Section 11: Significant Ongoing and Emerging Issues

Photo: U.S. Fish & Wildlife Service

11.1 Introduction

The dynamic nature of Lake Erie means that things change, often unpredictably. Section 2 describes how the issues of concern in the lake have changed over time. Some of the issues were resolved through management actions over a short period of time, while others required long-term and ongoing management plans. Some goals, such as phosphorus concentrations in the lake, were considered achieved until zebra mussels invaded and concentrations began fluctuating again. The invasion of a host of new non-native species has created much alteration in the biological community. The ecosystem management objectives for Lake Erie attempt to set goals for management actions in the areas of land use, nutrient management, contaminants, resource use and non-native invasive species. It may be necessary to continually revisit these goals as new unexpected situations arise. This section provides some insight into programs and problems that are currently important in the lake, as well as those that may be emerging as important future issues. The adaptive management approach of the LaMP process accepts the fact that change is inevitable. The challenge to the LaMP is to keep abreast of lake conditions, identify and encourage research in areas needed to make the appropriate management decisions, and modify management goals and actions when needed.

11.2 2003 Update on Non-Native Invasive Species in Lake Erie *(Prepared by Lynda D. Corkum & Igor A. Grigorovich, University of Windsor)*

A detailed overview on the history of non-native invasive species in Lake Erie was presented in Section 11 of the Lake Erie LaMP 2000 document. An update of ongoing and emerging issues (including non-native invasive species) was presented in Section 10 of the 2002 Lake Erie LaMP report. This is the second update on the status of non-native invasive species (NIS) in Lake Erie. The material presented represents new information on NIS (and anticipated invasions) as well as historical information that was not presented in the previous reports.

Of the approximately 170 NIS in the Laurentian Great Lakes drainage basin (A. Ricciardi, McGill University, personal communication), there are about 132 NIS in the Lake Erie watershed, including: algae (20 species), submerged plants (8 species), marsh plants (39 species), trees/shrubs (5 species), disease pathogens (3 species), molluscs (12 species), oligochaetes (9 species), crustaceans (9 species), other invertebrates (4 species), and fishes (23 species) (Leach 2001). The number of NIS is a conservative estimate because small organisms, or those that are difficult to classify, are typically less well studied.

The increase in NIS during the 20th century is attributed to the shift from solid to water ballast in cargo ships and to the opening of the St. Lawrence Seaway in 1959 (Mills et al. 1993). Ballast water discharge from ships has been the primary vector for NIS entering the Great Lakes (Mills et al. 1993). Despite voluntary (1989-1992) or mandatory (1993 onward, United States Coast Guard, 1993) compliance with the ballast water exchange program, the rate of NIS introductions from 1989 to 1999 has tripled compared to the previous three decades (Grigorovich et al. 2003a). Unfortunately, vessels with cargo designated with "no ballast on board" (NOBOB) status are not subject to regulations even though these vessels carry residual ballast water and associated organisms (Bailey et al. 2003). Between 1981 and 2000, about 72% of NOBOB vessels made their first stop at Lake Erie ports where they unloaded cargo and took on Great Lakes water to compensate for the loss in cargo weight (Grigorovich et al. 2003a). The mixing of water with residual sediment could result in increased invasions. The Lake Huron-Lake Erie corridor has been identified as one of the four invasion "hotspots" along with the Lake Erie-Lake Ontario corridor, the Lake Superior-Huron corridor and the western end of Lake Superior (Grigorovich et al. 2003a). The hotspots represent less than 5.6% of the total Great Lakes water surface area, but account for more than half of the NIS documented since 1959 (Grigorovich et al. 2003a).

Lake Erie ranks second to Lake Ontario (31 sites) of all Great Lakes for first records of NIS. There have been 22 sites in the open waters of Lake Erie where non-native invasive aquatic animals and protists were first reported (Table 11.1). Explanations for the large number of NIS reported in the lower Great Lakes may be due to the intensive sampling in the region, similar physical/chemical characteristics between donor and recipient regions, lake productivity, and facilitation of invasion by previously established invaders. Given the many species introductions into Lake Erie by human activities, natural barriers to dispersion and gene flow among the Great Lakes have been essentially eliminated (de LaFontaine and Costan 2002).

There have been reports of new invaders in Lake Erie. Protozoans (Rhizopoda), *Psammonobiotus communis* (two sites east of Wheatley to Rondeau on the north shore of Lake Erie) and *P. dziwnowii* (eastern Lake Erie), were reported in a 2002 survey of Lake Erie (Nicholls and MacIsaac 2004). It is likely that these euryhaline species entered the Great Lakes through ballast water. *Psammonobiotus communis* is pandemic, whereas *P. dziwnowii* was found only on the Polish coast of the Baltic Sea before it was reported in Great Lakes waters. A new species, *Corythionella golemanskyi*, also has been described. These three species have been described from several Great Lake locations where they occur in beach sand. It is likely that these species became established long ago, but investigators simply had not looked for them (Nicholls and MacIsaac 2004).

Lake Erie proper has 34 non-native invasive fish species and new species are likely to enter the lake from the Mississippi drainage basin and from adjacent lakes. The common carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*) were likely the first introduced fishes into the Great Lakes. Carp were intentionally introduced into the Great Lakes in 1879 as a food fish (Emery 1985). By the 1890s, carp were "very abundant in the Maumee River at Toledo, Ohio and in the west end of Lake Erie" (Kirsch 1895). Carp are a nuisance because they degrade habitat for native fish and waterfowl and feed on eggs of other fish (Fuller et al. 1999). Goldfish, often cultured for bait and used in the aquarium trade, may have been the first foreign fish to be introduced to North America (Courtenay et al. 1984). Back-crossing and hybridization between goldfish and carp is common. In Lake Erie, hybrids may be more abundant than either parental species (Trautman 1981). Western Lake Erie has some of the largest populations of goldfish in the continental United States (Fuller et al. 1999), particularly in the shallower waters of the basin with dense vegetation and in the low-gradient tributaries of the lake (Trautman 1981).

Table 11.1: Non-native Metazoans and Protists First Established in Lake Erie Since the 1800s (Grigorovich et al. 2003b). Taxonomic groups are listed from most ancient to most advanced; species are listed in alphabetical order within each taxonomic group. The Protista were reported in hosts of other animals.

Number	Taxonomic Group	Species Name	Year of 1st Discovery	Location
1	Protista	*Acineta nitocrae*	1997	Lake Erie
2	Protista	*Glugea hertwigi*	1960	Lake Erie
3	Protista	*Myxosoma cerebralis*	1968	Ohio drainage, Lake Erie
4	Cnidaria	*Cordylophora caspia*	1956	Lake Erie
5	Cnidaria	*Craspedacusta sowerbyi*	1933	Lake Erie
6	Bryozoa	*Lophopodella carteri*	1934	Lake Erie
7	Mollusca	*Cipangopaludina japonica*	1940	Lake Erie
8	Mollusca	*Corbicula fluminea*	1980	Lake Erie
9	Mollusca	*Dreissena bugensis*	1989	Port Colborne, Lake Erie
10	Mollusca	*Pisidium moitessierianum*	1895	Lake Erie
11	Annelida	*Barbidrilus paucisetus*	2001	Lake Erie
12	Annelida	*Potamothrix vejdovskyi*	1965	Lake Erie
13	Annelida	*Pristina acuminata*	1977	Lake Erie
14	Annelida	*Pristina longisoma*	2001	Lake Erie
15	Annelida	*Psammoryctides barbatus*	2001	Lake Erie
16	Crustacea	*Daphnia galeata*	1980s	Lake Erie
17	Crustacea	*Daphnia lumholtzi*	1999	Lake Erie
18	Crustacea	*Echinogammarus ischnus*	1994	Lake Erie
19	Crustacea	*Eurytemora affinis*	1991	Lake Erie
20	Pisces	*Lepomis humilis*	1929	Lake Erie
21	Pisces	*Oncorhynchus kisutch*	1933	Lake Erie
22	Pisces	*Phenacobius mirabilis*	1950	Ohio drainage, Lake Erie

There have been a few instances of accidental occurrences of other species of Asian carp in Lake Erie. In 2000, there were unusual sightings of the Chinese bighead carp, *Hypophthalmichthys nobilis*. On October 16, 2000, the third specimen ever of Chinese bighead carp was caught in a trap net on the west side of Point Pelee in the western basin of Lake Erie (T. Johnson, Ontario Ministry of Natural Resources, Wheatley, personal communication). The fish is native to eastern China and introduced into the United States in 1973. The 2000 sighting was probably the result of a fish escape from aquaculture ponds (T. Johnson, personal communication). In October 30, 2003, a grass carp (*Ctenopharyngodon idella*) was caught at the mouth of the Don River, Lake Ontario (Beth MacKay, OMNR, personal communication). It is believed that this record was an isolated occurrence and that there are no established populations of grass carp in the Great Lakes. Earlier (1985), a grass carp was reported from Lake Erie.

Southern U.S. fish farmers introduced several species of Asian carp to control vegetation (grass carp), algal blooms (bighead and silver carp) and snails (black carp) in aquaculture facilities. The grass carp, bighead carp, silver carp (*Hypophathlmichthys molitrix*) and the black carp (*Mylopharyngodon piceus*) have been released and/or have escaped into the wild. All of these species are large fish with adults ranging from 20 to 40 kg. Both bighead carp and silver carp are moving upstream in the Mississippi and Illinois Rivers towards the Great Lakes basin (Taylor et al. 2003). These species of Asian carp will likely spread into the Great Lakes if mechanisms are not established to stop their upstream spread. Bighead and silver carp are a threat to Great Lakes fish because they filter and consume plankton. The competition threat from these species exists for all fish because each fish species consumes plankton early in development. There is also anticipated competition between the Asian carp and adults of commercially important lake whitefish, *Coregonus clupeaformis,* and bloaters, *Coregonus hoyi*, that rely on plankton.

An electric barrier (energized in April 2002) on the Des Plaines River, Illinois, was designed to impede the exchange of organisms between the Great Lakes and Mississippi basins. In addition to the electric barrier, other guidance systems (Sound Projection Array, SPA) are being tested to deter the species of Asian carp from upstream movement. The SPA uses an air bubble curtain that creates a wall of sound that deters fish away from designated regions. This technique combined with a graduated electric field barrier was effective in laboratory studies in repelling 83% of fish that attempted to cross the barrier (Taylor et al. 2003). Field studies on the effectiveness of the electric barrier in preventing fish passage are on-going.

Kolar and Lodge (2002) used a quantitative model to predict potential invasive fishes and their impact in the Laurentian Great Lakes. If introduced, five Ponto-Caspian fishes will likely become established in the Great Lakes and are expected to spread quickly (Table 11.2). Intentional introductions result from aquaculture, sport fishing, pet trade and bait fishes. Three species (Eurasian minnow, European perch and monkey goby) are currently in the water garden or aquarium trade in Europe.

Table 11.2: Ponto-Caspian Fishes and Pet, Sport, Aquaculture and Bait Species Predicted to Become Established in the Great Lakes if Introduced (Kolar and Lodge 2002). Family names are listed from most ancient to most derived groups.

Family	Scientific name	Common name	Unintentional Introductions	Intentional Introductions
Clupeidae	*Clupeonella cultriventris*	Tyulka	X	
Cyprinidae	*Phoxinus phoxinus*	Eurasian minnow	X	
Cyprinidontidae	*Aphanius boyeri*	Black Sea silverside	X	
Percidae	*Perca fluviatilis*	European perch		X
Gobiidae	*Neogobius fluviatilis*	Monkey goby		X

The non-native invasive round goby fish has continued to expand its range in the Great Lakes basin. The fish entered western Lake Erie in 1993 and, since 1999, has occupied all three basins of the lake. There were an estimated 14.5 billion round gobies in western Lake Erie in 2001 (Johnson et al. 2003). Videography was the most effective tool (in comparison with trawls or traps) used to determine the density of this bottom-dwelling species (Johnson et al. 2003). Lee (2003) determined that the round goby population in western Lake Erie consumes more than 2.6×10^4 tonnes of benthic prey each year, 17% of which is represented by invasive dreissenids. Clearly, zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*) have facilitated the establishment of the round goby.

Efforts in Great Lakes jurisdictions are being made (and more are needed) to control the entry of non-native invasive species introduced through ballast water, canals and recreational boating (Vásárhelyi and Thomas 2003). However, there are relatively few practices in place to control established invasive species without affecting non-target species or resulting in collateral environmental damage. Because attempts to eliminate a NIS throughout an ecosystem are not possible, control programs are typically species and site specific. "Introductions, like extinctions, are forever" (Marsden 1993).

One recent example to develop an effective control measure focuses on reducing the reproductive success of the round goby. Laboratory findings support the hypothesis that mature female round gobies actively respond by moving to sex attractants released by conspecific males (Corkum et al. 2003). It is expected that the application of this research will lead to the development of a control strategy using natural pheromones to disrupt reproductive behaviours of the invasive round goby. Because juvenile and adult round gobies feed on eggs of several native fishes (lake trout, Chotkowski and Marsden 1999; lake sturgeon, Nichols et al. 2003; and smallmouth bass, Steinhart et al. 2004), there is great value in reducing the reproductive success of this invasive predator. The ultimate goal is to develop a pheromone trap that targets round gobies (and no other species) to be deployed at known spawning locations of native fishes where round gobies co-occur and are known to prey on eggs of native fishes (Corkum et al. 2003).

Although the focus of NIS in Lake Erie is on aquatic invasive species, a metallic wood-boring beetle (Family, Buprestidae), known as the emerald ash borer (*Agrilus planipennis*), has damaged millions of ash trees in the western Lake Erie drainage basin (Michigan, Department of Agriculture Fact Sheet). The exotic beetle, native to Asia, was first discovered in southeast Michigan in 2002. It has now spread to northwest and central Ohio. Many infested trees in these areas have been cut down and burned. The beetle also has been reported in Windsor, Ontario, and is expanding throughout Essex County into southwestern Ontario. A quarantine is established to help prevent the movement of ash trees and ash products outside the infested regions. Evidence of infestation is the characteristic D-shaped beetle exit holes on the branches and trunks on ash trees. Although little is known about the control or management of this pest, research projects are currently underway.

Once NIS colonize a waterbody, become established, disperse and ultimately affect either native species or habitat, the management options to control the species become more limited at each step in the process (Kolar and Lodge 2002). In November 2001, Environment Canada and the Ontario Ministry of Natural Resources organized a national workshop on invasive alien species to identify issues in the management of invasive species. Since then, the federal, provincial and territorial Ministers for Wildlife, Forests, and Fisheries and Aquaculture approved a "blueprint" for a National Plan and requested the establishment of four working groups including: 1) invasive aquatic species; 2) terrestrial animals; 3) terrestrial plants; and, 4) leadership and co-ordination. A discussion document was prepared, providing a hierarchical approach to respond to invasive alien species that prioritizes: 1) the prevention of new invasions; 2) the early detection of new invaders; 3) rapid response to new invaders; and, 4) the management of established and spreading invaders (containment, eradication, and control) (Anonymous 2003) (Beth MacKay, OMNR, personal communication).

Public awareness efforts are essential in reporting, preventing and slowing the spread of established non-native invading species. The Great Lakes Sea Grant Network in the United States and the Ontario Federation of Anglers and Hunters in collaboration with the Ontario Ministry of Natural Resources have established effective Invasive Species Awareness programs (Dextrase 2002). There is a Great Lakes Panel on Aquatic Nuisance Species to develop and co-ordinate invasive species in the Great Lakes basin. For information, contact the Great Lakes Commission web site (www.glc.org), Sea Grant State Offices or the Ontario Federation of Anglers and Hunters Invasive Species Hotline at 1-800-563-7711. It is the collaborative and co-operative efforts among the public, government agencies, non-government agencies, academic institutions and industry that will result in effective management of non-native invasive species (Dextrase 2002).

Photo: Eric Engbretson, U.S. Fish & Wildlife Service

11.3 Nutrients and the Food Web: a Summary of the Lake Erie Trophic Status Study *(Presented at the Lake Erie Millennium Network Third Biennial Conference 2003, prepared by Jan Ciborowski, University of Windsor)*

Photo: Upper Thames River Conservation Authority

Long-term records relating to Lake Erie's nutrient status suggest a process of reduced nutrient status. U.S. EPA's water quality data show a downward trend of eutrophy (the Carlson Trophic State Index) for the period 1983-2000. Furthermore, concentrations of total phosphorus in the water, averaged over the whole year have been falling by about 0.2 mg/m^3/yr. However, the amounts of nutrients present in the water in early spring have continued to rise, extending to eight years a trend that was first seen in 1995. Much of the among-year variation in the amount of phosphorus entering the lake over the last few years is due to the intensity and timing of storms, which cause flooding and erosion, rather than to municipal inputs. Data from the last several years indicate that more phosphorus is leaving Lake Erie in the waters of the Niagara River than is entering the Lake from the major tributaries.

The period of water turbidity associated with spring is persisting longer than formerly. The planktonic algal cells are smaller than they were in the 1980s, and there seem to be more algae during the spring than in the late 1990s. However, zooplankton are not more abundant than previously. Over the period 1991-2000, the biological demand for oxygen in the bottom waters of Lake Erie's central basin has not changed, when averaged over the whole year. Biological oxygen demand of the sediments seems to increase over the course of the summer.

In summertime, light is penetrating deeper into the water - algae are now growing (and producing oxygen) in the deep layers of the central basin and on the western and central basin lake bottoms. Extensive layers of the filamentous alga, *Cladophora* are common along rocky shorelines around the Lake. There is also more bacterial activity deep in the water, but there are very few planktonic algae in the shallow water near shore, where zebra mussels are most abundant. There is only limited evidence that the scarcity of planktonic algae is due to nutrient limitation, either in the spring, or later in summer. Microbes in the water are more likely to be limited by the availability of carbon than by either phosphorus or nitrogen. Studies to determine if the scarcity of trace metals such as iron, copper or zinc may be limiting algal production have been inconclusive. The picoplankton are most responsive to experimental additions of these metals.

Populations of dreissenid (zebra and quagga) mussels and *Hexagenia* mayflies are steady or declining. The development of thick mats of algae along shorelines, especially in the eastern and central basins, reduces the living space available for dreissenid mussels. Zebra mussels have all but disappeared from eastern and central basins, being supplanted by quagga mussels. Overall mussel densities seem to be lower than in recent previous years, possibly because there are so many gobies now in the lake. The diversity and abundance of invertebrate animals, especially mayflies and net-spinning caddisflies in the wave-washed zone of the shoreline, have dropped markedly since the last time they were surveyed in the 1970s.

The goby population in Lake Erie is large, but the numbers are quite a bit lower than they were two years ago. Most of the gobies occur in rocky and sandy areas closer to shore in all three basins. Gobies will likely become an acceptable source of food for walleye. Gobies are now common in the diets of almost all of the Lake Erie sports fish.

Evidence seems to suggest that we are seeing new pathways of internal cycling of nutrients, likely caused by the activities of dreissenids, which may be altering the size structure and dynamics of particles in Lake Erie. However, the consequences of physical (weather-related) influences cannot be ruled out as an accompanying explanation for the apparent increasing frequency and extent of central basin anoxia events. The persistent periods of spring turbidity may be due to the effects of heavy fall and winter storms, which contribute more sediment for a given amount of precipitation than summer storms. Also, cold water is more viscous than warm water, causing particles to settle more slowly. Spring water temperatures in 2002 and 2003 have been among the coldest on record, perhaps partly accounting for the greater concentrations of spring turbidity and possibly associated nutrients.

11.4 Double-Crested Cormorants in the Great Lakes
(Prepared by Mike Bur, USGS)

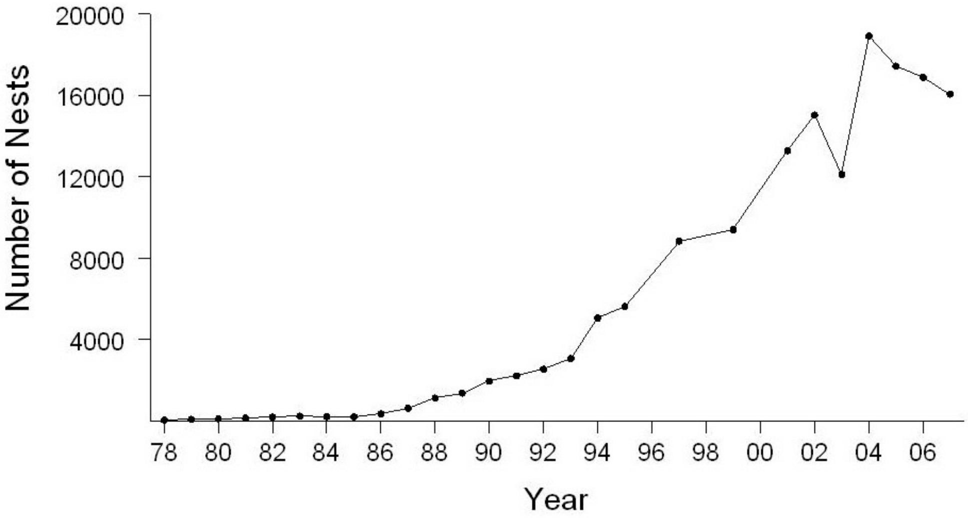

Photo: Lee Karney, U.S. Fish & Wildlife Service

Double-crested cormorants are colonial waterbirds that breed in large colonies, often mixed with other species, and nest on the ground or in trees. They have an extensive range in North America, occurring throughout the interior as well as on both coasts. For the contiguous United States as a whole, the breeding population increased at an average rate of 6.1% per year from 1966 to 1994, and now stands at approximately 370,000 breeding pairs. The total number of breeding and non-breeding birds is estimated at nearly two million birds. Resident populations in the south-central United States disappeared or declined throughout the middle of the 20th century. The interior and California populations declined from 1950 to 1970 (Hatch 1995). However, by the late 1980s most populations were increasing (Jackson and Jackson 1995; Carter et al. 1995; Krohn et al. 1995).

The first report of cormorant nesting on the Great Lakes occurred between 1913 and 1920, and by 1950 the breeding population was at 900 pairs (Weseloh et al. 1995). Human persecution and environmental contaminants led to the virtual extinction of cormorants on the Great Lakes by the early 1970s. From 1970 to 1991, the Great Lakes cormorant population increased from 89 nests to more than 38,000 nests. The population has increased at an annual rate of 23% from 1990 to 1994 (Tyson et al. 1999). Major factors leading to an increase in the Great Lakes population were reduced contaminants and persecution plus an abundance of prey fish (Weseloh et al. 1995; Blokpoel and Tessier 1996). By 2006 there were nearly 119,000 nesting pairs in the Great Lakes. On Lake Erie there has been a dramatic increase in the number of nests. In 1978, there were 58 nests; the nest count peaked at 19,000 in 2004 and, in 2007, the nest count was down to 16,050 (Figure 11.1).

With the burgeoning cormorant population there has been an increase in conflicts with commercial and sport fisheries in the Great Lakes. The common opinion of many fishers is that cormorants have a negative impact on the fish communities. After increasing concerns arose, diet and related studies were conducted to identify impacts of cormorant feeding on the Great Lakes fisheries. The effect of cormorants on fish populations in open waters is less clear than at aquaculture facilities. Studies conducted worldwide have repeatedly shown that while cormorants can, and often do, take fish species that are valued in commercial and sport fisheries, those species usually comprise a very small proportion of the birds' diet. One

Figure 11.1: Total number of double-crested cormorant nests on Lake Erie



study found that in Lake Erie the number of these fish (i.e., yellow perch, smallmouth bass, and walleye) consumed by cormorants was less than 5% of the total consumed (Bur et al. 1999). Other studies suggest that cormorants have the ability to deplete fish populations in localized areas (Burnett 2001; Lantry et al. 1999; Rudstam et al. 2004).

In Canada, double-crested cormorants are managed under the authority of the provincial agencies. The Ontario Ministry of Natural Resources is currently conducting a research program to assess the effects of cormorants on fish stocks, and is working with U.S. state and federal agencies to manage cormorants where necessary and appropriate.

A major concern is the adverse impacts cormorants have on vegetation in nesting colonies and roosting areas. These birds often inadvertently kill trees and vegetation with their feces. Some of these areas include stands of uncommon or rare species, such as the Kentucky coffee tree (*Gymnocladus dioicus*) remaining on most of the Lake Erie islands. Vegetation alteration may affect the ecological balance of an area and, to a lesser extent, possibly lower property, recreational, and aesthetic values. Cormorants can affect other colonial waterbirds at mixed and breeding colonies directly by physical displacement, and indirectly by altering the vegetation (Trapp et al. 1999). Lake Erie's West Sister Island has the largest colonial waterbird colony in the Great Lakes.

Since 1972, depredation permits allowing the taking of double-crested cormorants have been authorized on a case-by-case basis, usually when negative impacts on aquaculture operations and habitat have been demonstrated. Most permits were for birds causing depredation problems at aquaculture operations. The U.S. Department of Agriculture's Wildlife Services Division is responsible for documenting economic losses.

The persistence of conflicts associated with double-crested cormorants, widespread public and agency dissatisfaction with the status quo, and the desire to develop a more consistent and effective management strategy for double-crested cormorants has steered the U.S. Fish & Wildlife Service to the decision to prepare a national cormorant management plan for the contiguous United States. The purpose of the management plan for double-crested cormorants is threefold: to reduce resource conflicts associated with double-crested cormorants in the contiguous United States; to enhance the flexibility of natural resource agencies in dealing with double-crested cormorant-related resource conflicts; and to ensure the conservation of healthy, viable double-crested cormorant populations.

Under an Environmental Assessment, the public resource depredation order authorizes States, Tribes, and U.S. Department of Agriculture's Wildlife Services to manage and control double-crested cormorants to protect public resources (fish, wildlife, plants, and habitats). The order allows control techniques to include egg oiling, egg and nest destruction, cervical dislocation, shooting, and CO_2 asphyxiation. The order applies to 24 states including the Lake Erie states: Michigan, Ohio, Pennsylvania and New York. Agencies acting under the order must have landowner permission, may not adversely affect other migratory bird species or threatened and endangered species, and must satisfy annual reporting and evaluation requirements. The USFWS will ensure the long-term conservation of cormorant populations through annual assessment of agency reports and regular population monitoring.

In recent years, natural resource agencies have conducted population reduction procedures (e.g., egg oiling and shooting) to reduce the populations of cormorants on the Great Lakes. Major justifications were to protect rare native vegetation and reduce impacts on colonial bird nesting habitats. Ohio implemented a double-crested cormorant damage management program in 2005. In the past two years Ohio DNR, U.S. Department of Agriculture's Wildlife Services, and U.S. Fish & Wildlife Service initiated population control measures on several islands in western Lake Erie. In 2006, the population of adult cormorants was reduced by 5,868, and 3,579 cormorants were removed in 2007.

Conservation measures will also protect fish, other birds, vegetation, federally listed threatened and endangered species, water quality, human health, economic impacts, fish hatcheries, property losses, and aesthetic values.

11.5 Status of the Fish Community *(Prepared by Jeff Tyson, Ohio Department of Natural Resources and Rich Drouin, Ontario Ministry of Natural Resources)*

Lake Erie's fisheries differ strongly from the other Great Lakes because the Lake Erie fisheries rely predominantly upon natural reproduction of native species within the lake and its tributaries. Rehabilitation of these environments is critical to restoration of biological integrity of the Lake Erie ecosystem. The Lake Erie Committee of the Great Lakes Fishery Commission has established Fish Community Goals and Objectives and Environmental Objectives to define rehabilitation, and to recognize that the Lakewide Management Plan is vital to recovery of ecosystem integrity. A healthy fish community will be a measure of restoration of that integrity.

Walleye is a critically important species to the ecology and fisheries of Lake Erie. As a top predator with broad distribution, this species is expected to bring more stability to the fish community. Information from tagging and genetics studies shows that the population is composed of several distinct stocks. There are three major spawning sites in western Lake Erie: the Maumee River, Sandusky River, and the island shoals. There are also three major spawning areas in eastern Lake Erie: the New York shoreline, Grand River (ON) and nearby shoals. The success of Lake Erie's walleye in reproduction depends on environmental conditions at these sites (e.g., total suspended solids in the Maumee and Grand Rivers) and other river and lake habitats that support the early life history of this species.

The walleye population built up in the 1980s with the help of two very strong year classes, but began a long-term decline in the 1990s. The Lake Erie Committee of the Great Lakes Fishery Commission recognized the need to protect the reproductive potential of the population under the "Coordinated Percid Management Strategy." Harvest levels were reduced from 2001 to 2003 by Ontario, Michigan, New York, Ohio and Pennsylvania. Conservative harvest levels were established earlier in eastern Lake Erie (East Basin Rehabilitation Plan 2000-04) in Ontario's jurisdiction.

Subsequent to implementation of the Coordinated Percid Management Strategy, the Lake Erie Committee has developed a Walleye Management Plan with an exploitation strategy that is tied to population abundance. At lower population levels, exploitation rates are reduced significantly, while at higher abundances exploitation rates are higher. The intent of this exploitation strategy is to reduce fishing mortality at low abundances to enhance the recovery of the population to sustainable levels. A strong year class of walleye in 2003 provided the potential to bring the population back up to desirable levels; however, recruitment of subsequent year classes has been well below long-term averages. In accordance with the Walleye Management Plan it will be necessary to have the new exploitation strategy in place for several years to determine whether the strategy adequately addresses overall walleye abundance and fish community stability.

The yellow perch population in Lake Erie also declined in the 1990s, but its recovery began with the strong 1996-year class in the western and central basins. A strong year class in 1998 has supported recovery in eastern Lake Erie. Recovery in all three basins has continued with strong year classes in 2001 and 2003. The Lake Erie Committee is also in the process of developing a Fisheries Management Plan and exploitation strategy for yellow perch that is similar to the Walleye Management Plan.

Photo: Mike Weimer, U.S. Fish & Wildlife Service

Lake trout is an important top predator for the cold-water fish community in eastern Lake Erie. The species is being re-established by stocking. Survival of stocked fish was depressed in the 1990s, but has improved in recent years. Recently, little natural reproduction has been documented for lake trout. Other stocking strategies, as well as different strains, are being explored by the Lake Erie Committee.

Like walleye, lake whitefish had a strong year-class in 2003. Lake herring have been rare in Lake Erie since the early 1960s. While they are still considered to be rare, there are signs that a slow increase in the lake herring population is occurring.

The current state of Lake Erie's fisheries and strategies for coordinated management will be published by the Great Lakes Fishery Commission in a "State of the Lake" report due out in 2008.

11.6 Cyanobacteria *(Prepared by Thomas Bridgeman, University of Toledo and Julie Letterhos, Ohio EPA)*

Blooms of cyanobacteria (blue-green algae) are again becoming noticeable at certain places and times. Some species produce chemicals that are potent toxins to humans and wildlife. Others create a nuisance for aesthetics, recreational use and cause taste and odor problems in drinking water.

In the 1960s and 1970s, cyanobacteria blooms were commonplace in Lake Erie. Shorelines were often rimmed in the color aqua, and offshore waters were thick with algae in the warm calm months of August and September. As Lake Erie began to respond to the efforts of phosphorus reduction, and phosphorus levels dropped toward the limits promoted by research under the Great Lakes Water Quality Agreement, cyanobacteria blooms decreased and then disappeared altogether.

Quite suddenly and unexpectedly, cyanobacteria blooms recurred in the western basin in 1995. This time the blooms were dominated by *Microcystis aeruginosa*, a non-nitrogen-fixing species that produces the hepatotoxin microcystin. Past blooms were dominated by nitrogen-fixing species such as *Anabaena* and *Aphanizomenon*. It was suspected that the blooms were associated with ecological changes in the system brought about by dreissenids and potentially with a changing P/N ratio in the lake.

Blooms of *Microcystis* did not occur in 1996 or 1997, but returned in 1998, and have occurred to varying extent every year since 2001. *Microcystis* blooms in 2003 were particularly heavy, not just in the western basin, but also in the central basin (Figure 11.2). The percent biomass of cyanobacteria is also increasing in the eastern basin. Year to year variation in bloom intensity may be influenced by annual variation in weather patterns but, overall, the recurrence of open-water algal blooms, along with the expanded areas of anoxia and hypoxia in the central basin, is suggesting a change in eutrophy in parts of the lake. In addition to potential hepatotoxins produced by *Microcystis* species, other toxic compounds have been identified in Lake Erie waters associated with other species of cyanobacteria. Cyanobacterial taste, odor and biomass issues have also occurred.

In 2006 and 2007, large blooms of the benthic, mat-forming cyanobacteria species *Lyngbya wollei* occurred along the shoreline of Maumee Bay. Although *L. wollei* is not necessarily new to Lake Erie, such massive blooms were previously unknown in the lake, suggesting a further change in the ecosystem. Mats have washed up on the shore and created a substrate upon which vegetation has taken hold (Figure 11.2a). Massive amounts

Figure 11.2: *Microcystis* bloom in the Western Basin, August 18, 2003 (LANDSAT 7 Image)

Figure 11.2a: *Lyngbya wollei* mats along the Maumee Bay shoreline (Sandy Bihn, Western Basin Waterkeeper)

of *Lyngbya* create a strong odor and impact the use of beaches and nearshore areas where they accumulate.

The University of Toledo, NOAA's Great Lakes Environmental Research Laboratory, the Ohio Department of Natural Resources and other academic researchers are continuing to track the occurrence of *Microcystis*, *Lyngbya* and other cyanobacteria as well as the status of other components of the plankton community in various Lake Erie locations. There is a continuing need to do more research to better understand the biology of cyanobacteria and the causes of their blooms. Several such investigations are currently underway. Samples collected in various open-water areas revealed a correlation between locations where blue-green algal pigments were most abundant and places where dreissenid mussels were abundant. There is a need to track the distribution and incidence of such blooms to improve our understanding of their risk to human and animal health. Increasing tributary loads of dissolved, bioavailable phosphorus may also be contributing to the increased algal growth.

Although human poisoning by ingestion of cyanobacterial toxins is very unlikely in Lake Erie waters, direct contact with water containing noticeable amounts of cyanobacteria should be avoided. Prolonged contact with mats that have washed up along the shore should also be avoided because of the potential of these species to cause skin irritation or harbour other bacteria.

11.7 *Cladophora* (Prepared by Scott Higgins, University of Waterloo and Todd Howell, Ontario Ministry of the Environment)

Cladophora glomerata is a filamentous green alga that grows attached to rocky lake bottoms and man-made structures in relatively well illuminated and alkaline waters. It was first identified in western Lake Erie in 1848. While *Cladophora* has a ubiquitous distribution throughout the Laurentian Great Lakes and associated tributaries, historical 'nuisance' growths were most often associated with excessive phosphorus loading. Where *Cladophora* growths are extensive the blooms are followed by a major sloughing, or dieback, event where filaments detach from the lake bottom and become free floating. Floating *Cladophora* mats tangle fishing nets, reducing their efficiency and increasing downtime for net-cleaning, and are a potential hazard for swimmers. The mats also clog intake screens of municipal and industrial water intakes (IJC 2003; Kraft 1993; Michard 2005) increasing maintenance costs and sometimes resulting in costly short-term shut-downs. Shoreline accumulations of decaying *Cladophora* release obnoxious odors, reducing shoreline property values, the aesthetic value of beaches and associated tourism. Recent research by Byappanahalli et al. (2003) has documented high concentrations and survival rates (>6 months at 5ºC) of *E. coli* within shoreline accumulations of *Cladophora*. This research indicates that *Cladophora* mats are a potential source of *E. coli* to recreational waters, potentially confusing the use of *E. coli* as an indicator organism for pathogens derived from fecal material.

Cladophora filaments require hard surfaces such as rocky lake bottoms or man-made structures such as piers or breakwalls for attachment. Significant areas of shallow bedrock are restricted to the eastern basin, portions of the central basin's southern shoreline, and islands of the western basin. Man-made structures, however, are common to all basins.

The most recent systematic *Cladophora* surveys (1995-2002) by Howell (1998) and Higgins et al. (2005b) have been restricted to the eastern basin. Across the northern shoreline of the east basin dense *Cladophora* mats were found over 96% of available rocky lake bottom (Figure 11.3) and were not spatially limited to nutrient point sources such as the mouths of tributaries or sewage treatment outfalls. The standing biomass of *Cladophora* along this reach of shoreline was estimated to be 11,000 tonnes (dry weight). Shoreline accumulations of *Cladophora* (Figure 11.4) were common during July and August, causing noxious odors and prompting numerous complaints from local homeowners. Heavy shoreline accumulations of *Cladophora* were also noted along the southern shorelines of eastern Lake Erie in Dunkirk, NY (Obert 2003).

Figure 11.3: Underwater photograph of Lake Erie lake bottom overlain with *Cladophora*. Photo taken at Grant Point, 2 m depth, July 2003.

Figure 11.4: Shoreline fouling by *Cladophora* in eastern Lake Erie. Photo taken approximately 2 km south of Peacock Point, August 2001.

In the central basin, persistent shoreline fouling by *Cladophora* has been noted in Rondeau Bay, Ontario (Shepley 1996), Cleveland, OH (Kraft 1993), and Pennsylvania shorelines (GLRR 2001). Data for other areas are not available. In the western basin, *Cladophora* is currently found growing on bedrock areas surrounding offshore islands, and on man-made structures at the basin perimeter. However, to date no complaints from area residents have occurred regarding *Cladophora* fouling of shorelines in the western basin.

The depth distribution of *Cladophora* is related to light availability, and the maximum depth of colonization in eastern Lake Erie was approximately 15 metres. The biomass of *Cladophora* at shallow depths (<5 m) was found to be similar to levels during the 1960s and 1970s (median value 176 g DM m^{-2}). Depth integrated biomass likely increased due to increases in water clarity caused by zebra and quagga mussels. A *Cladophora* growth model (Canale and Auer 1982), originally developed on Lake Huron, was revised and validated in eastern Lake Erie (Higgins et al. 2005a). The model predicted that *Cladophora* growth was highly sensitive to soluble phosphorus concentrations during the spring and that reductions in ambient phosphorus concentrations would significantly reduce bloom occurrences. The modeling results were supported by direct evidence, indicating that phosphorus concentrations within *Cladophora* tissues rapidly declined to critical levels by early summer. A preliminary phosphorus addition study using slow release nutrient agar also suggested *Cladophora* growth and biomass accrual were strongly P-limited (Figure 11.5, 11.6) (S. Higgins, University of Waterloo).

Previous studies by Lowe and Pillsbury (1995) documented increases in benthic algal growth, including *Cladophora*, over zebra mussel beds in Saginaw Bay of Lake Huron. Unfortunately, benthic algal surveys were not conducted over the colonization period in Lake Erie. Efforts are currently ongoing to use the *Cladophora* growth model to estimate the influence of zebra and quagga mussels on *Cladophora* resurgence in the east basin (S.

Figure 11.5: *In situ Cladophora* growth chamber with non-nutrient enriched agar.

Figure 11.6: *In situ Cladophora* growth chamber with phosphorus enriched agar.

Higgins, University of Waterloo) and to investigate the influence of tributaries on growth potential in eastern Lake Erie (S. Higgins, University of Waterloo; and Ontario Ministry of the Environment).

11.8 Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants in the Environment

(Prepared by Jacqueline Fisher, U.S. EPA for the Great Lakes Human Health Network)

Over the past few decades, an increasing concern has developed about the potential and inadvertent contamination of water resources from the production, use, and disposal of the numerous chemicals used to improve industrial, agricultural, and medical processes. Analgesics, anti-inflammatory drugs, birth control chemicals, Prozac-like drugs, and cholesterol-lowering drugs have all been found in the effluent from water treatment plants discharging into the Detroit River, although at low concentrations (Lake Erie Millennium Network 2003). Even some commonly used household chemicals have raised concerns. Increased knowledge of the toxicological behavior of these chemicals raises the need to determine any potentially adverse effects on human health and the environment. For many of these contaminants, public health experts do not fully understand the toxicological significance, particularly the effects of long-term exposure at low levels. Further study needs to be done to determine the transport of these chemicals at trace levels through the environment and to determine any resulting adverse human health effects.

The U.S. Geological Survey conducted the first nationwide reconnaissance of the occurrence of pharmaceuticals, hormones, and other organic wastewater contaminants (OWCs) in water resources in 1999 and 2000. Concentrations of 95 OWCs in water samples from a network of 139 streams across 30 states were measured using five newly developed analytical methods. The selection of sampling sites was biased toward streams susceptible to contamination (i.e. downstream of intense urbanization and livestock production). OWCs were prevalent during this study, being found in 80% of the streams sampled. The compounds detected represent a wide range of residential, industrial, and agricultural origins and uses with 82 of the 95 OWCs being found during this study. The most frequently detected compounds were coprostanol (fecal steroid), cholesterol (plant and animal steroid), *N,N*-diethyltoluamide (DEET insect repellant), caffeine (stimulant), triclosan (antimicrobial disinfectant), tri(2-chloroethyl)phosphate (fire retardant), and 4-nonylphenol (nonionic detergent metabolite). Measured concentrations for this study were generally low and rarely exceeded drinking water guidelines, drinking water health advisories, or aquatic life criteria. Many compounds, however, do not have such guidelines established.

The detection of multiple OWCs was common for this study, with a median of seven and as many as 38 OWCs being found in any given water sample. Little is known about the potential interactive effects (such as synergistic or antagonistic toxicity) that may occur from complex mixtures of OWCs in the environment. In addition, results of this study demonstrate the importance of obtaining data on metabolites to fully understand not only the fate and transport of OWCs in the hydrologic system but also their ultimate overall effect on human health and the environment. (http://toxics.usgs.gov/regional/emc_sourcewater.html)

11.9 Fish and Wildlife Deaths Due to Botulism Type E
(Prepared by Jeff Robinson, Canadian Wildlife Service)

Since 1999 there have been annual large scale die-off events of fish, fish-eating birds and mudpuppies (a native aquatic amphibian) observed in Lakes Erie, Huron and, in 2003, Lake Ontario. These events have occurred annually in Lake Erie and it is here where the largest toll of fish and wildlife has occurred. The type E botulism bacterium is believed to be the cause of the die-off events.

Type E botulism is caused by *Clostridium botulinum,* a bacterium that is native to North America. The bacterium is quite widespread in the soils and sediments around the Great Lakes. Movement of the bacterium through the food chain resulted in mortality events of fish-eating birds in the Great Lakes basin during the 1960s. Humans were affected by food poisoning from poorly handled fish or wildlife and improperly prepared canned products. In the past, it has rarely been known to kill large numbers of fish or birds. Previous events primarily affected loons and grebes on Lakes Huron and Michigan.

On Lake Erie, shoreline landowners have observed remarkable natural fish die-offs as a result of strong storm fronts moving over the lake in the late summer or early fall. The lake has been warming through the summer and sets up a layer of warm surface water and a much colder layer in the deeper water generally well offshore. As these storm events or strong cold fronts pass, there are often sustained strong winds from the north that push the warmer surface waters to the south shore and bring the much colder water from deeper parts of the lake into the nearshore zone on the north shore. This results in a drop of the ambient water temperature so quickly and so drastically that resident fish, unable to escape the sudden temperature change, tend to be disabled or die. These events are quite regular as weather patterns, shoreline configuration and nearshore morphology do not change much over time. These dead fish afford an easy meal for inexperienced juvenile gulls and bald eagles learning to forage on their own. Occurring at a critical time of dispersal of young birds, this phenomenon has likely gone on for centuries.

What has been rarely observed in the past is apparent botulism type E poisoning of hundreds, if not thousands of fish-eating birds as well as dead fish and mudpuppies washing ashore in unprecedented numbers during the late summer and early fall period. Fall and early winter events have been less of a perceived problem as the number of recreational users on the beaches at that time of year is much lower.

Outbreaks

The earliest known or suspected incidents of type E botulism poisoning on Lake Erie have occurred during June, involving mudpuppies and gulls. These June incidents generally involved a few gulls found dead or dying along beaches or several hundred dead mudpuppies washed ashore or floating in the eastern basin of Lake Erie.

Summer die-off events tend to affect resident fish and wildlife whereas late summer events (August and September) start to affect populations of wildlife migrating through the Great Lakes. The fish affected tend to be bottom dwelling, warm water species such as: the round goby, stonecat, sheepshead, smallmouth bass, rock bass and sturgeon. The birds affected in the die-offs include: ring-billed gull, herring gull, double crested cormorant, greater black-backed gull, Caspian tern, common tern and a few shorebird species. Most of the birds involved breed near the areas where they are found dead. However, end of August outbreak events have found cormorants, breeding as far away as Lake Huron and eastern Lake Ontario, dead on Lake Erie.

The Canadian Wildlife Service reported that the fish die-off of freshwater drum and round goby at Wheatley, Ontario on August 16, 2001 did not result in any unusual bird mortalities. However, after a similar die-off of fish near Port Dover, Ontario also on August 16, there were 38 dead birds, one mudpuppy, three shorebirds and a report of a sick great blue heron. On October 29, 2001, the Canadian Wildlife Service reported die-offs of the common loon, ring-billed gulls, red-breasted mergansers, gadwalls, and long-tailed ducks (old squaw) along the northeast shore of Lake Erie between Port Dover and Dunnville in Ontario. In addition, there were dead fish along the beach including round goby, carp, and catfish as well as a mudpuppy. Specimens were sent to the Canadian Cooperative Wildlife Health Centre at the University of Guelph for assessment.

Similar mortalities of fish and birds occurred along the New York shoreline of Lake Erie during the same period. Among fish found dead along the New York shoreline in September 2001, 81% were freshwater drum (Figure 11.7) with the remainder consisting of nine other species. Bird collections in fall 2000 revealed an estimated 5,000 to 6,000 birds died that year, with red-breasted merganser the most common species (Figure 11.8). Estimates of dead common loons in New York were over 500 birds in 2000, and over 1000 birds in 2001. In addition, seven dead lake sturgeon (a threatened species in New York) were found in 2000, while 27 individuals were collected in 2001.

During the months of November and December bird deaths generally occur after the passage of strong cold fronts that appear to be related to mixing of lake waters, movement of migrant birds into Lake Erie and movement of fish from the nearshore to deeper water off shore. Thousands of waterfowl and loons have been observed over the past four years dead due to apparent botulism type E poisoning.

Migration of Die-off Events

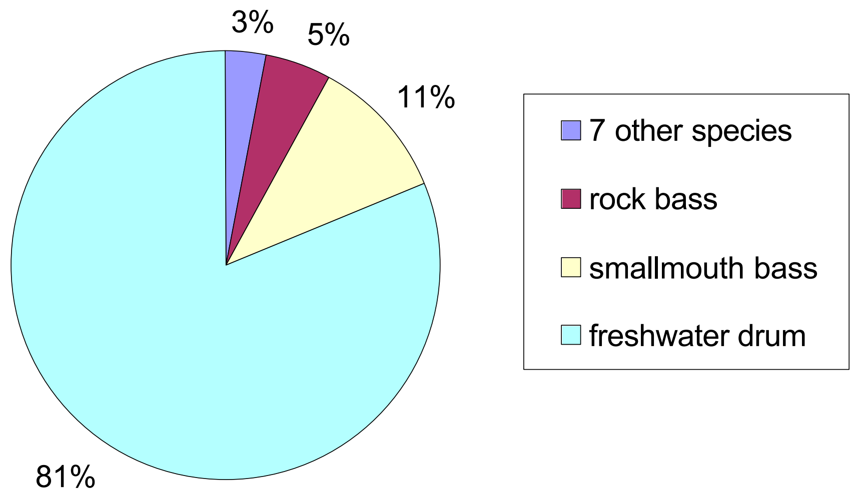
In 1999, botulism type E mortality was first observed in October along beaches at Pinery Provincial Park, Ontario on Lake Huron and beaches west of Rondeau Bay, Ontario in the central basin of Lake Erie. The Lake Huron event involved primarily common loons while the Lake Erie event was primarily red-breasted mergansers.

In 2000, there were no reports from Lake Huron. The major mortality was observed along stretches of shoreline in the central basin of Lake Erie, primarily the area east of Rondeau Bay and near Presque Isle Bay, Pennsylvania. Starting in 2000, fish die-offs in late summer saw the first bird die-offs of gulls. Fall events involved gulls, cormorants, common loons and grebes.

In 2001, the mortality events moved further east into the eastern basin of Lake Erie with some reports from the north shore of the western basin but not in any numbers. In the late fall of 2001 large numbers of red-breasted mergansers were killed along with an estimated several thousand common loons during November and December.

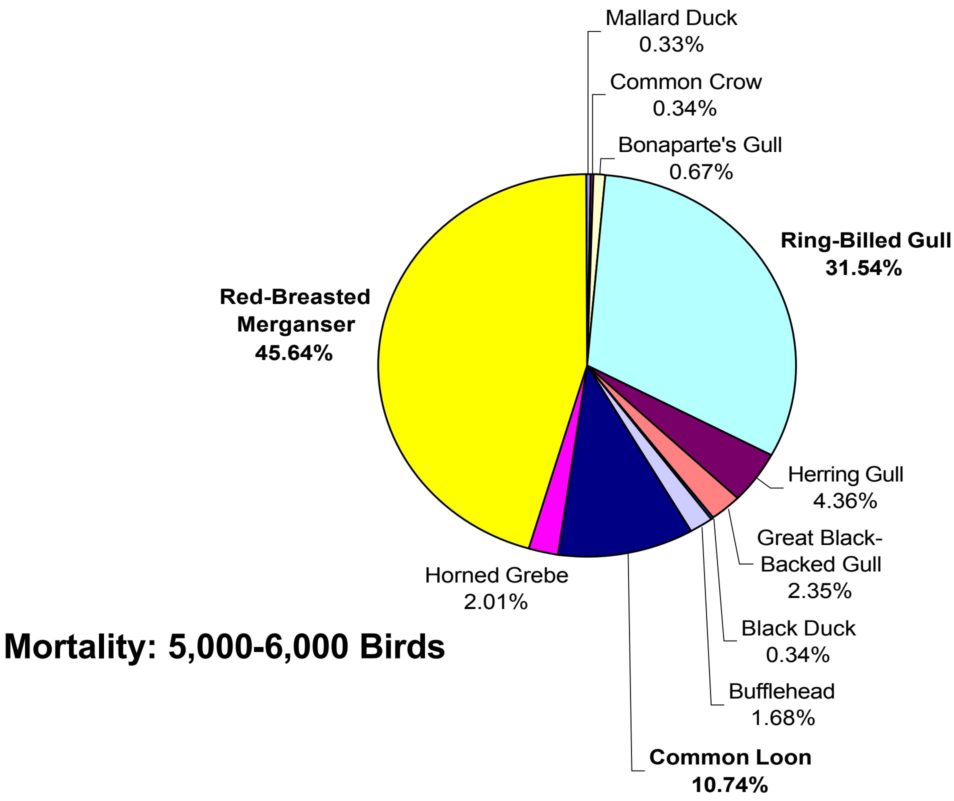
In 2002, there was virtually no observed mortality in the western or central basins, but large mortalities observed at several locations in the eastern basin. Large numbers of gulls at a colony near Buffalo, New York died during July. A major event occurred over the Labour Day weekend at Long Point involving gulls, cormorants and shorebirds as well as thousands of fish (mostly sheepshead as well as a sturgeon). In the November to December period, several thousand common loons and grebes were again encountered dead in the eastern basin and thousands of long-tailed ducks washed ashore dead from apparent botulism type E poisoning. During this period there were also reports of dead common loons washing

Figure 11.7: Frequency of dead fish species observed along NY Lake Erie beaches, September 2001



Information from NYSDEC

Figure 11.8: Percent mortality on NY Lake Erie shoreline by species observed, fall 2000



ashore on Lake Huron from Goderich to Kincardine in Ontario. During the botulism type E events in the eastern basin, several adult sturgeon were found washed ashore, mostly in New York, which is a real management concern for this small population in Lake Erie. The same can be said of the mouth of the Niagara River on Lake Ontario as the last two years have seen reports of dead sturgeon and birds there due to apparent botulism type E poisoning as well.

In 2003, there were not any remarkable events in the summer and early fall on Lake Erie. Common loons and grebes were found dead on beaches of the eastern basin, but at much lower numbers than in previous years. As well, birds apparently suffering from botulism type E were recovered further north in Lake Huron (between Kincardine and Port Elgin, Ontario) and in eastern Lake Ontario. Government employees and private citizens continue to monitor the beaches on Lakes Huron, Erie and Ontario to report fish and bird die off events that may be related to botulism type E or other causes.

What Do We Know to Date

Most initial work concentrated on counting the numbers of fish and birds being affected by the botulism outbreaks. This only served to identify the possible locations of the die-offs in the lake and did little to help understand the mechanism for the toxin getting into the food chain or the environmental conditions on the bottom of the lakes that led to production of toxin at levels that start to affect the food chain.

The current thinking on what is causing these outbreaks is that ecological changes in the Great Lakes due to recent non-native species invasions have changed the way the food chain operates, with much more energy in the system staying on or near the bottom of the lake. When zebra and quagga mussel populations expanded into the Great Lakes there were no observable occurrences of unusual mortalities in wildlife or fish that tend to consume them as food (e.g. scaup ducks, freshwater drum or sheepshead). Over the last eight years, there has been the more recent invasion of the round goby into the Great Lakes and this has seen a tremendous change in fish productivity in Lake Erie where the bulk of the fish biomass is now dominated by these bottom dwelling fish. Formerly, the fish community was much more balanced, and it is thought that very rarely would the benthic community, where the botulism toxin is thought to be produced, be able to mobilize the toxin into the upper levels of the food web. Consequently, much of the current research effort is working to determine if this theory is indeed valid.

Alicia Perez-Fuentetaja and Theodore Lee at the State University of New York in Fredonia are currently studying bottom ecology near Dunkirk, New York to better understand possible triggers for toxin production. Preliminary results suggest that ambient water temperature may be important. They also measured redox potential at the bottom and found that the lowest value generally preceded summer outbreaks by several days in 2002. Results are not complete for 2003 when no major summer events were observed. U.S. EPA/Great Lakes National Program Office and the U.S. Fish and Wildlife Restoration Act funded this project.

At Cornell University, Paul Bowser and Rod Getchell have been examining the prevalence of the botulism bacteria in healthy, moribund, and dead fish in areas of confirmed botulism outbreaks and in unaffected areas in Lake Erie and Lake Ontario. Answers will be sought to the questions: is the bacterium more likely to be present in healthy, moribund or dead fish; is one species of fish more likely to carry the bacterium; does the toxin form in fish prior to and after death and, are fish carrying the bacterium associated with waterfowl death events? The researchers are working with the New York State DEC to collect fish, primarily carp and round gobies, from both lakes for examination. Tests will assess the cause of death as well as other pathogens present in the fish. The New York Sea Grant Program funds this project.

Photo: Mike Weimer, U.S. Fish & Wildlife Service

In Ontario, Richard Moccia at the University of Guelph has been working with Health Canada to study the behavior of various native and non-native fish species to known doses of botulinin toxin. Fish studied or proposed to be studied are: round goby, walleye, yellow perch and possibly lake sturgeon and mudpuppies. This study is designed to enable a better understanding of the role, if any, that key fish species play in the bird deaths occurring within the Great Lakes. This study attempts to refute, or support, the current working hypothesis that fish and mudpuppies represent a potential "living transport vector" of botulism neurotoxin in the lake, and that they may be a primary source of lethal doses of the type E toxin to affected bird populations. Furthermore, this work will also contribute to a better understanding of the ecology of botulism neurotoxin production in the Great Lakes, and help to assess the potential for human health consequences resulting from the infection, or intoxication, of freshwater fish and birds with *Clostridium botulinum* (Types E botulism). Environment Canada, Ontario MNR, Health Canada and the University of Guelph support this work. As well, wildlife pathologists with New York DEC in Albany and the Canadian Co-operative Wildlife Health Centre at the University of Guelph continue to examine dead birds and fish submitted during these outbreaks to determine cause of death and retrieve specimens for further assessment.

A much more complete description of monitoring and research on botulism in the Great Lakes is available at the following link hosted by New York, Pennsylvania and Ohio Sea Grant at: www.nyseagrant.org/. This link lists proceedings from annual workshops held in 2001, 2002 and 2003 on botulism in the Great Lakes.

11.10 The 2005 Fall Turnover Incident *(Prepared by Jim Grazio, Pennsylvania Dept. of Environmental Protection)*

Because phosphorus is a key macronutrient governing eutrophication in the Great Lakes, Annex 3 of the Great Lakes Water Quality Agreement set forth specific goals with respect to its control. For Lake Erie, these specific goals were "substantial reduction in the present [1978] levels of algal biomass to a level below that of a nuisance condition in Lake Erie" and "restoration of year-round aerobic conditions in the bottom waters of the central basin of Lake Erie." As a result of binational efforts to reduce phosphorus loading from municipal sewage discharges, household detergents, agriculture, and other major sources, phosphorus loading to Lake Erie decreased by over 50% since 1965 and phosphorus concentrations reached record lows in 1995. It seemed to all observers that the cultural eutrophication of Lake Erie had been halted and that the target loads and specific management goals for phosphorus had been attained. In the last decade, however, phosphorus concentrations in Lake Erie have begun to increase once again and signs of cultural eutrophication are again apparent. Nuisance growths of *Cladophora*, *Microcystis* and other undesirable algae are again being reported and seasonal dissolved oxygen depletion in the central basin may be intensifying.

Both the central and eastern basins of Lake Erie thermally stratify into a warmer upper layer (epilimnion) and cooler lower layer (hypolimnion) in the summertime. The epilimnion of the lake maintains its life-giving dissolved oxygen through the photosynthesis of aquatic plants and algae and by mixing with oxygen from the air. The dark hypolimnion is isolated from the oxygen rich epilimnion, and oxygen levels naturally decrease throughout the summer growing season as the result of aquatic organism respiration and the biochemical oxygen demand of decomposing plant matter. With an average depth of 25 meters (82 ft.), oxygen is never completely depleted in the eastern basin. In the central basin, however, with an average depth of 18 meters (60 ft.), the size of the hypolimnion is much smaller and the water may become devoid of oxygen by the end of the summer growing season. As the limiting macronutrient for aquatic plant growth, increases in the amount of bioavailable phosphorus fertilize the growth of algae, thereby accelerating the rate of eutrophication in the lake.

Monitoring of dissolved oxygen levels in the central basin by the US E.P.A.'s Great Lakes National Program Office has suggested that the rate of dissolved oxygen depletion in the central basin hypolimnion may be increasing and that the depletion may be occurring earlier in the summer. For example, average dissolved oxygen concentrations of less than 1.0 mg/L were recorded by the end of August in the central basin during 2001, 2002, and 2003—a hypoxic condition documented only twice in the monitoring period of record from 1985 through 2004. Still, the data are quite variable from year-to-year and definitive trends and causes have yet to be established. Nonetheless, dramatic additional evidence that central basin hypoxia is intensifying occurred on September 29, 2005 when a large "burp" of anaerobic gases was released from the central basin during the annual fall overturn.

Hydrogen sulfide odors were detected by residents along the southern shore from roughly Cleveland, Ohio to Buffalo, New York, causing mild panic among some lakeshore residents and prompting hundreds of phone calls to regulatory and law enforcement agencies. Odors were typically described as "rotten eggs", "sewer gas", or "sulfur", generating widespread speculation of causes ranging from sewage treatment facility upsets to natural gas leaks to distant chemical plant explosions. Emergency response teams were called in to investigate the source of the odors in one Pennsylvania community. Fortunately, an experimental, real-time monitoring buoy deployed in the central basin by the National Oceanic and Atmospheric Administration's International Field Year on Lake Erie (IFYLE) effort allowed scientists to correlate the sulfurous odors to the abrupt mixing of the upper and lower layers of the central basin of Lake Erie.

The "big burp" of 2005 was a not-so-subtle reminder of the importance of systematically monitoring water quality parameters and conditions related to the onset of hypoxia in the central basin. More generally, it was a reminder of the importance of ongoing monitoring and research to truly understand and manage the ever-changing Lake Erie ecosystem. It is also important to note that without the nutrient controls imposed on point and nonpoint sources, unpleasant conditions related to the lake turnover would be a lot more common.

11.11 Climate Change, Water Quality and Habitat

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has concluded that the warming of the climate system is unequivocal, as evidenced by actual observations of global increases in air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (IPCC 2007). Over the years, considerable research has been done to document the evidence of global warming, why it is occurring, how climate patterns may change, and what impacts these changes may have on existing ecosystems human use.

The member agencies of the Lake Erie LaMP Management Committee are particularly concerned about how global warming may impact Lake Erie water quality, habitat and the diversity of biological communities in or dependent upon the lake. Climate change and its impact on the Great Lakes Region have been assessed and summarized (IJC 2003; Kling et al. 2003; MacIver 2007). Projected changes in the Great Lakes Basin climate include: further increases in air temperatures; a decrease in the daily temperature range; an increase in the intensity and frequency of extreme events (heat waves, drought, intense precipitation); more winter precipitation falling as rain and less as snow with a subsequent increase in winter runoff; earlier spring freshet with potentially less flow; increased evapotranspiration with warmer temperatures; and less ice cover (IJC 2003). While it is natural for Lake Erie's water level to fluctuate seasonally, annually and over decades, most impact assessments of climate change on the hydrology of the Great Lakes Basin project lower net basin supplies and increased frequency and duration of low water levels (Mortsch et al. 2000, 2006; Quinn and Lofgren 2000; Lofgren et al. 2002; Croley 2003).

Photo: Upper Thames River Conservation Authority

Mortsch et al. (2006) examined the potential impacts of projected climate change on Great Lakes coastal wetlands, including Long Point, Turkey Point, Rondeau Bay and Dunnville wetland complexes in Lake Erie. Using models developed for this purpose, the study assessed how low water levels would affect wetland vegetation communities and wetland-dependent birds and fishes. Modeling results project major shifts are likely in all taxonomic groups beginning with vegetation changes. Lower water levels favor the expansion of drier vegetation types, particularly along the upper margins of the wetland, and a reduction in open water and submerged vegetation in embayments. The wetland bird and fish communities have the ability to respond to potential changes in vegetation community redistributions, although it is not equitable. Over-water nesting bird species and fish species that required flooded vegetation for reproduction and nursery habitat were most vulnerable. Hydrogeomorpholgy plays a critical role in wetland and habitat responses and there were site-specific differences in responses.

Climate change is an additional stressor compounding the ecosystem management challenges already posed by increasing population, land use change, chemical contamination, eutrophication and invasive species. A portfolio of adaptation measures will be required to respond to climate change in the Lake Erie Basin. Adaptation measures are aimed at reducing risks or impacts and taking advantage of new opportunities presented by climate change. The objective becomes how to mainstream climate change adaptation or incorporate climate change information into decision making in the Basin, in light of other important technological, social, economic and ecological trends. LaMP managers will require access to information on regional climate change scenarios and projected impacts on the natural environment, as well as the tools to assess options for incorporating climate change information into lake management strategies that address both human and ecosystem needs.

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