



Type E Botulism

State of the Ecosystem

Background

Botulism is a neuromuscular disease caused by several different strains of the bacterium, *Clostridium botulinum*. The Type E strain is responsible for the botulism outbreaks that are currently affecting fish and large numbers of birds in the Great Lakes. Dormant spores of this bacterium are endemic to the region and are naturally abundant in all soils and sediments, but are not always in the vegetative state capable of producing botulism toxin. These spores are not only found in the sediments of the Great Lakes, but can also be found in the intestinal tracts of live, healthy animals. These spores are resistant to extreme temperatures and desiccation, and so are capable of remaining in the ecosystem for long periods of time (Domske 2003).

The botulism toxin is only produced when spores germinate and the bacterium enters the vegetative growth stage. This change occurs in anoxic environments containing a suitable nutrient source, such as in areas with decaying plant material, favorable temperatures, and pH levels (Brand *et al.* 1988). Once these factors lead to the production of the toxin, it is possible for it to enter the food chain.

Animals, especially fish-eating birds, can contract botulism when they prey on other animals that harbor the toxin (Leighton and CCWCH 2000). The effects of toxin poisoning include paralysis and eventually death. Affected birds often have trouble holding up their heads (also known as limber neck) and may drown. Affected fish will lose their equilibrium and may be found floating or swimming erratically near the surface, which may actually attract birds to prey upon these fish. Dead fish and birds that wash up on the beach can become sources for *C. botulinum* growth, and shorebirds may ingest the toxins as they feed on maggots and carrion beetles within the decaying carcasses. Removal of dead birds (potential vectors) is important in dealing with an avian botulism outbreak. Rehabilitation of sick birds is limited due to the large geographic areas involved, but may be possible in cases when the birds did not ingest an acute dose of the toxin and anti-toxins and electrolytes are administered immediately, but it is frequently unsuccessful (USGS-NWHC 2006).

Occurrence of Type E Botulism in the Great Lakes

The frequency and severity of Type E botulism outbreaks have gone through cycles over the last several decades (Figure 1), with recent increases and expansion of affected areas and species leading to disturbing conclusions for the ecological health of the nearshore waters. Although outbreaks have been documented in the Great Lakes region as far back as 1963 (Kaufmann and Fay 1964), annual die-offs of birds and fish on the shores of Lake Huron began again in 1998, in Lake Erie in 1999, and in Lake Ontario in 2002 (Leighton and CCWHC 2007). Over the past few years, botulism outbreaks have been particularly severe in Lake Michigan. Sleeping Bear Dunes National Lakeshore experienced an extensive botulism-related waterbird die-off in 2006 that killed nearly 3,000 grebes, gulls, cormorants, loons and mergansers (personal communication with Ken Hyde, Park Biologist for Sleeping Bear Dunes National Lakeshore, 2007). In 2007, the Lake Michigan die-off impacted a much larger geographical area from Ludington State Park north including most of the Michigan beaches in the Upper Peninsula. Including the 1,135 birds killed due to botulism at Sleeping Bear Dunes in 2007 (personal communication with Ken Hyde, SLBE 2007), the total estimates for that year reached 17,125 avian mortalities for the entire Great Lakes region (Figure 2).

According to estimates compiled from the USGS National Wildlife Health Center's databases, a total of approximately 96,864 avian mortalities were attributed to Type E botulism from 1963 through 2007 in the Great Lakes (USGS-NWHC 2008), although the actual number of deaths is likely much higher due to monitoring and reporting inconsistencies. These outbreaks involved a variety of species (Table 1); including species of special interest, such as lake sturgeon, loons, and endangered piping plovers. The mortalities in recent years have the potential to cause population and species level effects, which make this an important focus for future monitoring efforts.

Numerous state and federal agencies, universities, non-profits, and volunteer groups participate in botulism research, outbreak monitoring, clean-up, reporting and outreach. With the geographic area of occurrence expanding in recent years, keeping up with these tasks is increasingly difficult, as numerous jurisdictions are affected and resources are limited. Several workshops have been held in previous years to help foster coordination in dealing with the issue.

The most recent workshop in June of 2008 highlighted a series of focus areas in need of development within the research and management sectors. These included the desire for a more formalized botulism taskforce to help facilitate future activities, such as improved web-based reporting and tracking of outbreaks, database enhancement, development of cost-effective field-testing kits, and coordination and funding of additional research.

Despite the evidence that the suspected current ecological pathway of botulism is heavily related to the impacts from a host of invasive species, the exact mechanism that transports it through the food chain has not been scientifically documented, nor were the causes of past historical botulism outbreaks in the 1960s (possibly linked with alewife die-offs, (Fay 1966)) fully understood. Additionally, appropriate control measures on a Great Lakes scale have not yet been developed for either the invasive species or the current suspected pathways. Research aimed at better understanding, or even disrupting, the environmental factors that lead to outbreaks is currently in progress, but actual prevention or mitigation may prove difficult. It seems apparent that the ecological balance of the nearshore waters has been upset to a point that allows these outbreaks to continue, and it will be challenging to find the exact recipe of actions to restore a healthy equilibrium in a natural setting.

Pressures

Many of the specific conditions needed for production of the botulism toxin can be facilitated by a variety of stressors. For example, the prolific growth of the native *Cladophora* algae believed to occur because of increased water clarity and sunlight penetration resulting from the invasive *Dreissenids'* water filtration capabilities, is a likely factor which may be linked with botulism outbreaks. The subsequent decay of large mats of sloughed algae in the nearshore area may lead to pockets of anoxia in a rich growth medium, thereby creating an ideal environment for the vegetative state of *C. botulinum* and the resultant toxin production (Hecky *et al.* 2004 in Getchell and Bowser 2006). Additionally, other pressures linked to the growth of *Cladophora*, such as nearshore nutrient loading and cycling, may potentially influence botulism outbreaks.

Invasive species may also play a key role in the recent outbreaks. Current hypotheses under study suggest that invasive quagga mussel beds also create additional habitat for *C. botulinum* and accumulate the toxin. They may then facilitate transport of the toxin up the food chain as they are consumed by fish, and especially by the round goby (Getchell and Bowser 2006). The round goby is a recent invader of the Great Lakes that has spread rapidly due to its ability to produce large numbers of young annually, and it feeds heavily on *Dreissenid* mussels. The gobies and native forage fish, after ingesting toxin-laden food items, are in turn consumed by larger predatory fish and piscivorous water birds. The obvious symptoms of this nearshore outbreak are evident in the numerous stretches of beach with dead and dying birds and fish strewn along the waters' edge.

Management Implications

The numerous fish and wildlife mortalities caused by botulism across a widening geographic region are a continuing cause for concern. Botulism is affecting native and sensitive wildlife populations, and it has implications for the overall ecological health of the Great Lakes. It may also impact tourism and the enjoyment of the many visitors to local beaches. Lastly, the frustration of not being able to mitigate the outbreaks and ambiguities around the risk posed to human health are issues of concern.

Type E botulism toxin poisoning cases in humans are extremely rare, with the only documented cases of human sickness originating in the Great Lakes region having resulted from the consumption of cold-smoked, vacuum packed fish during the 1960s. Botulinum toxins are heat-inactivated during cooking, thus using common safety precautions when handling fish or waterfowl and following correct food preparation guidelines help ensure maximum safety from the toxin. With the recent outbreaks in fish and birds becoming an increasingly public issue, there are frequent requests for official statements that specifically relate to the current situation. Most existing safety-related documentation includes general state agency food handling and preparation guidelines, or it refers to cases where specific fish curing and preparation methods led to production of the toxin during non-environmental outbreak conditions in Alaska. Recent laboratory-based studies investigating botulism's effects on fish and resulting toxin levels in their viscera and tissues have further supported the assumption that Type E botulism associated with Great Lakes wildlife poses minimal human health risks (Yule *et al.* 2006). However, additional laboratory and field research and definitive government health agency statements regarding consumption of sport fish and waterfowl during an outbreak would assist in delivering a cohesive message to the general public about their safety when questions arise.

As long as botulism outbreaks continue to occur on an annual basis, Great Lakes managers will be called upon to facilitate coordination and support of the actions needed to understand, prevent, mitigate and respond to this problem.

Comments from the author(s)

The current historical data on botulism mortalities exists in numerous locations and with various inconsistencies. Mortality estimates presented in this report are not meant to be interpreted as actual counts, but should serve to highlight the overall magnitude of botulism's effects.

If the level of data quality could be improved, it would enable more rigorous data analysis projects that might begin to answer some of the research questions at hand. Refinement of a centralized reporting mechanism and data repository could also be beneficial for dealing with other existing wildlife diseases and those that have yet to come.

Acknowledgments

Authors: Chiara Zuccarino-Crowe, Oak Ridge Institute for Science and Education (ORISE) Research Fellow on appointment to the U.S. Environmental Protection Agency (U.S. EPA), Great Lakes National Program Office (GLNPO), zuccarino-crowe.chiara@epa.gov

Contributors:

Anne Ballmann, DVM, Ph.D., Wildlife Disease Specialist, USGS - National Wildlife Health Center
 David Blehert, Ph.D., Microbiologist, USGS - National Wildlife Health Center
 Murray Charlton, Environment Canada - retired
 Stacey Cherwaty, Environment Canada
 Helen Domske, Coastal Education Specialist, New York Sea Grant
 Elizabeth Hinchey Malloy, Ph.D., Great Lakes Ecosystem Extension Specialist, Illinois-Indiana Sea Grant
 Ken Hyde, Wildlife Biologist, Sleeping Bear Dunes National Lakeshore, National Park Service
 Elizabeth Murphy, MPH, Great Lakes Fish Monitoring Program Manager, U.S. EPA, GLNPO
 Eric Obert, Extension Director, Pennsylvania Sea Grant
 James Schardt, Life Scientist, U.S. EPA, GLNPO

Information Sources

- Brand, C.J., S.M. Schmitt, R.M. Duncan and T.M. Cooley. 1988. An outbreak of Type E Botulism among common loons (*Gavia immer*) in Michigan's Upper Peninsula. *Journal of Wildlife Diseases* 24(3): 471-476.
- Breederland, M. 2008. Botulism Coordination Meeting, Feb 6, 2008 - Final Summary.
- Canadian Cooperative Wildlife Health Center (CCWHC). 2008. "Ontario's 2007 Botulism Incidents." February 25, 2008. http://www.ccwhc.ca/en/botulism_ontario_news.php (accessed September 2008).
- Domske, H. 2003. Botulism in Lakes Erie 2003 Workshop Proceedings. New York Sea Grant, Ohio Sea Grant and Pennsylvania Sea Grant. [http://seagrant.psu.edu/publications/proceedings/Botulism\(2003\).pdf](http://seagrant.psu.edu/publications/proceedings/Botulism(2003).pdf)
- Domske, H. 2004a. Botulism Update. New York Sea Grant. <http://www.seagrant.sunysb.edu/botulism/pdfs/botulism-updateSu04.pdf>
- Domske, H. 2004b. Botulism in Lakes Erie 2004 Workshop Proceedings. New York Sea Grant, Ohio Sea Grant and Pennsylvania Sea Grant. <http://www.seagrant.sunysb.edu/botulism/pdfs/Botulism-Proc04.pdf>
- Fay, L.D. 1966. Type E botulism in Great Lakes water-birds. *Michigan Department of Conservation, Research and Development Report* No. 54. March 3, 1966. Rose Lake Wildlife Research Center, East Lansing, MI. Presented at the 31st North American Wildlife and Natural Resources Conference, March 14, 1966.
- Getchell, R.G. and Bowser, P.R. 2006. Ecology of Type E Botulism within Dreissenid Mussel Beds. *Aquatic Invaders*. 17(2): 1-8.

- Great Lakes Sea Grant Network and U.S. EPA. 2007. Botulism in the Great Lakes – Frequently Asked Questions. <http://www.miseagrant.umich.edu/habitat/avian-botulism-faq.html>
- Kaufmann, O.W. and L.D. Fay. 1964. *Clostridium botulinum* type E toxin in tissues of dead loons and gulls. *Michigan State University Agricultural Experiment Station Quarterly Bulletin*. 47(2):236-242.
- Leighton, F.A. Botulism, “Type E Botulism in Birds”. Canadian Cooperative Wildlife Health Centre (CCWHC). March 2000 (Revised 2007). http://www.ccwhc.ca/wildlife_health_topics/botulism/botulisme_org.php (accessed January 2008).
- Ludwig, J.P. and Bromley, D.D. 1988. Observations on the 1965 and 1966 Mortalities of Alewives and Ring-Billed Gulls in the Saginaw Bay – Lake Huron Ecosystem. *The Jack-Pine Warbler*, March 1988, 66(1).
- Mortality figures for 2004-2007 in Eastern Lake Ontario from Laird Schutt and Chip Weseloh, unpublished data from Colonial Nesting Waterbird Surveys. Estimates supplied via personal communication with Chip Weseloh, 2008.
- Mortality figures thru 2006 from internal databases maintained by the USGS - National Wildlife Health Center. Estimated totals compiled in February, 2007.
- Mortality figures for 2007 compiled through the coordination of USGS – National Wildlife Health Center. Estimated totals supplied via personal communication with Mark Jankowski, February 2008 and Nathan Ramsay, March 2008.
- New York State Department of Environmental Conservation. “Type E Botulism in Lakes Erie and Ontario.” <http://www.dec.ny.gov/animals/28433.html> (accessed December 2006).
- Pennsylvania Sea Grant and Penn State Erie. 2003. Botulism Factsheet: http://www.pserie.psu.edu/seagrant/publications/fs/Botulism_12-2003.pdf.
- Sleeping Bear Dunes mortality estimates supplied via personal communication with Ken Hyde, Sleeping Bear Dunes National Lakeshore, March 2007 and December 2007. <http://www.nps.gov/slbe/>
- U.S. EPA and GeoSyntec. 2008 (in development). Great Lakes Basinwide Botulism Coordination Workshop Proceedings, June 24-25, 2008.
- USGS National Wildlife Health Center. *Disease Information*, “Avian Botulism,” 7 November 2006. http://www.nwhc.usgs.gov/disease_information/avian_botulism/index.jsp (accessed December 2006).
- Yule, A.M., J.W. Austin, I. Barker, B. Cadieux and R.D. Moccia. 2006. Persistence of *Clostridium botulinum* Neurotoxin Type E in Tissues from Selected Freshwater Fish Species: Implications to Public Health. *Journal of Food Protection*. 69(5): 1164-1167.

List of Tables

Table 1. Great Lakes bird species affected by Type E botulism. Represented species are from historical, as well as present day, outbreaks. Affected fishes are not listed here. Source: USGS – National Wildlife Health Center, 2007, 2008.

List of Figures

Figure 1. General distribution of Type E botulism outbreaks, 1963 – 2007. Highlighted areas are not drawn to scale, and are not representative of the exact areal extent of the outbreak. Areas highlighted with oval or circular marks refer to time frames as opposed to isolated years, and are not indicative of the outbreaks’ severity.

Sources: Compiled from maps developed by Thomas Cooley (Michigan DNR, Wildlife Disease Lab); Eric Obert (Pennsylvania Sea Grant); Mark Jankowski (USGS – National Wildlife Health Center); and the Canadian Cooperative Wildlife Health Center (CCWHC).

Figure 2. Estimated number of avian* mortalities attributed to Type E botulism in the Great Lakes region.

Please note: These numbers are total reported estimates which include the actual counts of collected carcasses. The actual figures may vary, as all mortalities are not necessarily reported to this singular database. A comprehensive historical dataset of suspected botulism mortalities is not maintained by one entity at this time.

*See accompanying list of included species in Table 1

Sources: USGS – National Wildlife Health Center maintained databases, 2008; Laird Shutt and Chip Weseloh, unpublished data from 2004-2007 Eastern Lake Ontario Colonial Waterbird Surveys, 2008.

American Black Duck	Great Blue Heron	Piping Plover
American Coot	Greater Scaup	Red-breasted Merganser
American White Pelican	Grebe	Redhead Duck
Bald Eagle	Gull, unidentified species	Red-necked Grebe
Barred Owl	Hawk, unidentified species	Red-tailed Hawk
Belted Kingfisher	Heron, unidentified species	Red-throated Loon
Black-bellied Plover	Herring Gull	Red-Winged Blackbird
Blue Jay	Horned Grebe	Ring-billed Gull
Bonaparte's Gull	Killdeer	Rock Dove
Bufflehead	Lesser Scaup	Sabine's Gull
Canada Goose	Long-Tailed Duck	Sanderling
Canvasback Duck	Loon, unidentified species	Scaup, unidentified species
Caspian Tern	Mallard Duck	Scoter, unidentified species
Common Goldeneye	Merganser, unidentified species	Semipalmated Sandpiper
Common Loon	Northern Flicker	Sharp-Shinned Hawk
Common Merganser	Northern Yellow-shafted Flicker	Spotted Sandpiper
Common Tern	Oldsquaw Duck	White-winged Scoter
Double-crested Cormorant	Pheasant, unidentified species	Winter Wren
Duck, unidentified species	Pied-Billed Grebe	
Great Black-backed Gull	Pigeon, unidentified species	

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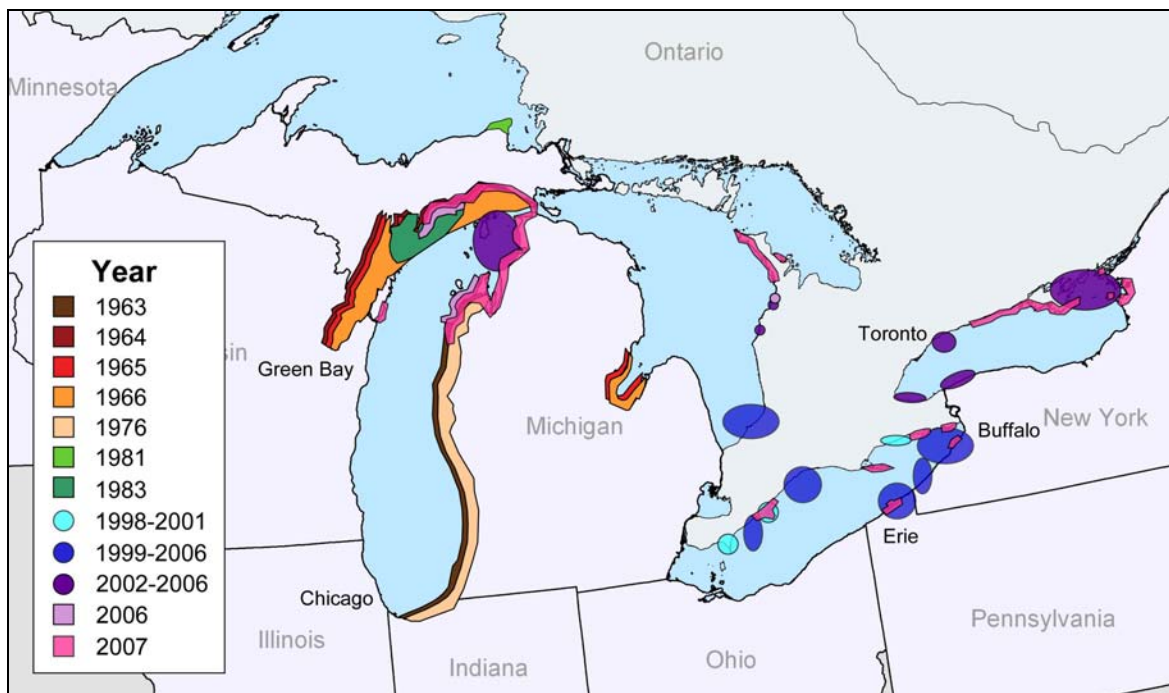


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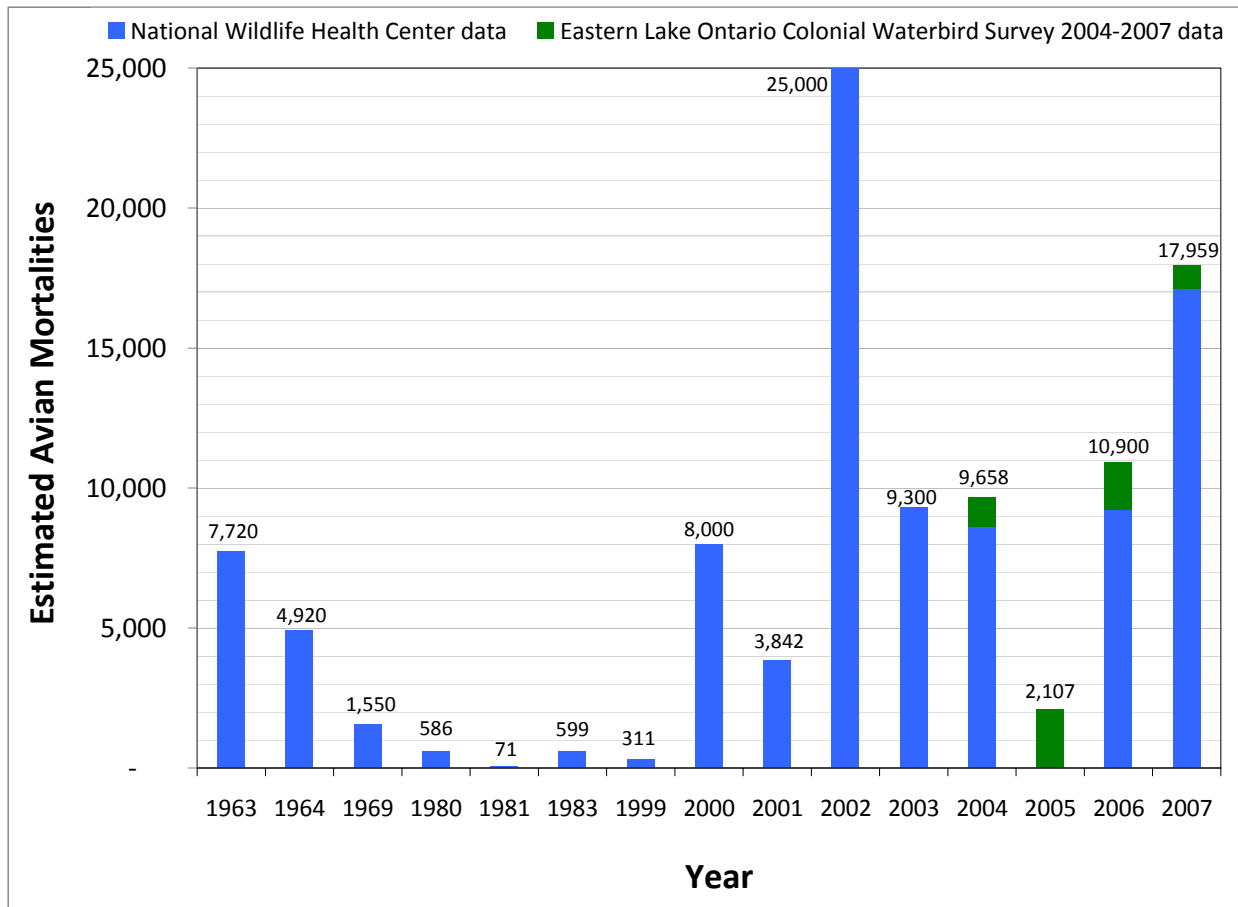


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