

Botulism in the Great Lakes – Frequently Asked Questions

Botulism is a neuromuscular disease caused by the bacterium *Clostridium botulinum*. Botulism poisoning of fish and wildlife has recently increased in the Great Lakes. Researchers, state and federal agencies and a variety of non-government organizations are tracking the occurrences of botulism and are investigating the possible causes behind these outbreaks.

The information provided in this publication is designed to answer questions that occur when there is a botulism outbreak in a specific area of the Great Lakes and to explain the associated ecological implications. Recent botulism outbreaks have primarily impacted bird populations, although some species of bottom-dwelling fish have suffered localized die-offs. The threat to human health is minimal, and the only documented cases of human sickness resulting from Type E botulism were caused by consumption of cold-smoked, vacuum packed fish during the 1960s. This information is provided so that hunters, recreational anglers, coastal residents and interested citizens can take simple, common sense precautions to reduce or eliminate any risk from handling or consuming waterfowl or fish that have been exposed to botulism toxin.

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What is Botulism?

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What can I do to help?

- *What steps can I take to help stop the spread of botulism?*
- *How should I notify authorities of a potential botulism related fish or bird kill?*
- *How can people who want to help clean up the beach after a bird kill best protect themselves?*
- *What is the best way to dispose of dead fish/birds in my area, especially after a botulism outbreak?*
- *Is rehabilitation of sick birds possible? If so, how, and who should I contact about it?*

Contact Information

-----Questions with Answers-----

What is Botulism?

- *What is botulism?*
 Botulism is a serious neuromuscular illness caused by a toxin that is produced by the bacterium *Clostridium botulinum*. Avian botulism has been recognized as a major cause of mortality in migratory birds since the 1900s. Human botulism is typically caused by eating improperly canned or stored foods. The bacterium is classified into 7 types (A-G) by characteristics of the neurotoxins that are produced. Four of these types (A, B, E and rarely F) cause human botulism, while types C, D and E cause illness in mammals, birds and fish. All types of botulism are paralytic to some degree, due to the nature of the neurotoxins produced by the bacteria. The following are the four most common types of botulism:
 - *Type A or Type B botulism* is most commonly caused by the consumption of bacteria in improperly home-canned foods. Diluted and purified forms of the type A and B toxins are also used in certain facial aesthetic products.
 - *Type C botulism* and *Type E botulism* are responsible for extensive waterfowl and some fish kills. They are both brought on by the consumption of these particular types of the botulinum toxin through food web interactions. Type C botulism mostly impacts waterfowl (especially ducks) and is typically restricted to marshes and wetlands in prairie regions, primarily found west of the Mississippi River. Type E botulism is more prevalent in the Great Lakes, but has also been documented in California.
- *What species are affected by Type E botulism? Type C botulism?*

A large number of bird and fish species are susceptible to the Type E botulinum toxin, as are some amphibians, like mudpuppies, and most mammals. A few cases of Type E botulism in humans have been reported in North America and were the result of eating improperly smoked or cooked fish, but these types of cases in humans are rare.

Loons, mergansers, long tail ducks, grebes, scaup, cormorants and gulls in particular are the bird species affected by Type E botulism. Commonly affected fish species include, Freshwater Drum (Sheepshead), Smallmouth Bass, Rock Bass, Stonecats, Round Gobies, Channel Catfish and Sturgeon.ⁱ

Type C botulism outbreaks on prairie wetlands have mainly affected ducks, coots, grebes, gulls and other shorebirds.ⁱⁱ

- ***Is Type E botulism responsible for the recent bird and fish kills?***

Yes. Pathology conducted on victims of the recent die-offs points to Type E botulism as the cause. Type E Botulism is contracted by ingesting invertebrates, fish or birds contaminated with the toxin (*Clostridium botulinum*).

- ***Where does botulism come from?***

Botulism spores (the resting stage of the bacteria) are abundant in anaerobic habitats, such as soils, and aquatic sediments of many lakes and can be readily found in the gills and digestive tracts of fish living in those lakes. The spores can remain in the ecosystem for extended periods of time, even years, and are quite resistant to temperature changes and drying. These spores, themselves, are harmless until the correct environmental factors and anaerobic conditions prompt them to germinate and begin vegetative growth of the toxin-producing bacterial cells.ⁱⁱ

The active bacteria that cause botulism only grow in a nutrient-rich substrate, such as areas with large amounts of decaying plant growth, which are free of oxygen (anaerobic). Fish that die for any reason and that contain the bacterial spores in their tissues are also suitable substrates for growth and toxin production by the bacteria.ⁱⁱ

- ***How do birds end up dying as a result of the botulism toxin?***

Fish-eating birds that died of Type E botulism were poisoned by eating fish that contained the toxin. However, it is not clear exactly how this happens. Birds, such as loons and mergansers, normally capture and eat only live fish. Yet, *Clostridium botulinum* Type E should not grow and produce the actual toxin in living fish.ⁱⁱ (See also: *Where does botulism come from?*).

It is possible there are circumstances that can cause toxin production in the tissues and digestive tracts of live, perhaps dying, fish. Alternatively, it may be that the fish captured alive and eaten by the birds had themselves

fed on a source of Type E toxin. In these cases, it would be the toxin in the digestive tracts of the live fish that was the source of toxin for the birds in these outbreaks. ⁱⁱ

It is also possible that the live fish captured by the birds were already partially paralyzed by the Type E toxin and were therefore particularly easy prey for the birds. This might account for preferential feeding on toxin-containing fish by the affected birds. ⁱⁱ

Scientists also think that ingestion of maggots from the carcass of an infected animal can continue the spread of botulism, which may be responsible for large kills of shorebirds.

- ***Why are we so concerned about avian botulism outbreaks?***

Natural resource managers, environmental organizations and others are concerned about the thousands of migrating birds that have died, including loons, and other species. According to estimates compiled from the USGS, National Wildlife Health Center's databases, about 52,140 avian deaths were attributed to Type E botulism from 2002 to 2006 on the Great Lakes. ⁱⁱⁱ Recent reports from the Sleeping Bear Dunes National Lakeshore also estimate that an additional 3,000 avian botulism-related mortalities occurred in 2006 on Lake Michigan. ^{iv} Some fish species, such as Lake Sturgeon, that have been listed as threatened, endangered or of special concern, are also now at an increased risk because of botulism. Additionally, dead wildlife may contain toxin levels that could harm other animals, including pets.

- ***Has botulism always been in the Great Lakes?***

While Botulism has been around for a long time, records of it did not appear on the Great Lakes until recently. Type C botulism was first identified in the Great Lakes in 1936 on Lake Michigan, ^v and Type E botulism in the Great Lakes was first documented on Lake Michigan in 1964 regarding a 1963 outbreak. ^{vi} Since 1999, significant die-offs of birds and fish have occurred regularly in Lake Erie and Lake Ontario, with estimated avian mortalities coming to about 61,630 type E botulism-attributed deaths for 1999 thru 2006, (mortality figures from databases maintained by the USGS - National Wildlife Health Center.) ⁱⁱⁱ

Different types of avian botulism have had destructive effects on birds throughout the U.S. for a considerable time, and probably predate written records. One of the earliest major reported die-offs of a large number of waterfowl was encountered in the Great Salt Lake area of the United States in the early 1900s. Since early observations occurred on alkaline lakes in areas of western North America, the phenomenon was suspected of being a form of alkali poisoning and became known as Western Duck Sickness. It wasn't until a quarter of a century later that the cause of these die-offs was determined to be Type C botulism poisoning. ^{vii}

- ***Why are botulism outbreaks occurring now?***

Scientists believe that there are outbreaks of Type E botulism only when a variety of particular ecological factors occur simultaneously, such as warmer water temperatures, anoxic (oxygen deprived) conditions, and adequate levels of bacterial substrate. As average air and water temperatures have been rising on a global scale, warmer temperatures and anoxic conditions are occurring more frequently. Once these factors lead to the production of the toxin in food material eaten by fish, the toxin can be passed up the food chain as birds consume the infected fish or eat maggots from the decaying carcasses of infected individuals. ⁱⁱ

Invasive species may also play a role. Current hypotheses under study suggest that zebra and quagga mussel beds may create additional habitat for the bacterium that causes botulism. Many scientists believe that quagga mussels also have the potential for filtering the bacteria and passing it up the food chain when the quagga mussels are eaten by fish such as the round goby.

Invasive mussels may also be responsible for the increase in growth of the algae *Cladophora* (which is also potentially tied to botulism outbreaks), since the mussel's filtration of the water makes it clearer, therefore prompting increased algal growth. This increase in algal growth and the subsequent decay of the algae can increase the oxygen demand in the ecosystem leading to possible anaerobic conditions necessary for botulism toxin production.

- ***Is there a link between botulism outbreaks and fluctuating water levels?***

There is some evidence that outbreaks correspond to low water level events. Historically, larger bird die-offs as a result of Type E botulism have occurred during periods of low or rapidly declining water levels, and water level fluctuations and draw down events in wetlands have also correlated with Type C botulism outbreaks. The mechanism behind this possible link still needs to be researched but is likely to be related to warmer water and sediment temperatures during low water events.

- ***What are some possible symptoms that an animal with botulism could display?***

As Type E botulism results in paralysis, infected species begin to exhibit unusual behavior. Water birds may not be able to hold their head up and as a result, often drown. Gulls can often walk, but not fly. Other birds may drag one or both wings (poor posture) while standing.

Once infected with Type E botulism, fish may flounder or swim erratically near the surface of the water. Their equilibrium may be affected, and they may have trouble staying right-side up. "Breaching" may also occur, during which a fish will float with its head near the surface and tail end lowered below. Infected fish usually die quickly and are most likely to be seen washed up on shore. ^{viii}

Note: ANY fish or waterfowl that seem sick should not be harvested or eaten.

- ***Why is it difficult for scientists to positively determine that birds have died from Type E botulism?***

Both Type C and Type E botulism, as well as a few other types of poisoning, can produce similar symptoms in affected wildlife. Definitive diagnosis of Type E botulism requires that the Type E botulinum toxin be found in the blood of a live, sick bird. Although finding the toxin in a recently dead bird may be evidence that the bird died of botulism, it is also possible that the toxin detected was produced after death, during putrefaction, and may not have been the cause of the bird's death. ⁱⁱ

- ***Do the recent algal blooms of the macro algae *Cladophora* play any role in the botulism outbreaks?***

The recent increases in the growth of *Cladophora* ultimately result in increased decaying plant matter in some areas of the Great Lakes. This decomposition can create an oxygen-deprived environment that is suitable to the bacterium that produces the Type E botulism toxin. (See also: *Why are Botulism outbreaks occurring now?*)

- ***Are inland lakes susceptible to Type E botulism outbreaks?***

The Michigan Department of Natural Resources has cited rare reports of Type E botulism on the state's inland lakes. Scientists believe that there is a minimal threat of botulism outbreak transfer from the Great Lakes to inland lakes, since the disease itself is not transferable from a transportation standpoint. The likelihood of an infected animal getting from the Great Lakes to an inland lake is small, since it will probably be too incapacitated by the toxin to travel.

With botulism spores already existing everywhere, the most likely way an outbreak would occur in a new location is if the optimal environmental factors exist that allow the bacteria to enter a vegetative state and produce the toxin. (See also: *Why are botulism outbreaks occurring now?*)

Human & Pet Health

- ***Is it safe to eat fish/waterfowl?***

When fishing or hunting on the Great Lakes, you should only harvest fish and waterfowl that act and look healthy. Don't take any fish or game that show signs of illness, and follow good sanitary practices when preparing them. ^{viii} It is especially important to stay away from the gut area when cleaning fish; filleting is recommended. Similarly, when preparing waterfowl, the gut should be immediately removed and care should be taken to not disturb the gut contents. (See also: *What steps should I take when preparing healthy fish or birds for consumption to ensure maximum safety?*)

- ***Can I get botulism?***

Botulism in humans is usually caused by the consumption of improperly home-canned foods and is most often a result of the Type A or Type B botulinum toxin. A few cases of Type E botulism in humans have been reported in North America as the result of eating improperly smoked or cooked fish, but these cases are very rare. ⁱⁱ

Thorough cooking is necessary to destroy the bacteria and bacterial toxins. Consult your local health agency for recommended cooking temperatures.

As a precaution, any fish or waterfowl that are sick or act abnormally should not be harvested or eaten because cooking may not destroy the botulism Type E toxin. ^{viii} (*More information on botulism from a human health and food safety standpoint can be obtained through the USDA Food Safety Research Information Office's Clostridium botulinum resource list at,*

http://fsrio.nal.usda.gov/document_reslist.php?product_id=137).

(See also: *What steps should I take when preparing healthy fish or birds for consumption to ensure maximum safety?*)

- ***Can I swim in the water?***

You are not at risk for botulism poisoning by swimming in Great Lakes waters. Botulism is only contracted by ingesting fish or birds contaminated with the toxin. If you have concerns about water quality, contact your local health department or swim in a regulated beach area. Remember that beaches sometimes close for other reasons such as fecal contamination. (*More information regarding beach advisories can be found through the U.S. EPA's Beaches website at, www.epa.gov/beaches.)*

- ***Is it safe to walk dogs on the beach after a bird kill?***

If you bring pets to the shore, keep them away from dead animals on the beach.

- ***Will my dog get sick if it eats a dead bird?***

Dead wildlife may contain potentially harmful bacteria or toxins. In cases where you think your pet may have ingested a contaminated carcass, monitor them for signs of sickness and contact a veterinarian if you suspect they are falling ill.

- ***Do I have to wash my hands after I touch a dead bird?***

Yes, you should always wash your hands after handling any wildlife. Ideally, you should also wear gloves to handle any dead animal.

- ***What steps should I take when preparing healthy fish or birds for consumption to ensure maximum safety?***

Wear rubber or plastic protective gloves while filleting, field dressing, skinning or butchering.

Remove the intestines of birds soon after harvest, don't eat the intestines and avoid direct contact with intestinal contents. Fish should be filleted, and contact with any gut material should be avoided. Hands, utensils and work surfaces should be washed before and after handling any raw food, including fish and game meat.

Please remember that proper and thorough cooking is necessary to destroy disease-causing organisms that occur naturally or that can be introduced during handling, storage, or preparation.

Contact your local health agency for more detailed information on suggested cooking temperatures and other possible health and fish consumption advisories.

- General information on food preparation is also available through the Food Safety Research Information Office of the USDA, Department of Agriculture, (http://fsrio.nal.usda.gov/document_reslist.php?product_id=130).
- Information on Great Lakes fish consumption advisories is available through the Great Lakes Information Network (GLIN) website, (<http://www.great-lakes.net/envt/flora-fauna/wildlife/fishadv.html>).

What can I do to help?

- ***What steps I can take to help stop the spread of botulism?***

Identifying possible cases of avian botulism at the early stages is the key to effective control. Public awareness of the conditions that lead to avian botulism and prompt corrective action can greatly reduce the epidemics which now claim hundreds of thousands of birds each year. Sick and dead birds in areas of avian botulism epidemics should be reported immediately to state and federal wildlife agencies. ^v Contacting your local education and outreach organization may also aid in their efforts to track outbreaks, and they can provide you with answers to additional questions. (*Please see contact information listed below*).

Immediate removal of dead birds and fish can also help prevent the spread of botulism, as the bacteria in the carcasses can serve as the source of outbreaks for months. Follow appropriate safety and disposal methods. (See also:

- *How can people who want to help clean up the beach after a bird kill best protect themselves?*
 - *What is the best way to dispose of dead fish/birds in my area, especially after a botulism outbreak?*
- ***How should I notify authorities of a potential botulism related fish or bird kill?***

In case of a die-off, individuals are urged to contact local agencies responsible for fish and wildlife management to report fish and bird mortalities. (*See contact numbers listed below*). It is important to record the location, type of birds or fish, and number of carcasses found.^{ix} By reporting accurate information about botulism, you will assist natural resources managers and others involved in wildlife conservation planning.

- ***How can people who want to help clean up the beach after a bird kill best protect themselves?***

People who handle dead wildlife should wear protective gear, such as disposable rubber gloves or an inverted plastic bag over their hands. In cases where a diseased or dead bird is handled without gloves, hands should be thoroughly washed with hot, soapy water or an anti-bacterial cleaner.

Please refer to: *What is the best way to dispose of dead fish/birds in my area, especially after a botulism outbreak?* for advice on wildlife disposal methods.

- ***What is the best way to dispose of dead fish/birds in my area, especially after a botulism outbreak?***

Be sure to follow local wildlife agency (e.g., Natural Resources, Fish and Wildlife, etc.) recommendations in handling dead fish and wildlife. Wear disposable, rubber or plastic gloves or invert a plastic bag over your hands when handling sick, dead, or dying fish, birds or other animals. In certain areas, burying of the carcasses is allowed, while in other areas incineration may be recommended. If birds are to be collected, they should be placed in heavy plastic bags to avoid the spread of botulism-containing maggots.^{ix}

The major goal should be to protect yourself, while also ensuring that the dead birds or fish are not available for consumption by other wildlife.

- ***Is rehabilitation of sick birds possible? If so, how, and who should I contact about it?***

Rehabilitation is unusual, but may be possible in cases where birds did not ingest a large amount of the toxin. Recovery can be aided by providing these birds with rest, fresh water and shade. They should be protected from predators during this process.

A botulism antitoxin is available, but it requires special handling and must be given early on. Surviving an outbreak will NOT give birds immunity to botulism.^x

Please remember that extreme caution should be practiced when handling wildlife. Contact the local office of your state's wildlife management agency for more information about rehabilitation possibilities. (*See contact numbers listed below*).

Contact Information

Canada

If you recognize sickness or death in Canadian wildlife, report this to local wildlife officials or make a report directly to the Canadian Cooperative Wildlife Health Center (CCWHC):

Call the Ontario/Nunavut Region office (Toll-Free in Ontario only): 1-866-673-4781
(Long Distance Charge 1-519-824-4120 Ext. 54662)

Email: ccwhc@ovc.uoguelph.ca

-or-

Call the National Toll-Free number (across Canada) to be routed to the Ontario/Nunavut office: 1-800-567-2033

Email: ccwhc@usask.ca

You can also call Ducks Unlimited Canada for other questions about botulism, or to report Canadian bird mortalities

Toll free: 1-800-665-DUCK

Illinois and Indiana

For botulism-related questions in Illinois or Indiana:

Elizabeth Hinchey Malloy, Illinois-Indiana Sea Grant

Email: hinchey.elizabeth@epa.gov

Phone: (312) 886-3451

Website: <http://www.iisgcp.org/>

Michigan

For questions about botulism (or any wildlife diseases), or to report a suspected Botulism outbreak in Michigan:

Dr. Tom Cooley, Michigan Department of Natural Resources (MDNR), Wildlife Disease Laboratory

Lab email: cooleytm@michigan.gov

Phone: (517) 336-5034

For other botulism-related questions in Michigan:

Mark Brederland, Michigan Sea Grant

Email: brederl@msu.edu

Phone: (231) 922-4628

Website: www.miseagrant.umich.edu

New York

For questions about Fish and Wildlife, or to report a suspected botulism outbreak in New York:

New York State Department of Environmental Conservation

Buffalo: (716) 851-7010; Avon: (585) 226-2466; Syracuse: (315) 426-7400; Cortland: (607) 753-3095; Watertown: (315) 785-2261; Cape Vincent Research Fisheries Station: (315) 654-2147; Lake Erie Fisheries Research Unit: (716) 366-0228

For other botulism-related questions in New York:

Helen Domske, New York Sea Grant

E-mail: hmd4@cornell.edu

Phone: (716) 645-3610

Website: <http://www.seagrant.sunysb.edu/botulism/default.htm>

Ohio

For botulism-related questions in Ohio:

Frank Lichtkoppler, Ohio Sea Grant

E-mail: Frank.Lichtkoppler@lakecountyohio.gov

Phone: (440) 350-2267

Websites: <http://www.seagrant.sunysb.edu/botulism/default.htm> or <http://www.sg.ohio-state.edu/>

For other fish or wildlife-related questions in Ohio:

Ohio Department of Natural Resources, Division of Wildlife

Email: wildinfo@dnr.state.oh.us

Phone: 1-800-WILDLIFE (1-800-945-3543)

Website: <http://www.dnr.ohio.gov/wildlife/default.htm>

Pennsylvania

To report dead or dying birds in Pennsylvania call:

- PA Game Commission at: (877) 877-0299
- Presque Isle State Park: (814) 833-7424
- Erie County Health Department: (814) 451-6700

For botulism-related questions in Pennsylvania:

Eric Obert, Pennsylvania Sea Grant

E-mail: ecol@email.psu.edu

Phone: (814) 217-9018

Websites: <http://www.pserie.psu.edu/seagrant/publications/botulism.htm> or <http://www.seagrant.sunysb.edu/botulism/>

United States (general)

For additional information on botulism or any other federal wildlife health issue in the U.S.:

USGS, National Wildlife Health Center

Phone: (608) 270-2400

Website: <http://www.nwhc.usgs.gov/>

Wisconsin

For botulism-related questions in Wisconsin:

Victoria Harris, Wisconsin Sea Grant

Email: harrisv@aqua.wisc.edu

Phone: (920) 465-2795

Website: <http://www.seagrant.wisc.edu/>

For general fish and wildlife questions in Wisconsin:

Wisconsin Department of Natural Resources, Bureau of Wildlife Management
Website: <http://dnr.wi.gov/org/land/wildlife/>

For rehabilitation of sick birds in the Green Bay area of Wisconsin:

Bay Beach Wildlife Sanctuary, rehabilitation center

Phone: (920) 391-3685

Website: www.baybeachwildlife.com

FAQ Sources and Websites of Interest

- i.) Pennsylvania Sea Grant factsheet on botulism:
http://www.pserie.psu.edu/seagrant/publications/fs/Botulism_12-2003.pdf
Citation:
Pennsylvania Sea Grant and Penn State Erie. 2003. Botulism Factsheet:
http://www.pserie.psu.edu/seagrant/publications/fs/Botulism_12-2003.pdf.
- ii.) Canadian Cooperative Wildlife Health Centre website on botulism:
http://wildlife1.usask.ca/wildlife_health_topics/botulism/botulisme.php
Citation:
Leighton, F.A. *Wildlife Health Topics, "Botulism"*. Canadian Cooperative Wildlife Health Centre (CCWHC), March 2000,
http://wildlife1.usask.ca/wildlife_health_topics/botulism/botulism.php
(accessed December 2006).
- iii.) Mortality figures from internal databases maintained by the USGS - National Wildlife Health Center. Estimate totals compiled in February, 2007.
- iv.) Sleeping Bear Dunes mortality estimates supplied via personal communication with Ken Hyde, Sleeping Bear Dunes National Lakeshore, 1 March 2007.
<http://www.nps.gov/slbe/>
- v.) Michigan DEQ website on botulism: http://www.michigan.gov/dnr/0,1607,7-153-10370_12150_12220-26493--,00.html
Citation:
Michigan State Department of Natural Resources. *Michigan Wildlife Disease Manual, "Botulism"*. State of Michigan, 2001-2006,
http://www.michigan.gov/dnr/0,1607,7-153-10370_12150_12220-26493--,00.html (accessed December 2006).
- vi.) 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.
- vii.) Environment Canada, Prairie and Northern Region website's page on Type C avian botulism: <http://www.pnr-rpn.ec.gc.ca/nature/migratorybirds/avianb/dc22s00.en.html>
Citation:
Avian Botulism Task Force. *Avian Botulism*. Environment Canada, Prairie and Northern Region, 27 November 2006, <http://www.pnr-rpn.ec.gc.ca/nature/migratorybirds/avianb/dc22s00.en.html> (accessed December 2006).

- viii.) NY DEC website's botulism FAQ:
<http://www.dec.state.ny.us/website/dfwmr/faqbotu.html>
Citation:
New York State Department of Environmental Conservation. *Type E Botulism in Lakes Erie and Ontario - Q & A*,
<http://www.dec.state.ny.us/website/dfwmr/faqbotu.html> (accessed December 2006).
- ix.) NY-PA-OH Sea Grant website on botulism:
<http://www.seagrant.sunysb.edu/botulism/default.htm>
Citation:
New York, Pennsylvania and Ohio Sea Grant. *NY/PA/OH Sea Grant: Botulism in Lakes Erie, Ontario*, 30 November 2006,
<http://www.seagrant.sunysb.edu/botulism/default.htm> (accessed December 2006).
- x.) USGS National Wildlife Health Center website on avian botulism:
http://www.nwhc.usgs.gov/disease_information/avian_botulism/index.jsp
Citation:
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).
- xi.) Michigan Sea Grant web page on avian botulism:
<http://www.miseagrant.umich.edu/habitat/avian.html>
Citation:
Michigan Sea Grant. *Avian Botulism*, 30 January 2007,
<http://www.miseagrant.umich.edu/habitat/avian.html> (accessed February 2007).