

Chapter G2: Evaluation of Impingement and Entrainment in the Great Lakes Region

INTRODUCTION

Great Lakes fisheries are among the most important in the world, providing \$4 billion in landings and recreation for some 5 million recreational anglers (Great Lakes Fishery Commission, 2003).

Historically, the top predators in the Great Lakes included lake trout (*Salvelinus namaycush*), sturgeon (*Acipenser fulvescens*), lake whitefish (*Coregonus clupeaformis*), northern pike (*Esox lucius*), walleye (*Sander vitreus*), and muskellunge (*Esox masquinongy*). Today, as a result of numerous stressors such as habitat destruction,

damming, and the introduction of sea lamprey and other exotic species, dominant species are primarily non-native salmon sustained by hatcheries. Not all introductions have been harmful, however. For example, alewife was introduced to provide forage for sport fish (Jude et al., 1987b). Losses of alewife (*Alosa pseudoharengus*), emerald shiner (*Notropis atherinoides*), and other forage species to impingement and entrainment (I&E) at Great Lakes facilities are sometimes substantial. Impinged and entrained species of commercial and/or recreational importance include yellow perch (*Perca flavescens*), white bass (*Morone chrysops*), gizzard shad (*Dorosoma cepedianum*), and walleye.

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G2-1 I&E SPECIES AND SPECIES GROUPS EVALUATED

Table G2-1 provides a list of species and associated species groups that were evaluated in EPA’s analysis of I&E in the Great Lakes.

Species Group	Species	Recreational	Commercial	Forage
Alewife	Alewife			X
Black bullhead	Black bullhead			X
Black crappie	Black crappie	X		
Bluegill	Bluegill			X
Bluntnose minnow	Bluntnose minnow			X
	Fathead minnow			X
	Hornyhead chub			X
	Lake chub			X
	Longnose dace			X

Species Group	Species	Recreational	Commercial	Forage
Brown bullhead	Brown bullhead		X	
Bullhead species	Stonecat		X	
	Tadpole madtom		X	
	Yellow bullhead		X	
Burbot	Burbot			X
Carp	Bowfin			X
	Carp			X
	Common carp			X
	Goldfish			X
Channel catfish	Channel catfish		X	
	Flathead catfish	X	X	
Crappie	White crappie	X		
Emerald shiner	Emerald shiner			X
Freshwater drum	Freshwater drum		X	
Gizzard shad	Gizzard shad		X	
Golden redhorse	Golden redhorse			X
	Shorthead redhorse			X
	Silver redhorse			X
Logperch	Logperch			X
	Trout-perch			X
Muskellunge	Grass pickerel	X		
	Muskellunge	X		
	Northern pike	X		
Other (forage)	Central mudminnow			X
	Chestnut lamprey			X
	Johnny darter			X
	Lake sturgeon			X
	Longnose gar			X
	Ninespine stickleback			X
	Pirate perch			X
	Sea lamprey			X
Silver lamprey			X	
Other (recreational)	Deepwater sculpin	X		
	Mottled sculpin	X		
	Slimy sculpin	X		
Rainbow smelt	Rainbow smelt	X	X	
	Smelt	X	X	

Species Group	Species	Recreational	Commercial	Forage
Shiner species	Common shiner			X
	Golden shiner			X
	Spotfin shiner			X
	Spottail shiner			X
Smallmouth bass	Largemouth bass	X		
	Smallmouth bass	X		
Spotted sucker	Spotted sucker			X
Sucker species	Lake chubsucker			X
	Longnose sucker			X
	Northern hog sucker			X
	Quillback			X
	White sucker			X
Sunfish	Green sunfish			X
	Hybrid sunfish	X		
	Orangespotted sunfish	X		
	Pumpkinseed			X
	Rock bass	X		
	Warmouth	X		
Walleye	Walleye	X		
White bass	White bass	X	X	
White perch	White perch			X
Whitefish	Bloater	X	X	
	Brown trout	X	X	
	Chinook salmon	X	X	
	Coho salmon	X	X	
	Lake herring	X	X	
	Lake trout	X	X	
	Lake whitefish	X	X	
	Rainbow trout	X	X	
	Round whitefish	X	X	
Yellow perch	Yellow perch		X	

Life histories of the species with the highest losses are summarized in the following section. The life history data used in EPA's analysis and associated data sources are provided in Appendix G1 of this report.

G2-2 LIFE HISTORIES OF PRIMARY SPECIES IMPINGED AND ENTRAINED IN THE GREAT LAKES REGION

Alewife (Alosa pseudoharengus)

Alewife is a member of the herring family, Clupeidae, and ranges along the Atlantic coast from Newfoundland to North Carolina (Scott and Crossman, 1998). Alewives entered the Great Lakes region through the Welland Canal which connects Lake Erie and Lake Ontario, and by 1949, they were present in Lake Michigan (University of Wisconsin Sea Grant Institute, 2001a). Because alewives are not a freshwater species, they are particularly susceptible to osmotic stress associated with freshwater. Freshwater fish have larger kidneys which they use to constantly pump water from their bodies. Since they lack this physiological adaptation, alewives are more susceptible to environmental disturbances.

In the Great Lakes, alewives spend most of their time in deeper water. During spawning season, they move towards shallower inshore waters to spawn. Although alewives generally do not die after spawning, the fluctuating temperatures that the adults are exposed to when they move to inshore waters often results in mortality due to osmotic stress. In certain years, temperature changes caused by upwelling may result in a massive die-off of spawning alewives (University of Wisconsin Sea Grant Institute, 2001a).

Alewife has been introduced to a number of lakes to provide forage for sport fish (Jude et al., 1987b). Ecologically, alewife is an important prey item for many fish.

Spawning is temperature-driven, beginning in the spring as water temperatures reach 13 to 15 °C, and ending when they exceed 27 °C (Able and Fahay, 1998). In their native coastal habitats, alewives spawn in the upper reaches of coastal rivers, in slow-flowing sections of slightly brackish or freshwater. In the Great Lakes, alewives move inshore toward the outlets of rivers and streams to spawn (University of Wisconsin Sea Grant Institute, 2001a).

In coastal habitats, females lay demersal eggs in shallow water less than 2 m (6.6 ft) deep (Wang and Kernehan, 1979). They may lay from 60,000 to 300,000 eggs at a time (Kocik, 2000). The demersal eggs are 0.8 to 1.27 mm (0.03 to 0.05 in.) in diameter. Larvae hatch at a size of approximately 2.5 to 5.0 mm (0.1 to 0.2 in.) total length (Able and Fahay, 1998). Larvae remain in the upstream spawning area for some time before drifting downstream to natal estuarine waters. Juveniles table a diurnal vertical migration in the water column, remaining near the bottom during the day and rising to the surface at night (Fay et al., 1983a). In the fall, juveniles move offshore to nursery areas (Able and Fahay, 1998).

Maturity is reached at 3 to 4 years for males, and 4 to 5 years for females (Able and Fahay, 1998). The average size at maturity is 265 to 278 mm (10.4 to 10.9 in.) for males and 284 to 308 mm (11.2 to 12.1 in.) for females (Able and Fahay, 1998). Alewife can live up to 8 years, but the average age of the spawning population tends to be 4 to 5 years (Waterfield, 1995; PSEG, 1999).



ALEWIFE
(*Alosa pseudoharengus*)

Family: Clupeidae (herrings).

Common names: River herring, sawbelly, kyak, branch herring, freshwater herring, bigeye herring, gray herring, grayback, white herring.

Similar species: Blueback herring.

Geographic range: Along the western Atlantic coast from Newfoundland to North Carolina.^a Arrived in the Great Lakes via the Welland Canal.^b

Habitat: Wide-ranging, tolerates fresh to saline waters, travels in schools.

Lifespan: May live up to 8 years.^{c,d}

Fecundity: Females may lay from 60,000 to 300,000 eggs at a time.^e

Food source: Small fish, zooplankton, fish eggs, amphipods, mysids.^d

Prey for: Striped bass, weakfish, rainbow trout.

Life stage information:

Eggs: demersal

- ▶ Found in waters less than 2 m (6.6 ft) deep.^e
- ▶ Are 0.8 to 1.27 mm (0.03 to 0.05 in) in diameter.^f

Larvae:

- ▶ Approximately 2.5 to 5.0 mm (0.1 to 0.2 in) at hatching.^f
- ▶ Remain in upstream spawning area for some time before drifting downstream to natal estuarine waters.

Juveniles:

- ▶ Stay on the bottom during the day and rise to the surface at night.^g
- ▶ Emigrate to ocean in summer and fall.^f

Adults: anadromous

- ▶ Reach maturity at 3-4 years for males and 4-5 years for females.^f
- ▶ Average size at maturity is 265-278 mm (10.4-10.9 in) for males and 284-308 mm (11.2-12.1 in) for females.^f
- ▶ Overwinter along the northern continental shelf.^f

^a Scott and Crossman, 1998.

^b University of Wisconsin Sea Grant Institute, 2001a.

^c PSEG, 1999.

^d Waterfield, 1995.

^e Kocik, 2000.

^f Able and Fahay, 1998.

^g Fay et al., 1983a.

Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

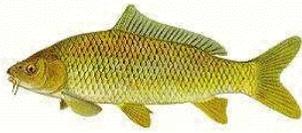
Carp (*Cyprinus carpio carpio*)

Carp is a member of the family of carps and minnows, Cyprinidae, and is abundant in Lake Erie. Carp were first introduced from Asia to the United States in the 1870's and 1880's, and by the 1890's were abundant in the Maumee River and in the west end of Lake Erie (Trautman, 1981). Carp are most abundant in low-gradient, warm streams and lakes with high levels of organic matter, but tolerate all types of bottom and clear to turbid waters (Trautman, 1981). Carp overwinter in deeper water and migrate to shallow water, preferably marshy environments with submerged aquatic vegetation in advance of the spawning season (McCrimmon, 1968). Adults feed on a wide variety of plants and animals, and juveniles feed primarily on plankton.

Carp are often considered a nuisance species because of their habit of uprooting vegetation and increase turbidity when feeding (McCrimmon, 1968; Scott and Crossman, 1973). Carp are not widely popular fishes for anglers, although carp fishing may be an important recreational activity in some parts of the United States (Scott and Crossman, 1973). They are occasionally harvested commercially and sold for food (Scott and Crossman, 1973).

Male carp reach sexual maturity between ages 3 and 4, and the females reach maturity between ages 4 and 5 (Swee and McCrimmon, 1966). Spawning can occur at temperatures between 16 and 28 °C (60.8 and 82.4 °F) with optimum activity between 19 and 23 °C (66.2 and 73.4 °F) (Swee and McCrimmon, 1966). Fecundity in carp can range from 36,000 eggs for a 39.4 cm (15.5 in.) fish to 2,208,000 in a 85.1 cm (33.5 in.) fish (Swee and McCrimmon, 1966) but individuals may spawn only about 500 eggs at a given time (Dames and Moore, 1977). Eggs are demersal and stick to submerged vegetation.

Eggs hatch 3 to 6 days after spawning and larvae tend to lie in shallow water among vegetation (Swee and McCrimmon, 1966). The lifespan of a typical carp in North America is less than 20 years (McCrimmon, 1968). Adult carp can reach 102-122 cm (40-48 in.) long, and weigh 18-27 kg (40-60 lb) (Trautman, 1981).



CARP
(*Cyprinus carpio carpio*)

Family: Cyprinidae (minnows or carp).

Common names: Carp.

Similar species: Goldfish, buffalofishes, carpsuckers.^a

Geographic range: Wide-ranging throughout the United States.

Habitat: Low-gradient, warm streams and lakes with high levels of organic carbon. Tolerates relatively wide range of turbidity. Often associated with submerged aquatic vegetation.^b

Lifespan: Less than 20 years.^b

Fecundity: 36,000 to 2,208,000 eggs per season.^c

Food source: Omnivorous; diet includes invertebrates, small molluscs, ostracods, and crustaceans as well as roots, leaves, and shoots of water plants.^b

Prey for: Juveniles provide limited forage for northern pike, smallmouth bass, striped bass, and longnosed gar, as well as green frogs, bullfrogs, turtles, snakes, mink.^b

Life stage information:

Eggs: demersal

- ▶ During spawning, eggs are released in shallow, vegetated water. Eggs are demersal and stick to submerged vegetation.
- ▶ Eggs hatch in 3-6 days.^c

Larvae:

- ▶ Larvae are found in shallow, weedy, and muddy habitats.^d

Adults:

- ▶ May reach lengths of 102-122 cm (40-48 in.).^a

^a Trautman, 1981.

^b McCrimmon, 1968.

^c Swee and McCrimmon, 1966.

^d Wang, 1986.

Fish graphic from North Dakota Game and Fish Department (1986).

Channel catfish (*Ictalurus punctatus*)

Channel catfish is a member of the Ictaluridae (North American freshwater catfish) family. It is found from Manitoba to southern Quebec, and as far south as the Gulf of Mexico (Dames and Moore, 1977). Channel catfish can be found in freshwater streams, lakes, and ponds. They prefer deep water with clean gravel or boulder substrates and low to moderate currents (Ohio Department of Natural Resources, 2001).

Channel catfish reach sexual maturity at ages 5-8, and females will lay 4,000-35,000 eggs dependent on body weight (Scott and Crossman, 1998). Spawning begins when temperatures reach 24-29 °C (75-85 °F) in late spring or early summer. Spawning occurs in natural nests such as undercut banks, muskrat burrows, containers, or submerged logs. Eggs approximately 3.5 mm (0.1in) in diameter are deposited in a large, flat, gelatinous mass (Wang, 1986). After spawning, the male guards the nest and fans it to keep it aerated. Eggs hatch in 7-10 days at 24-26 °C (75-79 °F) and the newly hatched larvae remain near the nest for several days (Wang, 1986). Young fish prefer to inhabit riffles and turbulent areas. Channel catfish are very popular with anglers and are relatively prized as a sport fish (Dames and Moore, 1977).

 <p style="text-align: center;">CHANNEL CATFISH (<i>Ictalurus punctatus</i>)</p>	<p>Food source: Small fish, crustaceans, clams, snails.^a</p> <p>Prey for: Chestnut lamprey.^a</p> <p>Life stage information:</p> <p>Eggs: <i>demersal</i></p> <ul style="list-style-type: none"> ▶ 3-4 mm in diameter.^d ▶ Hatch in 7-10 days.^d <p>Larvae:</p> <ul style="list-style-type: none"> ▶ Remain near nest for a few days then disperse to shallow water.^d ▶ Approx. 6.4 mm (0.25 in.) upon hatching.^d <p>Adults: <i>demersal</i></p> <ul style="list-style-type: none"> ▶ Average length: 30-36 cm (12-14 in.).^c ▶ Maximum length: up to 104 cm (41 in.).^c
<p>Family: Ictaluridae (North American freshwater catfish).</p> <p>Common names: Channel catfish, graceful catfish.^a</p> <p>Similar species: Blue and white catfishes.^b</p> <p>Geographic range: South-central Canada, central United States, and northern Mexico.^a</p> <p>Habitat: Freshwater streams, lakes, and ponds. Prefer deep water with clean gravel or boulder substrates.^c</p> <p>Lifespan: Maximum reported age: 16 years.^a</p> <p>Fecundity: 4,000 to 35,000 eggs depending on body weight.^e</p>	
<p>^a Froese and Pauly, 2001. ^b Trautman, 1981. ^c Ohio Department of Natural Resources, 2001. ^d Wang, 1986. ^e Scott and Crossman, 1998. Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.</p>	

Emerald shiner (*Notropis atherinoides*)

Emerald shiner is a member of the family Cyprinidae. It is found in large open lakes and rivers from Canada south throughout the Mississippi Valley to the Gulf Coast in Alabama (Scott and Crossman, 1973). Emerald shiner prefer clear waters in the mid to upper sections of the water column, and are most often found in deep, slow moving rivers and in Lake Erie (Trautman, 1981). The emerald shiner is one of the most prevalent fishes in Lake Erie (Trautman, 1981). Because of their small size, they are an important forage fish for many species.

Spawning occurs from July to August in Lake Erie (Scott and Crossman, 1973). Females lay anywhere from 870 to 8,700 eggs (Campbell and MacCrimmon, 1970), which hatch within 24 hours (Scott and Crossman, 1973). Young-of-year remain in large schools in inshore waters until the fall, when they move into deeper waters to overwinter (Scott and Crossman, 1973). Young-of-year average 5.1 to 7.6 cm (2 to 3 in.) in length (Scott and Crossman, 1973).

Emerald shiner are sexually mature by age 2, though some larger individuals may mature at age 1 (Campbell and MacCrimmon, 1970). Most do not live beyond 3 years of age (Fuchs, 1967). Adults typically range from 6.4 to 8.4 cm (2.5 to 3.3 in.) (Trautman, 1981). Populations may fluctuate dramatically from year to year (Trautman, 1981).



EMERALD SHINER
(*Notropis atherinoides*)

Family: Cyprinidae (herrings).

Common names: Emerald shiner.

Similar species: Silver shiner, rosyface shiner.^a

Geographic range: From Canada south throughout the Mississippi valley to the Gulf Coast in Alabama.^{b,c}

Habitat: Large open lakes and rivers.^b

Lifespan: Emerald shiner live to 3 years.^{a,d}

Fecundity: Mature by age 2. Females can lay anywhere from approximately 870-8,700 eggs.³

Food source: Microcrustaceans, midge larvae, zooplankton, algae.^d

Prey for: Gulls, terns, mergansers, cormorants, smallmouth bass, yellow perch, and others.^d

Life stage information:

Eggs: demersal

- ▶ Eggs hatch in less than 24 hours.^d

Larvae: pelagic

- ▶ Individuals from different year classes can have varying body proportions and fin length, as can individuals from different localities.^a

Adults:

- ▶ Typically range in size from 6.4 to 8.4 cm (2.5 to 3.3 in.).^a

^a Trautman, 1981.

^b Froese and Pauly, 2000.

^c Campbell and MacCrimmon, 1970.

^d Scott and Crossman, 1973.

Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Freshwater drum (*Aplodinotus grunniens*)

Freshwater drum is a member of the drum family, Sciaenidae. Possibly tabling the greatest latitudinal range of any North American freshwater species, its distribution ranges from Manitoba, Canada, to Guatemala, and throughout the Mississippi River drainage basin (Scott and Crossman, 1973). The freshwater drum is found in deeper pools of rivers and in Lake Erie at depths between 1.5 and 18 m (5 and 60 ft) (Trautman, 1981). Drum is not a favored food item of either humans or other fish (Edsall, 1967; Trautman, 1981; Bur, 1982).

Based on studies in Lake Erie, the spawning season peaks in July (Daiber, 1953), although spent females have been found as late as September (Scott and Crossman, 1973). Females in Lake Erie produce anywhere from 43,000 to 508,000 eggs (Daiber, 1953). The eggs are buoyant, floating at the surface of the water (Daiber, 1953; Scott and Crossman, 1973). This unique quality may be one explanation for the freshwater drum's exceptional distribution (Scott and Crossman, 1973). Yolk-sac larvae are buoyant as well, floating inverted at the surface of the water with the posterior end of the yolk sac and tail touching the surface (Swedberg and Walburg, 1970).

Larvae develop rapidly over the course of their first year. Maturity appears to be reached earlier among freshwater drum females from the Mississippi River than females from Lake Erie. Daiber (1953) found Lake Erie females begin maturing at age 5, and 46 percent reach maturity by age 6. Lake Erie males begin maturing at age 4, and by age 5, 79 percent had reached maturity.

The maximum age for fish in western Lake Erie is 14 years for females and 8 years for males (Edsall, 1967). Adults tend to be between 30 to 76 cm (12 to 30 in.) long.

 <p style="text-align: center;">FRESHWATER DRUM (<i>Aplodinotus grunniens</i>)</p>	<p>Food sources: Juveniles: Cladocerans (plankton), copepods, dipterans.^d</p> <p>Adults: Dipterans, cladocerans,^d darters, emerald shiner.^e</p> <p>Prey for: Very few species.</p> <p>Life stage information:</p>
<p>Family: Sciaenidae.</p> <p>Common names: freshwater drum, white perch, sheepshead.^a</p> <p>Similar species: white bass, carsuckers.^a</p> <p>Geographic range: From Manitoba, Canada, to Guatemala. They can be found throughout the Mississippi River drainage basin.</p> <p>Habitat: Bottoms of medium- to large-sized rivers and lakes.^b</p> <p>Lifespan: The maximum age for fish in western Lake Erie is 14 years for females and 8 years for males.^c</p> <p>Fecundity: Females in Lake Erie produce from 43,000 to 508,000 eggs.^e</p>	<p>Eggs: <i>pelagic</i></p> <ul style="list-style-type: none"> ▶ The buoyant eggs float at the surface of the water, possibly accounting for the species' high distribution.^e <p>Larvae:</p> <ul style="list-style-type: none"> ▶ Prolarvae float inverted at the surface of the water with the posterior end of the yolk sac and their tail touching the surface.^f <p>Adults:</p> <ul style="list-style-type: none"> ▶ The species owes its name to the audible “drumming” sound that it is often heard emitting during summer months.^e ▶ Tend to be between 30 to 76 cm (12 to 30 in.) long.^a
<p>^a Trautman, 1981 ^b Froese and Pauly, 2001. ^c Edsall, 1967. ^d Bur, 1982. ^e Scott and Crossman, 1973. ^f Swedberg and Walburg, 1970. Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.</p>	

Gizzard shad (*Dorosoma cepedianum*)

Gizzard shad is a member of the family Clupeidae. Its distribution is widespread throughout the eastern United States and into southern Canada, with occurrences from the St. Lawrence River south to eastern Mexico (Miller, 1960; Scott and Crossman, 1973). Gizzard shad are found in a range of salinities from freshwater inland rivers to brackish estuaries and marine waters along the Atlantic Coast of the United States (Miller, 1960; Carlander, 1969). Gizzard shad often occur in schools (Miller, 1960). Young-of-year are considered an important forage fish (Miller, 1960), though their rapid growth rate limits the duration of their susceptibility to many predators (Bodola, 1966). In Lake Erie, gizzard shad are most populous in the shallow waters of western Lake Erie, around the Bass Islands, and in protected bays and mouths of tributaries (Bodola, 1966).

Spawning occurs from late winter or early spring to late summer, depending on temperature. Spawning has been observed in early June to July in Lake Erie (Bodola, 1966), and in May elsewhere in Ohio (Miller, 1960). The spawning period generally lasts 2 weeks (Miller, 1960). Males and females release sperm and eggs while swimming in schools near the surface of the water. Eggs sink slowly to the bottom or drift with the current, and adhere to any surface they encounter (Miller, 1960). Females release an average of 378,990 eggs annually (Bodola, 1966), which average 0.75 mm (0.03 in.) in diameter (Wallus et al., 1990).

Hatching time can be anywhere from 36 hours to 1 week, depending on water temperature (Bodola, 1966). Young shad may remain in upstream natal waters if conditions permit (Miller, 1960). By age 2 all gizzard shad are sexually mature, though some may mature as early as age 1 (Bodola, 1966). Unlike many other fish, fecundity in gizzard shad declines with age (Electric Power Research Institute, 1987).

Gizzard shad generally live up to 6 years in Lake Erie, but individuals up to 10 years have been reported in southern locations (Scott and Crossman, 1973). Mass mortalities have been documented in several locations during winter months, due to extreme temperature changes (Williamson and Nelson, 1985).

 <p>GIZZARD SHAD (<i>Dorosoma cepedianum</i>)</p>	<p>Food sources: Larvae consume protozoans, zooplankton, and small crustaceans.^c Adults are mainly herbivorous, feeding on plants, phytoplankton, and algae. They are one of the few species able to feed solely on plant material.^b</p> <p>Prey for: Walleye, white bass, largemouth bass, crappie, among others (immature shad only).^b</p>
<p>Family: Clupeidae (herrings).</p> <p>Common names: Gizzard shad.</p> <p>Similar species: Threadfin shad.^a</p> <p>Geographic range: Eastern North America from the St. Lawrence River to Mexico.^{b,c}</p> <p>Habitat: Inhabits inland lakes, ponds, rivers, and reservoirs to brackish estuaries and ocean waters.^{b,c}</p> <p>Lifespan: Gizzard shad generally live 5 to 6 years, but have been reported up to 10 years.^b</p> <p>Fecundity: Maturity is reached by age 2; females produce average of 378,990 eggs.^b</p>	<p>Life stage information:</p> <p>Eggs: demersal</p> <ul style="list-style-type: none"> ▶ During spawning, eggs are released near the surface and sink to the bottom, adhering to any surface they touch. <p>Larvae: pelagic</p> <ul style="list-style-type: none"> ▶ Larvae serve as forage to many species. ▶ After hatching, larvae travel in schools for the first few months. <p>Adults</p> <ul style="list-style-type: none"> ▶ May grow as large as 52.1 cm (20.5 in.).^a ▶ May be considered a nuisance species because of sporadic mass winter die-offs.³
<p>^a Trautman, 1981. ^b Miller, 1960. ^c Scott and Crossman, 1973. Fish graphic from Iowa Dept. of Natural Resources, 2001.</p>	

Walleye (*Stizostedion vitreum*)

Walleye is a member of the perch family, Percidae. It is found in freshwater from as far north as the Mackenzie River near the Arctic Coast to as far south as Georgia, and is common in the Great Lakes. Walleye are popular sport fish both in the summer and winter. They generally feed at night because their eyes are sensitive to bright daylight (Scott and Crossman, 1998).

Walleye spawn in spring or early summer, although the exact timing depends on latitude and water temperature. Spawning has been reported at temperatures of 5.6 to 11.1 °C (42 to 52 °F), in rocky areas in white water or shoals of lakes (Scott and Crossman, 1998). They do not fan nests like other similar species, but instead broadcast eggs over open ground, which reduces their ability to survive environmental stresses (Carlander, 1997). Females produce between 48,000 and 614,000 eggs in Lake Erie, and the eggs are 1.4 to 2.1 mm (0.06 to 0.08 in.) in diameter (Carlander, 1997). Eggs hatch in 12-18 days (Scott and Crossman, 1998). Larvae are approximately 6.0 to 8.6 mm (0.23 to 0.33 in.) at hatching (Carlander, 1997).

Walleye develop more slowly in the northern extent of their range; in Lake Erie they are 8.9 to 20.3 cm (3.5 to 8.0 in.) by the end of the first growing season. Males generally mature at 2-4 years and females at 3-6 years (Scott and Crossman, 1998), and females tend to grow faster than males (Carlander, 1997). Walleye may reach up to 78.7 cm (31 in.) long in Lake Erie (Scott and Crossman, 1998).

 <p style="text-align: center;">WALLEYE (<i>Stizostedion vitreum</i>)</p>	<p>Food source: Insects, yellow perch, freshwater drum, crayfish, snails, frogs.^a</p> <p>Prey for: Sea lamprey, northern pike, muskellunge, sauger.^a</p> <p>Life stage information:</p>
<p>Family: Percidae (perch).</p> <p>Common names: Blue pike, glass eye, gray pike, marble eye, yellow pike-perch.^a</p> <p>Similar species: Sauger.^b</p> <p>Geographic range: Canada to southern United States.^c</p> <p>Habitat: Large, shallow, turbid lakes; large streams or rivers.^c</p> <p>Lifespan: Maximum reported age: 12 years.^b</p> <p>Fecundity: 48,000 to 614,000 in Lake Erie.^b</p>	<p>Eggs: <i>demersal</i></p> <ul style="list-style-type: none"> ▶ 1.4 - 2.1 mm (0.06 - 0.08 in.) in diameter.^b ▶ Hatch in 12-18 days.^c <p>Larvae: <i>pelagic</i></p> <ul style="list-style-type: none"> ▶ Approx. 6.2 - 7.3 mm (0.24 - 0.29 in.) upon hatching.^b <p>Adults: <i>demersal</i></p> <ul style="list-style-type: none"> ▶ Maximum length: up to 78.7 cm (31 in.).^c
<p>^a Froese and Pauly, 2001. ^b Carlander, 1997. ^c Scott and Crossman, 1998. Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.</p>	

White bass (*Morone chrysops*)

White bass is a member of the temperate bass family, Moronidae. It ranges from the St. Lawrence River south through the Mississippi valley to the Gulf of Mexico, though the species is most abundant in the Lake Erie drainage (Van Oosten, 1942). White bass has both commercial and recreational fishing value.

Spawning take place in May in Lake Erie and may extend into June, depending on temperatures. Spawning bouts can last from 5 to 10 days (Scott and Crossman, 1973). Adults typically spawn near the surface, and eggs are fertilized as they sink to the bottom. Fecundity increases directly with size in females; the average female lays approximately 565,000 eggs. Eggs hatch within 46 hours at a water temperature of 15.6 °C (60 °F) (Scott and Crossman, 1973).

Larvae grow rapidly, and young white bass reach lengths of 13 to 16 cm (5.1 to 6.3 in.) by the fall (Scott and Crossman, 1973). They feed on microscopic crustaceans, insect larvae, and small fish. As adults, the diet switches to fish. Yellow perch are an especially important prey species for white bass (Scott and Crossman, 1973).

Most white bass mature at age 3 (Van Oosten, 1942). Upon reaching sexual maturation, adults tend to form unisexual schools, traveling up to 11.1 km (6.9 mi) a day. Adults occupy the upper portion of the water column, maintaining depths of 6 m or less (Scott and Crossman, 1973). On average, adults are between 25.4 to 35.6 cm (10 to 14 in.) long (Ohio Department of Natural Resources, 2001). White bass rarely live beyond 7 years (Scott and Crossman, 1973).

 <p style="text-align: center;">WHITE BASS (<i>Morone chrysops</i>)</p>	<p>Food source: Juveniles consume microscopic crustaceans, insect larvae, and small fish.^b Adults have been found to consume yellow perch, bluegill, white crappie,^b and carp.^{b,d}</p> <p>Prey for: Other white bass.^a</p> <p>Life stage information:</p> <p><i>Eggs: demersal</i></p> <ul style="list-style-type: none"> ▶ Eggs are approximately 0.8 mm (0.03 in.) in diameter.^b <p><i>Larvae: pelagic</i></p> <ul style="list-style-type: none"> ▶ White bass experience their maximum growth in their first year.^b <p><i>Adults:</i></p> <ul style="list-style-type: none"> ▶ Travel in schools, traveling up to 11.1 km (6.9 mi) a day.^b ▶ Most mature at age 3.^c ▶ Adults prefer clear waters with firm bottoms.^a
<p>Family: Moronidae.</p> <p>Common names: White bass, silver bass.</p> <p>Similar species: White perch, striped bass.^a</p> <p>Geographic range: St. Lawrence River south through the Mississippi valley to the Gulf of Mexico, highly abundant in the Lake Erie drainage.^b</p> <p>Habitat: Occurs in lakes, ponds, and rivers.^c</p> <p>Lifespan: White bass may live up to 7 years.^d</p> <p>Fecundity: The average female lays approximately 565,000 eggs.^b</p>	
<p>^a Trautman, 1981. ^b Scott and Crossman, 1973. ^c Froese and Pauly, 2000. ^d Carlander, 1997. ^e Van Oosten, 1942. Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.</p>	

Yellow perch (*Perca flavescens*)

The yellow perch is a member of the Percidae family and is found in fresh waters in the northern and eastern United States and across eastern and central Canada. Yellow perch are also occasionally seen in brackish waters (Scott and Crossman, 1973). They are typically found in greatest numbers in clear waters with low gradients and abundant vegetation (Trautman, 1981). Perch feed during the day on immature insects, larger invertebrates, fishes, and fish eggs (Scott and Crossman, 1973).

Yellow perch are of major commercial and recreational value in Lake Erie, and the Great Lakes are a major source of yellow perch to the commercial fishing industry.

Sexual maturity is reached at age 1 for males and at ages 2 and 3 for females (Saila et al., 1987). Perch spawn in the spring in water temperatures ranging from 6.7 to 12.2 °C (44-54 °F) (Scott and Crossman, 1973). Adults move to shallower water to spawn, usually near rooted vegetation, fallen trees, or brush. Spawning takes place at night or in the early morning. Females lay all their eggs in a single transparent strand that is approximately 3 cm (1.2 in.) wide (Saila et al., 1987) and up to 2.1 m (7 ft) long (Scott and Crossman, 1973). These egg cases are semi-buoyant and attach to submerged vegetation or occasionally to the bottom and may contain 2,000-90,000 eggs (Scott and Crossman, 1973). In western Lake Erie, fecundities for yellow perch were reported to range from 8,618 to 78,741 eggs (Saila et al., 1987).

Yellow perch larvae hatch within about 8-10 days and are inactive for about 5 days until the yolk is absorbed (Scott and Crossman, 1973). Young perch are initially pelagic and found in schools, but become demersal after their first summer (Saila et al., 1987).

Adult perch are inactive at night and rest on the bottom (Scott and Crossman, 1973). Females generally grow faster than males and reach a greater final length (Scott and Crossman, 1973). In Lake Erie, perch may reach up to approximately 31 cm (12 in.) in total length and have been reported to live up to 11 years.



YELLOW PERCH
(Perca flavescens)

Food source: Immature insects, larger invertebrates, fishes, and fish eggs.^c

Prey for: Almost all warm to cool water predatory fish including bass, sunfish, crappies, walleye, sauger, northernpike, muskellunge, and other perch, as well as a number of birds.^c

Life stage information:

Eggs: semi-buoyant

- ▶ Eggs laid in long tubes containing 2,000-90,000 eggs.^c
- ▶ Eggs usually hatch in 8-10 days.^c

Larvae: pelagic

- ▶ Larvae are 4.1-5.5 mm (0.16-0.22 in.) upon hatching.^d
- ▶ Found in schools with other species.^c
- ▶ Become demersal during the first summer.^d

Adults: demersal

- ▶ Reach up to 31 cm (12 in.) in Lake Erie.^c
- ▶ Found in schools near the bottom.

Family: Percidae (perches).

Common names: Yellow perch, perch, American perch, lake perch.^a

Similar species: Dusky darter.^b

Geographic range: Northern and eastern United States.^c

Habitat: Lakes, ponds, creeks, rivers. Found in clear water near vegetation.^{a,b}

Lifespan: Up to 11 years.^c

Fecundity: 2,000-90,000 eggs.^c

^a Froese and Pauly, 2001.

^b Trautman, 1981.

^c Scott and Crossman, 1973.

^d Saila et al., 1987.

Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

G2-3 I&E DATA EVALUATED

Table G2-2 lists Great Lakes facilities in scope of the Phase II rule and the facility I&E data evaluated by EPA to estimate current I&E rates for the region.

Table G2-2: Great Lakes Facilities In Scope of the Section 316(b) Phase II Rule and Facility I&E Data Evaluated		
In Scope Facilities	I&E Data?	Years of Data
AES Somerset (NY)	No - extrapolated	
Ashtabula (OH)	No - extrapolated	
Avon Lake (OH)	No - extrapolated	
B C Cobb (MI)	No - extrapolated	
Bailly (IN)	No - extrapolated	
Bay Front (WI)	No - extrapolated	
Bay Shore (OH)	No - extrapolated	
Belle River (MI)	No - extrapolated	
C R Huntley (NY)	No - extrapolated	
Connors Creek (MI)	No - extrapolated	
Crawford (IL)	No - extrapolated	
Dan E Karn (MI)	No - extrapolated	

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Table G2-2: Great Lakes Facilities In Scope of the Section 316(b) Phase II Rule and Facility I&E Data Evaluated

In Scope Facilities	I&E Data?	Years of Data
Davis-Besse (OH)	No - extrapolated	
Dean H Mitchell (IN)	No - extrapolated	
Donald C Cook Nuclear (MI)	Yes	1975-1982
Dunkirk (NY)	No - extrapolated	
Eastlake (OH)	No - extrapolated	
Edgewater (OH)	No - extrapolated	
Edgewater (WI)	No - extrapolated	
Fermi Nuclear (MI)	No - extrapolated	
Fisk (IL)	No - extrapolated	
Ginna (NY)	No - extrapolated	
Harbor Beach (MI)	No - extrapolated	
J B Sims (MI)	No - extrapolated	
J C Weadock (MI)	No - extrapolated	
J H Campbell (MI)	No - extrapolated	
J R Whiting (MI)	Yes	1978-1983, 1987, 1991
James A Fitzpatrick (NY)	No - extrapolated	
James De Young (MI)	No - extrapolated	
Kewaunee Nuclear (WI)	No - extrapolated	
Lake Shore (OH)	No - extrapolated	
M L Hibbard (MN)	No - extrapolated	
Manitowoc (WI)	No - extrapolated	
Marysville (MI)	No - extrapolated	
Michigan City (IN)	No - extrapolated	
Midland Cogeneration Venture (MI)	No - extrapolated	
Mistersky (MI)	No - extrapolated	
Monroe (MI)	Yes	1974, 1975, 1982, 1985
Nine Mile Point Nuclear (NY)	No - extrapolated	
Oswego (NY)	No - extrapolated	
Palisades Nuclear (MI)	No - extrapolated	
Perry Nuclear (OH)	No - extrapolated	
Point Beach Nuclear (WI)	No - extrapolated	
Port Washington (WI)	No - extrapolated	
Presque Isle (MI)	No - extrapolated	
Pulliam (WI)	No - extrapolated	
River Rouge (MI)	No - extrapolated	
Rochester 7 (NY)	No - extrapolated	
Shiras (MI)	No - extrapolated	
South Oak Creek (WI)	No - extrapolated	
St Clair (MI)	No - extrapolated	

Table G2-2: Great Lakes Facilities In Scope of the Section 316(b) Phase II Rule and Facility I&E Data Evaluated

In Scope Facilities	I&E Data?	Years of Data
Trenton Channel (MI)	No - extrapolated	
Valley (WI)	No - extrapolated	
Waukegan (IL)	No - extrapolated	
Will County (IL)	No - extrapolated	
Wyandotte (MI)	No - extrapolated	

G2-4 EPA'S ESTIMATE OF CURRENT I&E IN THE GREAT LAKES REGION EXPRESSED AS AGE 1 EQUIVALENTS, FOREGONE YIELD, AND PRODUCTION FOREGONE

Table G2-3 provides EPA's estimate of the annual age 1 equivalents, foregone fishery yield, and production foregone resulting from the impingement of aquatic species at facilities located in the Great Lakes region. Table G2-4 displays this information for entrainment.

Table G2-3: Current Annual Impingement in the Great Lakes Region Expressed as Age 1 Equivalents, Foregone Fishery Yield, and Production Foregone

Species Group	Age 1 Equivalents (#s)	Yield (lbs)	Production Foregone
Alewife	41,459	0	652
Bass (Micropterus sp.)	4,132	167	347
Black crappie	507	84	21
Bluegill	150	3	2
Bullheads	6,426	499	175
Burbot	3,614	0	568
Carp minnow	54,947	0	18,709
Crappie	1,676	279	70
Freshwater catfish	20,103	4,162	1,786
Freshwater drum	451,661	107,628	42,954
Gizzard shad	167,951,902	0	6,072,918
Logperch	326,715	0	1,339
Other (forage)	56,022	0	6
Other (recreational)	16,390	3,187	2,102
Pikes	19	71	11
Rainbow smelt	377,860	1,313	5,625
Redhorse	33	0	2
Salmonids (other)	128,267	115,041	27,994
Shiners	102,907,376	0	172,221
Spotted sucker	1	0	0
Suckers	7,813	0	1,258
Sunfish	150,023	108	253
Walleye	47,025	41,167	13,864

Table G2-3: Current Annual Impingement in the Great Lakes Region Expressed as Age 1 Equivalents, Foregone Fishery Yield, and Production Foregone

Species Group	Age 1 Equivalents (#s)	Yield (lbs)	Production Foregone
White bass	1,777,091	541,636	166,314
White perch	1,603,562	0	20,055
Yellow perch	1,516,297	20,202	16,554

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Table G2-4: Current Annual Entrainment in the Great Lakes Region Expressed as Age 1 Equivalents, Foregone Fishery Yield, and Production Foregone

Species Group	Age 1 Equivalents (#s)	Yield (lbs)	Production Foregone
Alewife	5,839	0	85,563
Bass (Micropterus sp.)	304,131	12,299	53,051
Burbot	3,218	0	1,749
Carp minnow	2,334,006	0	3,621,033
Crappie	48,623	8,106	49,604
Freshwater catfish	293,443	60,756	183,668
Freshwater drum	207,784	49,514	305,024
Gizzard shad	22,146,154	0	3,131,790
Logperch	448,198	0	37,182
Other (forage)	1,175,936	0	55,849
Other (recreational)	1,537	299	3,531
Rainbow smelt	160,820	559	38,249
Salmonids (other)	163	146	181
Shiners	1,586,308	0	75,338
Suckers	183,186	0	296,552
Sunfish	8,458,028	6,104	44,787
Walleye	31,500	27,576	78,999
White bass	2,344,707	714,638	3,597,786
Yellow perch	1,929,941	25,713	1,115,874

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G2-5 ASSUMPTIONS USED IN CALCULATING RECREATIONAL AND COMMERCIAL LOSSES

In order to estimate the economic value of these losses, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery. Table G2-5 presents the percentage impacts and commercial value per pound assumed for each species. Commercial and recreational fishing benefits are presented in Chapters G3 and G4.

Table G2-5: Percentage of Total Impacts Occurring to the Commercial and Recreational Fisheries and Commercial Value per Pound for Species Impinged and Entrained at Great Lakes Facilities

Species Group	Percent Impact to Recreational Fishery ^a	Percent Impact to Commercial Fishery ^a	Commercial Value per Pound (2002\$) ^b
Black crappie	100.0%	0.0%	na
Bluegill	100.0%	0.0%	na
Bullhead species	0.0%	100.0%	\$0.50
Channel catfish	50.0%	50.0%	\$0.50
Crappie	100.0%	0.0%	na
Freshwater drum	0.0%	100.0%	\$0.14
Muskellunge	100.0%	0.0%	na
Rainbow smelt	50.0%	50.0%	\$0.61
Smallmouth bass	100.0%	0.0%	na
Sunfish	100.0%	0.0%	na
Walleye	100.0%	0.0%	na
White bass	50.0%	50.0%	\$0.85
Whitefish	50.0%	50.0%	\$0.84
Yellow perch	50.0%	50.0%	\$2.12
Other (forage) ^c	50.0%	50.0%	\$0.71

^a Based on opinion of local experts and comments received at proposal. EPA collected recreational landings data by species from State fisheries experts. However, this data was limited to a few broad species groups and was not sufficient to calculate more accurate values.

^b Calculated using 1993-2001 commercial landings data from NMFS (2003a, http://www.st.nmfs.gov/commercial/landings/annual_landings.html).

^c Assumed equally likely to be caught by recreational or commercial fishermen. Commercial value calculated as overall average for region based on data from NMFS (2003a).

Age-1 equivalent fish that are spared from I&E are not necessarily old enough or large enough to be attractive to anglers. It may take one or more years for these fish to reach a harvestable age. For this reason, EPA discounts commercial and recreational benefits so that the cost and benefits estimates will be comparable. Tables G2-6 and G2-7 present the multiplicative discounting factors used in discounting benefits assuming a 3 percent real discount rate and a 7 percent real discount rate. For details on how these factors are developed, see Chapter A14.

Table G2-6: Factors Applied to Recreational Benefits to Implement Discounting in the Great Lakes

Species Group	Discount Factors for Entrainment		Discount Factors for Impingement	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Black crappie	na	na	0.928	0.845
Bluegill	na	na	0.925	0.838
Channel catfish	0.938	0.866	0.966	0.926
Crappie	0.901	0.789	0.928	0.845
Pikes	na	na	0.696	0.439
Rainbow smelt	0.904	0.796	0.931	0.851
Salmonids (other)	0.947	0.884	0.976	0.946
Smallmouth bass	0.926	0.839	0.953	0.897
Sunfish	0.908	0.803	0.936	0.859
Walleye	0.890	0.770	0.917	0.823
White bass	0.919	0.826	0.947	0.883
Yellow perch	0.899	0.783	0.925	0.838
Other (forage)	0.919	0.829	0.919	0.829

Table G2-7: Factors Applied to Commercial Benefits to Implement Discounting in the Great Lakes

Species Group	Discount Factors for Entrainment		Discount Factors for Impingement	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Bullhead species	na	na	0.895	0.778
Channel catfish	0.899	0.786	0.925	0.841
Freshwater drum	0.837	0.672	0.862	0.719
Rainbow smelt	0.889	0.765	0.915	0.818
Salmonids (other)	0.934	0.858	0.962	0.918
White bass	0.913	0.813	0.941	0.870
Yellow perch	0.895	0.776	0.921	0.830
Other (forage)	0.901	0.793	0.901	0.793