined and are therefore not included in the graphical assessment (Fig 4). Botulism outbreak estimates were collected sporadically for the next three decades either when a large enough event occurred or reports were available. It was not until recently that botulism outbreaks have once again become particularly severe in Lake Michigan. In 2006, the number of deceased water birds increased with over 3,000 mortalities in the Sleeping Bear Dunes National Lakeshore area. The next year brought an even greater die-off with over 4,000 mortalities ranging from Ludington State Park north and including most of the Michigan beaches in the Upper Peninsula (Zuccarino-Crowe 2009). The most recent large-scale outbreak occurred in 2010 with an estimated 2,677 bird mortalities spanning the Upper Peninsula, Sleeping Bear Dunes National Lakeshore and other locations north along the Michigan shoreline (personal communication with Thomas Cooley 2011). Lake Michigan has the most extensive data record and to date accounts for an estimated 34,269 water bird mortalities.

## *Lake Huron*

Documented cases of type E botulism outbreaks for Lake Huron began in 1965 with an estimated 400 deceased gulls in the Saginaw Bay area. Then again in 1967 with 579 gull kills at the mouth of Saginaw River, Saginaw Bay and north to Tawas Point and Oscoda (personal communication with Thomas Cooley 2011). According to data from the USGS National Wildlife Health Center, another estimated 1,300 water birds were killed in 1969 on the U.S. side of Lake Huron. No mortalities were reported again until 1998 presumably a combination of fewer occurrences, less notable outbreak events, and insufficient monitoring and reporting. At this time, the Canadian Cooperative Wildlife Health Center is the only known entity keeping track of avian mortalities from type E botulism in Lake Huron. As evident in the lake-by-lake graphical assessment, mortality numbers appear to be very low (Fig 5). The low mortality numbers are in part due to the available reporting mechanism. Only water birds that have tested positive for type E botulism and those that are of the same species found in the same location qualify as mortalities. It is likely that a greater number of mortalities are occurring, however, without additional monitoring we will not know for certain.

## *Lake Erie*

As opposed to the previous three lakes, Lake Erie presents the opportunity to compare data from the United States and Canada. In 1999, both countries began tracking mortalities from botulism outbreaks presumably due to greater or more noticeable mortalities in the lake. The increase in mortalities could be attributed to environmental conditions such as water level changes, storm events and temperature fluctuations as well as anthropogenic factors like increases in nutrient loading to the lake. Since Lake Erie is more shallow than the other Great Lakes, fluctuations tend to have a greater impact and as a result it is possible that the conditions needed to foster germination of the botulism bacteria can more easily occur. At any rate since 2000, Lake Erie has continuously experienced annual mortalities in the thousands. One year in particular, 2002 had a record estimate of 21,000 mortalities in the eastern basin according to the USGS National Wildlife Health Center. Testing on a subset of carcasses was performed and botulism was confirmed. The deaths were thus presumed to be the result of type E botulism and comprised of thousands of gulls, common loons, grebes, cormorants and shorebirds. Fish kills were also in the thousands, mostly sheepshead and a few sturgeon (Robinson 2008). The opportunity for comparison is reflected in the lake-by-lake graphical assessments for the United States and Canada (Fig 4 and Fig 5). According to data from the USGS National Wildlife Health Center there have been over 62,000 estimated water bird mortalities from 1999 to 2008. Data provided by the Canadian Cooperative Wildlife Health Center for the same time frame shows an estimated 111 water bird mortalities. Reasons for the disparity could be due in part to data collection and reporting methods, available monitoring and reporting mechanisms or perhaps even environmental causes. Regardless the difference is significant and requires further study.

## *Lake Ontario*

Annual reporting for Lake Ontario began in 2002 with the advent of a significant botulism outbreak killing an estimated 1,046 water birds. Since that time annual die-offs have been in the thousands. In 2006 and 2007, the number of die-offs escalated to an estimated 5,553 and 3,649 mortalities respectively (USGS-NWHC 2011). It is possible that environmental conditions were at play, for instance higher temperatures, due to the fact that increases in avian mortalities were seen during the same years for Lake Erie and Lake Michigan. The U.S. data for Lake Ontario was compiled by the USGS National Wildlife Health Center, however, the New York State Department of Environmental Conservation is the agency responsible for collecting, counting and conducting pathology on the birds. The U.S. data for Lake Erie was compiled by the New York Department of Environmental Conservation. In the past two years, budgetary constraints have impacted NY DEC's ability to continue monitoring botulism outbreaks, which is apparent in the data (personal communication with Helen Domske 2011).

Canadian data for Lake Ontario was provided by the Canadian Cooperative Wildlife Health Centre and the Canadian Wildlife Service. As previously mentioned, the number of recorded avian mortality estimates began in 2003, but the data shows a drastic increase in 2004. This increase is due to additional data provided by Chip Weseloh looking at colonial water bird mortalities offshore on five islands in the eastern basin and one island in the central basin (Weseloh et al. 2011). Funding for this project continued through to 2009, at which point the data once again reflects a decrease likely due to a reduction in monitoring efforts (Fig 5). The addition of the data from this one monitoring project also influences the overall Canadian avian mortalities that we see attributed to type E botulism (Fig 3). Lake Ontario serves as a prime example of how additional monitoring efforts would provide researchers and decision makers with a better idea of which species and areas are most heavily impacted, as well as some insight into how anthropogenic factors may play into this process.

## **Linkages**

As aforementioned many anthropogenic and environmental factors may contribute to the conditions suitable for *Clostridium botulinum* type E germination. Excess nutrient run-off, climate shifts and the impact of invasive species in the food chain and in fostering these conditions, have all been listed as probable factors leading to proliferation of botulism and the notable wide-spread mortalities in the Great Lakes.

The amount of dissolved oxygen in the water is key not only to the survival of oxygen-dependent species, but also because its absence satisfies one of the conditions needed to foster proliferation of the botulism pathogen. Temperature is inversely correlated with the amount of dissolved oxygen in the water, the higher the temperature the less dissolved oxygen. Similarly, the depth of the water can also affect concentrations of dissolved oxygen, although it may vary depending upon the processes of respiration, decomposition and photosynthesis (University of Maine 2006). The National Oceanic and Atmospheric Administration predicts climate change may potentially lead to decreases in lake-wide water levels and warmer water temperatures, meaning a greater likelihood of anoxic conditions leading to future botulism outbreaks in the Great Lakes (Quinn 1998).

The role of invasive species in this process only builds upon the impacts of climate change. *Cladophora glomerata*, for instance, is thought to be structurally rich in simple organics and may work with climate factors to produce an anoxic environment when decomposition occurs. Scientists have found that at Sleeping Bear Dunes National Lakeshore, incidences of avian die-offs due to type E botulism coincide with massive blooms of green algae, consisting mostly of *Cladophora*. Further research is needed to determine whether or not *Cladophora* may be providing the perfect substrate for germination and growth of *Clostridium botulinum*, and in turn providing a pathway into the food chain.

Zebra and quagga mussels are also thought to be a pathway for *Clostridium botulinum* type E into the food chain. Numerous species may rely on the mussels as a food source from fish and birds to reptiles and amphibians (Fig 1). Since the mussels are filter feeders and not known to be susceptible to the toxin produced by *Clostridium botulinum*, they may accumulate the toxin within their bodies and transfer it to other species. It is also believed that similar to *Cladophora*, the mussels themselves are organically rich and at times produce an anoxic substrate in which *Clostridium botulinum* may proliferate (personal communication with Thomas Cooley 2011; Getchell and Bowser 2006).

## **Management Challenges/Opportunities**

Through the objectives of the Great Lakes Water Quality Agreement as well as the Great Lakes Regional Collaboration and the Lakewide Management Plans, the goal is to further understand the epidemiology of *Clostridium botulinum* type E to identify methods of reducing its impact on fish and wildlife populations and

potential effects on human health.

Clearly identifying the factors that may produce an anoxic and nutrient rich environment that fosters proliferation of the pathogen is a necessary step in moving forward. It has been identified thus far that various anthropogenic and environmental factors may contribute to not only germination of the pathogen but its movement throughout the food web. Although it may likely be impossible to ever know the actual number of birds and other species dying, knowing more about species sensitivity, effects of seasonality and location of actual ingestion of the toxin may help us identify problem areas and target monitoring, research and on-the-ground efforts.

At this time we have no affordable real-time technology that would allow us to sample for the toxin on site and rely heavily on water birds either demonstrating symptoms of botulism poisoning or testing carcasses. Removal of carcasses early on is one of the few preventative measures that currently exist.

Of the monitoring efforts currently in place, data collection and analysis varies greatly for each country depending upon the organization involved. Consistency in these procedures may provide researchers and management with a clearer picture in regards to focusing future monitoring and research.

### Comments from the author(s)

The number of avian mortalities will always be an estimate due to the nature of this indicator and the inability of researchers to record with accuracy all the species that succumb to the *Clostridium botulinum* toxin. It may instead be useful to develop consistent data collection methods that include susceptible species, geospatial data and correlate this information with the probable contributing factors listed in the linkages section.

Also, it may be possible to identify specific water bird species as strong indicators of the presence of the toxin. One challenge with figuring out target areas is that most water birds can fly for a short time after ingesting the toxin or may drown and wash up on shore elsewhere. Identifying species that remain in a particular location during the late summer and fall season may assist researchers further in pinpointing target areas. The Red-Necked Grebe may be a potential indicator species due to its loss of primary feathers at that time of year and thus inability to travel far from its food source. However, further research is necessary to determine the benefit of using this species or any other as an indicator (personal communication with Thomas Cooley 2011).

### Assessing Data Quality

Insert “x” under the statement that best corresponds with each data characteristic

Data Characteristics	Strongly Agree	Agree	Neutral or Unknown	Disagree	Strongly Disagree	Not Applicable
1. Data are documented, validated, or quality-assured by a recognized agency or organization						X
2. Data are traceable to original sources		X				
3. The source of the data is a known, reliable and respected generator of data		X				
4. Geographic coverage and scale of data are appropriate to the Great Lakes basin			X			
5. Data obtained from sources within the U.S. are comparable to those from Canada				X		

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6. Uncertainty and variability in the data are documented and within acceptable limits for this indicator report						X
<p>Clarifying Notes: Budgetary constraints for monitoring have made it difficult to obtain sufficient scope of data, and many years have no reported estimates despite knowing that outbreak events did occur. Due to inconsistencies in data collection and analysis between organizations, the data is highly variable and not every case is documented. Although data is included for each of the Great Lakes, detailed geographic coverage is not always available and limited to areas that are actually monitored. Furthermore, not all birds reported as dead were tested for avian botulism, as such; many may have died from other causes.</p>						

## Acknowledgments

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 Chiara Zuccarino-Crowe, Michigan State University, East Lansing, MI  
 U.S. Fish and Wildlife Service  
 National Park Service  
 U.S Forest Service  
 Illinois Department of Natural Resources  
 Common Coast Research and Conservation, Michigan  
 New York State Department of environmental Conservation  
 Presque Isle State Park, Pennsylvania  
 Pennsylvania Sea Grant  
 Wisconsin Department of Natural Resources

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## List of Figures

Figure 1. Consumption of *Clostridium botulinum*. This figure is a simplified food web demonstrating the pathways through which *Clostridium botulinum* type E may transfer by way of ingestion.

Source: Cooley, T.M. 2011. Type E Botulism in Michigan: A Historical Review. Michigan Department of Natural Resources Wildlife Disease Laboratory.

Figure 2. Overall United States avian mortalities attributed to type E botulism. This figure shows the aggregated avian mortality totals for all five Great Lakes on the U.S. side during years with recorded estimates.

Source: Mortality figures compiled through the coordination of USGS National Wildlife Health Center and the Michigan Department of Natural Resources. Estimated totals supplied via personal communication with Jennifer Chipault, August 2011 and Thomas Cooley, September 2011.

Figure 3. Overall Canadian avian mortalities associated with type E botulism. This figure shows the aggregated avian mortality totals for all four Great Lakes on the Canadian side during years with recorded estimates.

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Figure 4. United States water bird mortalities associated with confirmed cases of type E botulism. The four graphs on the left-hand side represent recorded data from 1963-1983. A gap in the data set exists between 1983 and 1999, during which time no data was recorded for any Lake. The four graphs to the right display data recorded between the years 1999-2010. If no data is available for a Lake it will read 'No Reported Data.' Any years with no recorded data are designated with black stars.

Note: This data was provided by several sources and may vary. A comprehensive historical dataset of suspected botulism mortalities is not maintained by one entity at this time.

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Figure 5. Canadian lake-by-lake graphical assessment of *Clostridium botulinum* in water birds. The three graphs on the left-hand side are presented as a comparison to U.S. historical data from 1963-1983, however there is no known reported data during this time frame. A gap in the data set exists between 1983 and 1999, during which time no data was recorded for any Lake. The three graphs to the right display data recorded between the years 1999-2010. If no data is available for a Lake it will read 'No Reported Data.' Any years with no recorded data are designated with black stars.

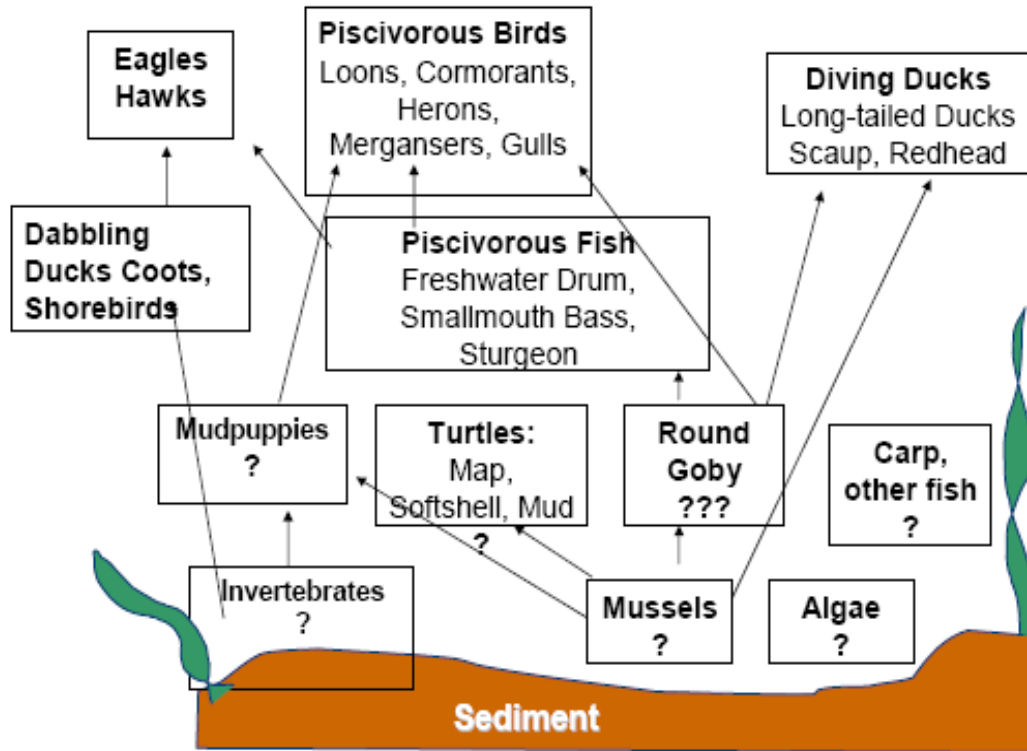
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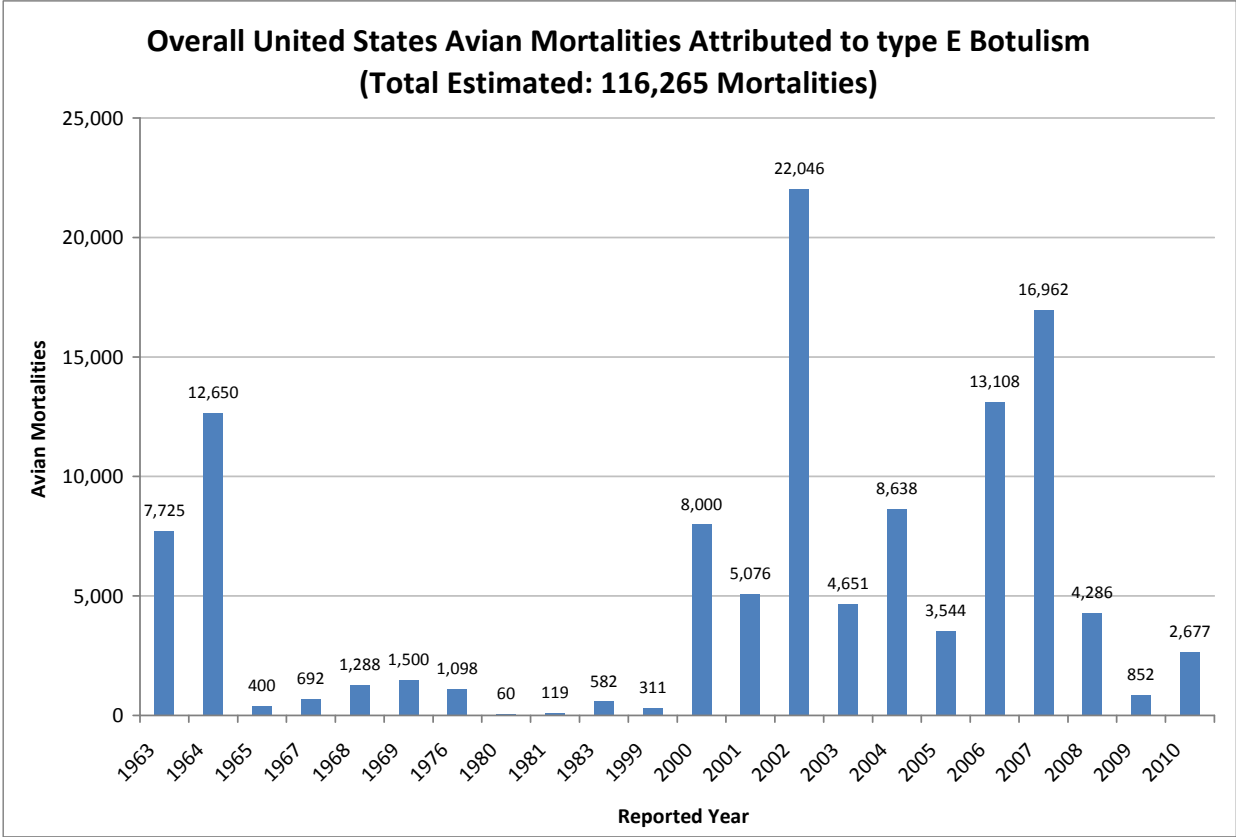
## **Last Updated**

State of the Lakes Ecosystem Conference (SOLEC) 2011

## Type E Botulism Cycle in Great Lakes

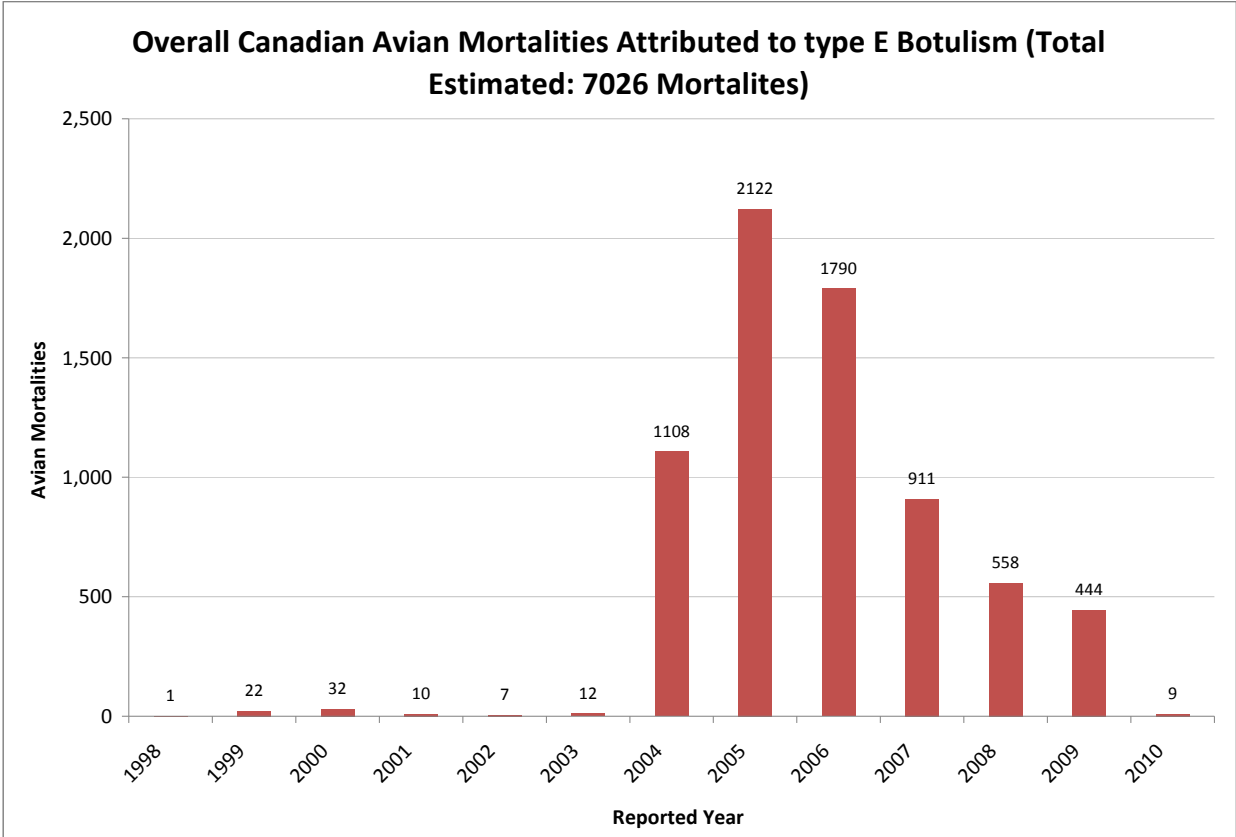


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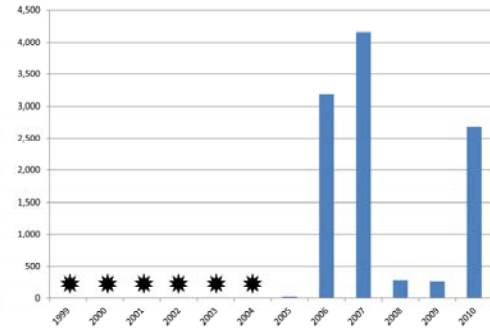
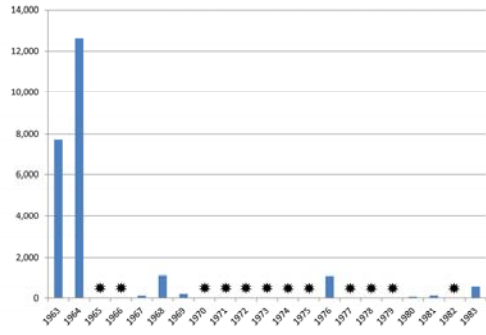
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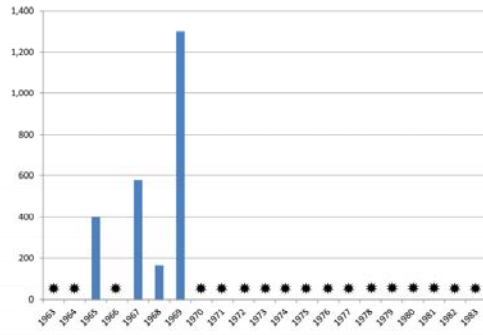
## United States water bird mortalities due to type E botulism

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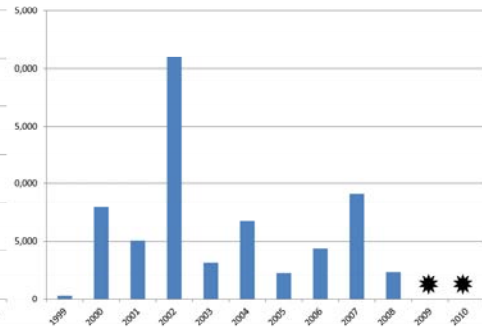


Lake Huron

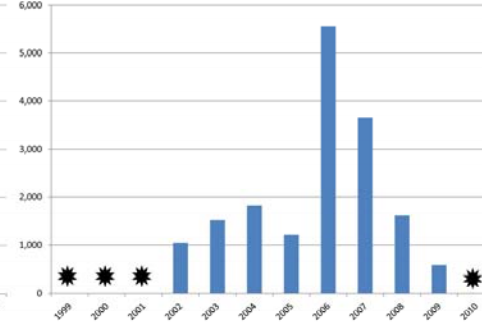
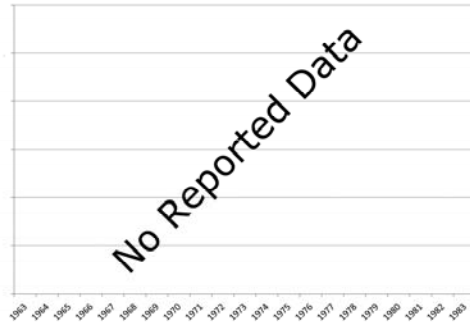
Avian Mortalities



Lake Erie



Lake Ontario



1963 - 1983

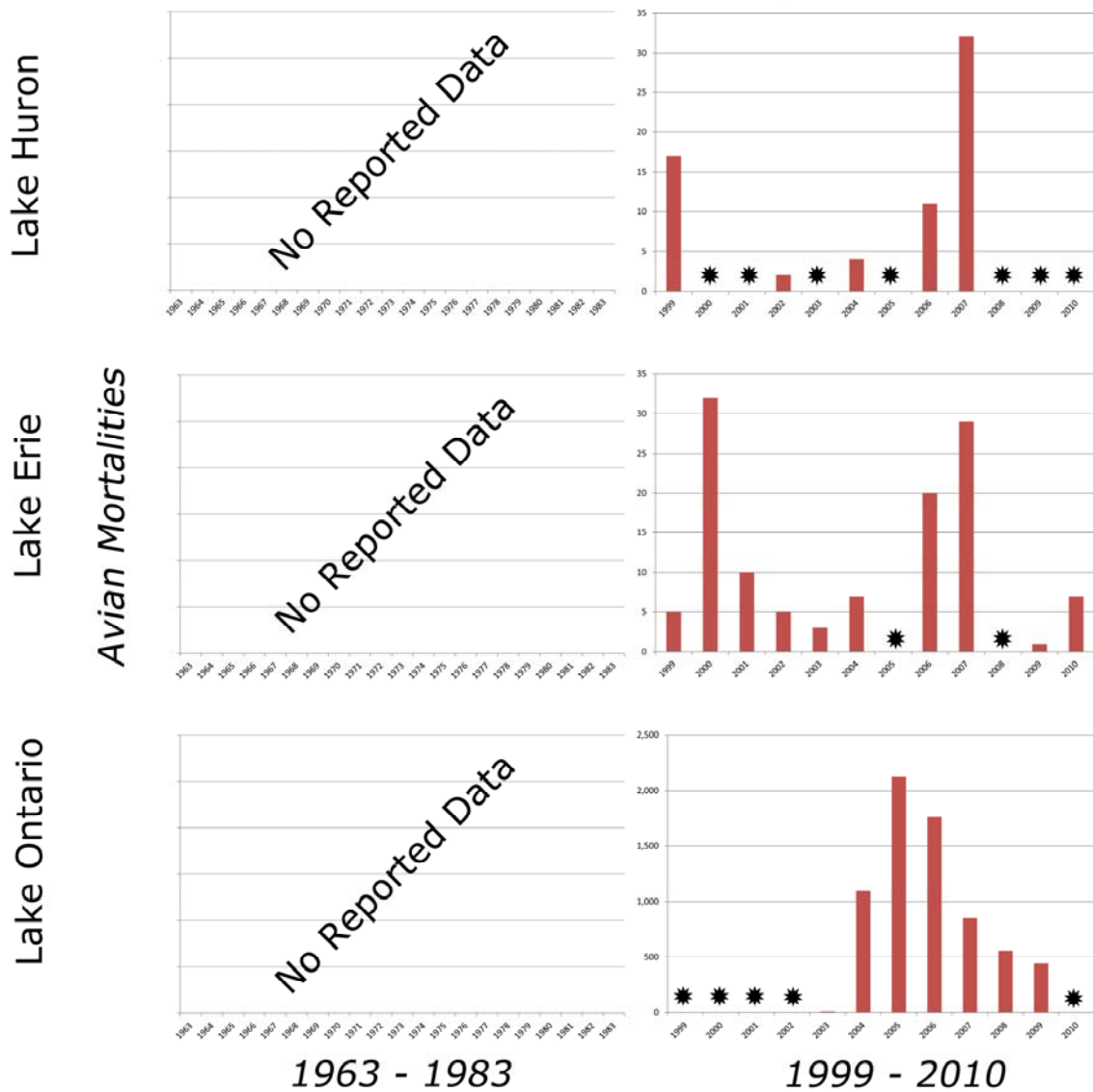
1999 - 2010

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### Canada water bird mortalities due to type E botulism



**Figure 5.** Canadian lake-by-lake graphical assessment of *Clostridium botulinum* in water birds. The three graphs on the left-hand side are presented as a comparison to U.S. historical data from 1963-1983, however there is no known reported data during this time frame. A gap in the data set exists between 1983 and 1999, during which time no data was recorded for any Lake. The three graphs to the right display data recorded between the years 1999-2010. If no data is available for a Lake it will read ‘No Reported Data.’ Any years with no recorded data are designated with black stars.

Note: This data was provided by several sources and may vary. A comprehensive historical dataset of suspected botulism mortalities is not maintained by one entity at this time.

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Source: Mortality figures compiled through the coordination of the Canadian Cooperative Wildlife Health Centre and the Canadian Wildlife Service. Estimated totals supplied via personal communication with David Cristo, June 2011 and Chip Weseloh, September 2011.