An Overview of Botulism Type E in Waterbirds on the Lower Great Lakes

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Spores of *Clostridium botulinum* Type E are widely distributed in aquatic ecosystems, but Type E intoxication has only rarely been associated with large-scale wildlife mortality. Since 1998, annual outbreaks of Type E botulism have occurred in Lake Huron and in Lakes Erie and Ontario, involving many thousands of shorebirds, gulls, terns, diving ducks, mergansers, grebes and loons. Unusual in terms of the number of avian species involved, their geographic scope, their size and their repetitive nature, these outbreaks may reflect fundamental shifts in the ecology of the lower Great Lakes, possibly associated with invading alien species.

The harbinger of this series of annual outbreaks occurred on the southeastern shore of Lake Huron in autumn 1998, when Type E botulism killed hundreds of common loons (*Gavia immer*). In subsequent years (1999, 2002) outbreaks in this area involved not only loons but gulls (*Larus* spp.) and grebes (*Podiceps* spp.).

Type E botulism on Lake Erie was first confirmed in gulls dying during summer 1999 at Presque Isle, Pennsylvania on the south shore. In autumn 1999, Type E botulism killed about 6,000 red-breasted mergansers (*Mergus serrator*), loons and grebes along the north shore of the west basin of Lake Erie. Over the next four years, Type E botulism on Lake Erie adopted a general annual pattern. In summer, local, usually relatively small-scale outbreaks involved scores to hundreds, rarely thousands, of resident gulls, terns (*Sterna* spp), double-crested cormorants (*Phalacrocorax auritus*) and shorebirds (Scolopacidae). In autumn larger outbreaks killed many hundreds to many thousands of southbound migrant fish-eating birds (mainly red-breasted mergansers, common loons, grebes) and diving ducks (mainly long-tailed ducks *Clangula hyemalis*). Fish-eating birds and diving ducks generally died off-shore; where the carcasses drifted in was determined by the prevailing winds.

The location of major outbreaks on Lake Erie shifted from the west basin (1999) to involve both the central basin and east basin (2000-2004), latterly concentrating in the east basin (2002-2004). Major mortalities were those of 1999 referred to above; 2000, when about 6,000 fish eating birds washed onto the New York shore at the east end of the lake; 2001, when 3,000 gulls, fish-eating birds and long-tailed ducks died along the New York shore; 2002, when over 3,000 ring-billed gulls (*Larus delawarensis*) died near Buffalo NY, and 12,600 long-tailed ducks and over 3,000 fish-eating birds came ashore on the New York coast; 2003 when 2,000 loons and hundreds of gulls and long-tailed ducks died on both sides of the east basin; 2004, when about 2,800 loons, 2,700 long tailed ducks, and hundreds of birds of other species were found on the New York shore.

Type E botulism was first confirmed on Lake Ontario in 2002, when it occurred in gulls and affected about 675 long-tailed ducks along the New York shore. About 1,500 deaths attributed to botulism occurred in gulls, diving ducks, cormorants and loons on the New York side of Lake Ontario in 2003, and botulism occurred in great black-backed gulls at the east end of the lake on the Canadian side. In 2004, over 1,750 carcasses were counted on breeding colonies and beaches at the east and west ends of Lake Ontario in late summer/fall: mainly double-crested cormorants, great black-backed gulls, long-tailed ducks and white-winged scoters (*Melanitta fusca*). On the New York shore about 1700 birds died, including long-tailed ducks, ring-billed gulls, cormorants, and common loons.

Since 1998 Type E botulism has been confirmed by mouse protection test in the following avian species from the lower Great Lakes: common loon, red-throated loon (*Gavia stellata*), horned grebe (*Podiceps auritus*), red-necked grebe (*Podiceps grisegena*), eared grebe (*Podiceps nigricollis*), great blue heron (*Ardea herodias*), ring-billed gull, herring gull (*Larus argentatus*), great black-backed gull (*Larus marinus*), Bonaparte's gull (*Larus philadelphia*), double-crested cormorant, red-breasted merganser, long-tailed duck, white-winged scoter, greater scaup (*Aythya marila*), common goldeneye (*Bucephala clangula*), American golden plover (*Pluvialis dominica*), sanderling (*Calidris alba*), semipalmated sandpiper (*Calidris pusilla*), American coot (*Fulica americana*), bald eagle (*Haliaeetus leucocephalus*), American crow (*Corvus americanus*). The population implications of recurrent botulism mortality on less common avian species are unknown.

Fish-eating birds dying during botulism outbreaks often had remains of fish in the ventriculus, the most common species identified being the round goby *(Neogobius melanostomus)*. A few abnormally behaving live fish, especially sheepshead (*Aplodinotus grunniens*), collected in New York waters, have contained detectable botulinus Type E toxin, supporting the contention that live intoxicated fish are available for consumption by fish-eating birds. Die-offs of mudpuppies (*Necturus maculosus*) sometimes were associated with mortalities, especially among gulls, while zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*) were present in the ventriculi of many divinged ducks and a few fish-eating birds. The presence of incompletely digested food items in the ventriculus of some birds suggests that they died rapidly after ingestion of toxin-laden prey.

Outbreaks were first observed on the southeast shore of Lake Huron and in the west basin of Lake Erie, moving eastward down Lake Erie, and ultimately into Lake Ontario, over a seven-year period. Predisposing factors may include ecological perturbations associated with eruptions of invasive alien zebra and quagga mussels, natives of the Black and Caspian Seas, first observed in the St. Clair river between Lakes Huron and Erie in 1988, and round gobies, also native to the Black and Caspian Seas, first detected in the same area in 1990. *Dreissena* spp. and gobies have rapidly expanded their range throughout the Great Lakes, and produce enormous biomass. In eastern Lake Erie the round goby first emerged as a prominent component of the forage fish community beginning in 2000, coincident with the first observations of widespread bird and fish mortalities in this area.

Type E botulism toxin may be produced by clostridia proliferating in a suitable redox environment in the extensive mussel beds on the lake bottom, and may be concentrated in mussels. Fish such as gobies, which are specialist mussel predators, may acquire toxin through feeding in mussel beds, and may then act as a source of toxin for predatory fish or for fish-eating birds higher in the food web. Mussel-feeding diving ducks may acquire toxin directly, rather than via a fish 'vector'. Scavengers such as gulls may acquire toxin through consumption of toxin-containing carcasses, and shorebirds through consumption of toxic invertebrates.