Chapter H3: Evaluation of I&E Data

EPA evaluated impacts to aquatic organisms resulting from the CWIS of the J.R. Whiting facility using the assessment methods described in Chapter A5 of Part A of this document. EPA's analysis focused on I&E rates at J.R. Whiting before and after installation of a deterrent net in 1980 to reduce impingement. The facility's I&E monitoring program was designed to evaluate the effectiveness of the net, and therefore included 2 years of sampling of baseline I&E losses before installation of the net and several years of impingement monitoring after (Wapora, 1979, 1980; Consumers Power Company, 1984, 1988, 1994). EPA evaluated these two sampling periods to estimate (1) I&E rates with no technology in place, and (2) the reduction in impingement resulting from the deterrent net. Section H3-1 of this chapter lists fish species that are impinged and entrained at J.R. Whiting, Section H3-2 presents life histories of the most abundant species in the facility's I&E collections, and Section H3-3 summarizes the facility's I&E collection methods. Section H3-4 presents annual I&E losses before installation of the deterrent net to reduce impingement, Section H3-5 presents impingement losses following net installation, and Section H3-6 summarizes these results.

CHAPTER CONTENTS

H3-1 Species Vulnerable to I&E

EPA evaluated all species known to be impinged and entrained by the J.R. Whiting facility based on information provided in facility I&E monitoring reports (Wapora, 1979, 1980; Consumers Power Company, 1984, 1988, 1994). Table H3-1 lists these species, and their classification as recreational, commercial, or forage species.

Table H3-1: Species Vulnerable to I&E by J.R. Whiting

Common Name	Scientific Name	Recreational	Commercial	Forage
Alewife	*Alosa pseudoharengus*			X
Bluegill	*Lepomis macrochirus*	X		
Bluntnose minnow	*Pimephales notatus*			X
Bullhead species	*Ameiurus* spp.		X	
Carp	*Cyprinus carpio carpio*		X	
Carpsucker or buffaloe	Catostomidae			X
Channel catfish	*Ictalurus punctatus*	X	X	
Crappie species	*Pomoxi* spp.	X		
Emerald shiner	*Notropis atherinoides*			X
Freshwater drum	*Aplodinotus grunniens*		X	
Gizzard shad	*Dorosoma cepedianum*		X	
Goldfish	*Carassius auratus auratus*		X	
Herring family	Clupeidae			X
Logperch	*Percina caprodes*			X
Minnow family	Cyprinidae			X
Orangespotted sunfish	*Lepomis humilis*	X		

Table H3-1: Species Vulnerable to I&E by J.R. Whiting (cont.)

Common Name	Scientific Name	Recreational	Commercial	Forage
Perch family	*Percidae*	X		
Pumpkinseed	*Lepomis gibbosus*	X		
Rainbow smelt	*Osmerus mordax mordax*			X
Shiner species	Cyprinidae			X
Smallmouth bass	*Micropterus dolomieui*	X		
Spottail shiner	*Notropis hudsonius*			X
Sucker species	Catostomidae		X	
Sunfish species	Centrarchidae	X		
Tadpole madtom	*Noturus gyrinus*			X
Troutperch	*Percopsis omiscomaycus*			X
Walleye	*Stizostedion vitreum*	X		
Warmouth	*Lepomis gulosus*	X		
White bass	*Morone chrysops*	X	X	
White perch	*Morone americana*	X		
Yellow perch	*Perca flavescens*	X		

Sources: Wapora, 1979, 1980.

H3-2 Life Histories of Major Species Impinged and Entrained

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, 2001). 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, 2001).

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, 2001).

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 exhibit 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, 1999c).

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, 2001.
[c] PSEG, 1999c.
[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.

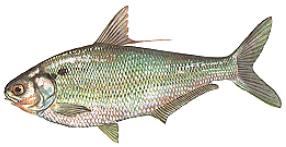
Gizzard shad (*Dorosoma cepedianum*)

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).



GIZZARD SHAD
(*Dorosoma cepedianum*)

Family: Clupeidae (herrings).

Common names: Gizzard shad.

Similar species: Threadfin shad.[a]

Geographic range: Eastern North America from the St. Lawrence River to Mexico.[b,c]

Habitat: Inhabits inland lakes, ponds, rivers, and reservoirs to brackish estuaries and ocean waters.[b,c]

Lifespan: Gizzard shad generally live 5 to 6 years, but have been reported up to 10 years.[b]

Fecundity: Maturity is reached by age 2; females produce average of 378,990 eggs.[b]

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]

Prey for: Walleye, white bass, largemouth bass, crappie, among others (immature shad only).[b]

Life stage information:

Eggs: *demersal*
- During spawning, eggs are released near the surface and sink to the bottom, adhering to any surface they touch.

Larvae: *pelagic*
- Larvae serve as forage to many species.
- After hatching, larvae travel in schools for the first few months.

Adults
- 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]

[a] Trautman, 1981.
[b] Miller, 1960.
[c] Scott and Crossman, 1973.
Fish graphic from Iowa Dept. of Natural Resources, 2001.

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.

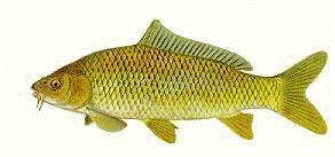
Carp (*Cyprinus carpio carpio*)

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 or 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, 1977a). 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 or 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, 1986a.
Fish graphic from North Dakota Game and Fish Department (1986).

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*)

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]

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.

[a] Froese and Pauly, 2001.
[b] Trautman, 1981.
[c] Scott and Crossman, 1973.
[d] Saila et al., 1987b.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

Channel catfish (*Ictalarus 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, 1977a). 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, 2001b).

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, 1986a). 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, 1986a). 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, 1977a).

CHANNEL CATFISH
(*Ictalarus punctatus*)

Family: Ictaluridae (North American freshwater catfish).

Common names: Channel catfish, graceful catfish.[a]

Similar species: Blue and white catfishes.[b]

Geographic range: South-central Canada, central United States, and northern Mexico.[a]

Habitat: Freshwater streams, lakes, and ponds. Prefer deep water with clean gravel or boulder substrates.[c]

Lifespan: Maximum reported age: 16 years.[a]

Fecundity: 4,000 to 35,000 eggs depending on body weight.[e]

Food source: Small fish, crustaceans, clams, snails.[a]

Prey for: Chestnut lamprey.[a]

Life stage information:

Eggs: *demersal*
- 3-4 mm in diameter.[d]
- Hatch in 7-10 days.[d]

Larvae:
- Remain near nest for a few days then disperse to shallow water.[d]
- Approx. 6.4 mm (0.25 in.) upon hatching.[d]

Adults: *demersal*
- Average length: 30-36 cm (12-14 in.).[c]
- Maximum length: up to 104 cm (41 in.).[c]

[a] Froese and Pauly, 2001.
[b] Trautman, 1981.
[c] Ohio Department of Natural Resources, 2001b.
[d] Wang, 1986a.
[e] Scott and Crossman, 1998.
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 exhibiting 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% reach maturity by age 6. Lake Erie males begin maturing at age 4, and by age 5, 79% 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.

FRESHWATER DRUM
(*Aplodinotus grunniens*)

Family: Sciaenidae.

Common names: freshwater drum, white perch, sheepshead.[a]

Similar species: white bass, carpsuckers.[a]

Geographic range: From Manitoba, Canada, to Guatemala. They can be found throughout the Mississippi River drainage basin.

Habitat: Bottoms of medium- to large-sized rivers and lakes.[b]

Lifespan: The maximum age for fish in western Lake Erie is 14 years for females and 8 years for males.[c]

Fecundity: Females in Lake Erie produce from 43,000 to 508,000 eggs.[e]

Food sources: Juveniles: Cladocerans (plankton), copepods, dipterans.[d]

Adults: Dipterans, cladocerans,[d] darters, emerald shiner.[e]

Prey for: Very few species.

Life stage information:

Eggs: *pelagic*

- The buoyant eggs float at the surface of the water, possibly accounting for the species' high distribution.[e]

Larvae:

- Prolarvae float inverted at the surface of the water with the posterior end of the yolk sac and their tail touching the surface.[f]

Adults:

- 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]

[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.

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, 2001b). White bass rarely live beyond 7 years (Scott and Crossman, 1973).

WHITE BASS
(*Morone chrysops*)

Family: Moronidae.

Common names: White bass, silver bass.

Similar species: White perch, striped bass.[a]

Geographic range: St. Lawrence River south through the Mississippi valley to the Gulf of Mexico, highly abundant in the Lake Erie drainage.[b]

Habitat: Occurs in lakes, ponds, and rivers.[c]

Lifespan: White bass may live up to 7 years.[d]

Fecundity: The average female lays approximately 565,000 eggs.[b]

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]

Prey for: Other white bass.[a]

Life stage information:

Eggs: *demersal*
- Eggs are approximately 0.8 mm (0.03 in.) in diameter.[b]

Larvae: *pelagic*
- White bass experience their maximum growth in their first year.[b]

***Adults*:**
- Travel in schools, traveling up to 11.1 km (6.9 mi) a day.[b]
- Most mature at age 3.[e]
- Adults prefer clear waters with firm bottoms.[a]

[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.

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).

WALLEYE
(*Stizostedion vitreum*)

Family: Percidae (perch).

Common names: Blue pike, glass eye, gray pike, marble eye, yellow pike-perch.[a]

Similar species: Sauger.[b]

Geographic range: Canada to southern United States.[c]

Habitat: Large, shallow, turbid lakes; large streams or rivers.[c]

Lifespan: Maximum reported age: 12 years.[b]

Fecundity: 48,000 to 614,000 in Lake Erie.[b]

Food source: Insects, yellow perch, freshwater drum, crayfish, snails, frogs.[a]

Prey for: Sea lamprey, northern pike, muskellunge, sauger.[a]

Life stage information:

Eggs: *demersal*
- 1.4 - 2.1 mm (0.06 - 0.08 in.) in diameter.[b]
- Hatch in 12-18 days.[c]

Larvae: *pelagic*
- Approx. 6.2 - 7.3 mm (0.24 - 0.29 in.) upon hatching.[b]

Adults: *demersal*
- Maximum length: up to 78.7 cm (31 in.).[c]

[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.

H3-3 J.R. Whiting's Methods for Estimating I&E

Sampling of impingement and entrainment was conducted from 1978 to 1991 at the J.R. Whiting facility. In 1980, a deterrent net was installed to reduce high impingement rates. Sampling methods are described in the following sections.

H3-3.1 Impingement Monitoring

The methods used by the J.R. Whiting facility to monitor impingement from April through December 1979 are described in Wapora (1980). There were 76 sampling events, with the most frequent sampling in the spring and fall, and comparatively less sampling in summer. Impingement monitoring involved backwashing intake traveling screens to remove debris and impinged organisms, and then collecting organisms for approximately 24 hours. During periods of high impingement rates, sampling periods were shortened. The collected organisms were then backwashed from the screens into a 9.5 mm (0.375 in.) mesh basket placed in the backwash trough adjacent to the traveling screen. Impingement sampling duration and intake and discharge water quality parameters were recorded. The total number of each species of fish was determined, and a representative subset of 25 fish per species were measured and weighed. Any remaining fish beyond the 25 selected for measurement were counted and weighed as a group.

Because the duration of sampling varied from collection to collection, impingement counts were first normalized to the total intake volume for the sampling period. Impingement densities were then scaled to estimate the total number of each species impinged using daily intake volumes for the monitoring period. The estimated impingement totals reported in Wapora (1980) were based on the assumption that sampling densities are representative of the overall rate of impingement.

Wapora (1980) does not contain an annual estimate based on the April-December 1979 impingement data. However, Consumers Power Company (1984) presents impingement estimates for 19 major species for March 1978 to March 1979, March 1979 to December 1979, February 1980 to December 1980, January 1981 to December 1981, January 1982 to December 1982, and January 1983 to December 1983. These annual rates were evaluated by EPA, as described in Sections H3-4 and H3-5.

H3-3.2 Entrainment Monitoring

Entrainment monitoring methods for the J.R. Whiting facility are reported in Wapora (1980). Sampling took place on 25 dates from April through October 1979, with most sampling in June and July. Entrained eggs and larvae were collected from the discharge canal using a 0.351 mm (0.01 in.) mesh plankton net fitted with a screw-on PVC collection bucket. On each sampling date, four samples were collected at various times during the day and night. Nets were placed in the canal perpendicular to the flow for a sampling period of at least 10 minutes.

The flow rate through the sampling net was monitored using a flowmeter centered in the mouth of the net. For each sample, the total collection time and flow rate were recorded and used to calculate the total volume of water filtered. Once sample collection was complete, the resulting collection of organisms was transferred to a 10% formalin solution to which Rose Bengal stain was added to facilitate sorting of ichthyoplankton.

Each entrainment sample was rinsed with tap water in a 0.125 mm (0.005 in.) sieve, and then washed into an enamel sorting tray. Eggs and larvae were removed from any debris. Samples containing greater than 100 larvae were subsampled with a plankton splitter, and no sample was split to less than 12.5% of the initial count.

All larvae were counted and the species and developmental stages were noted. In addition, up to 50 larvae of each species and developmental stage were measured to the nearest 0.1 millimeter. Eggs were counted and up to 50 per sample were measured to the nearest 0.1 millimeter.

Because the duration of entrainment sampling varied from collection to collection, entrainment counts were first normalized to the total volume of water filtered during sampling. Entrainment densities were then scaled to the daily intake volumes for the monitoring period to estimate the total number of each species entrained. The estimated entrainment totals were based on the assumption that sampling densities are representative of the overall rate of entrainment. Since no annual estimate was given, EPA used entrainment losses for October through August as an annual estimate for the calculations described in Sections H3-4 and H3-5.

H3-4 J.R. Whiting's Annual I&E Without the Net

H3-4.1 Annual Impingement Without the Net

Annual impingement before installation of the deterrent net to reduce impingement is presented in the following tables. Table H3-2 presents the annual number of impinged organisms without the net as estimated by J.R. Whiting, Table H3-3 presents these losses expressed as age 1 equivalents, Table H3-4 presents impingement losses of fishery species expressed as lost fishery yield, and Table H3-5 presents impingement losses expressed as production foregone. Details of these calculations are provided Chapter A5 of Part A of this document.

Table H3-2: J.R. Whiting Annual Impingement (numbers of organisms) Without Net, As Estimated by the Facility

Year	Alewife	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	Walleye	White Bass	Yellow Perch
1978	3,051	1,239	2,310	79,825	771	691,515	36,200	6,722,765	6,822	5,181	1,420	1,010	7,204	37,771	120,031
1979	311	2,203	2,291	30,817	364	582,946	31,353	16,709,084	5,078	433	660	1,054	965	35,226	56,837
Mean	1,681	1,721	2,300	55,321	568	637,230	33,776	11,715,924	5,950	2,807	1,040	1,032	4,084	36,498	88,434
Minimum	311	1,239	2,291	30,817	364	582,946	31,353	6,722,765	5,078	433	660	1,010	965	35,226	56,837
Maximum	3,051	2,203	2,310	79,825	771	691,515	36,200	16,709,084	6,822	5,181	1,420	1,054	7,204	37,771	120,031
SD	1,937	682	13	34,654	288	76,770	3,427	7,061,394	1,233	3,357	537	31	4,412	1,800	44,685
Total	3,362	3,442	4,601	110,642	1,135	1,274,461	67,553	23,431,849	11,900	5,614	2,080	2,064	8,169	72,997	176,868

Thu Jan 10 14:21:33 MST 2002 Raw.losses. IMPINGEMENT; Plant:jr.whiting.78.79;
PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/raw.losses.imp.jr.whiting.78.79.csv

Table H3-3: J.R. Whiting Annual Impingement Without Net, Expressed as Numbers of Age 1 Equivalents

Year	Alewife	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	Wall-eye	White Bass	Yellow Perch	Total
1978	3,505	1,441	2,977	87,500	933	818,373	41,766	11,739,860	9,117	6,970	1,701	1,683	8,288	50,643	141,464	12,916,222
1979	357	2,562	2,953	33,780	441	689,887	36,174	29,178,814	6,786	582	791	1,757	1,110	47,230	66,986	30,070,211
Mean	1,931	2,001	2,965	60,640	687	754,130	38,970	20,459,337	7,951	3,776	1,246	1,720	4,699	48,937	104,225	21,493,216
Minimum	357	1,441	2,953	33,780	441	689,887	36,174	11,739,860	6,786	582	791	1,683	1,110	47,230	66,986	12,916,222
Maximum	3,505	2,562	2,977	87,500	933	818,373	41,766	29,178,814	9,117	6,970	1,701	1,757	8,288	50,643	141,464	30,070,211
SD	2,226	793	17	37,986	348	90,853	3,954	12,331,203	1,648	4,516	644	52	5,075	2,413	52,664	12,129,702
Total	3,863	4,002	5,930	121,280	1,374	1,508,260	77,941	40,918,675	15,903	7,552	2,491	3,440	9,398	97,873	208,450	42,986,432

Note: Impingement losses expressed as age 1 equivalents are larger than raw losses (the actual number of organisms impinged). This is because the ages of impinged individuals are assumed to be distributed across the interval between the start of year 1 and the start of year 2, and then the losses are normalized back to the start of year 1 by accounting for mortality during this interval (for details, see description of S*j in Chapter A5, Equation 4 and Equation 5). This type of adjustment is applied to all raw loss records, but the effect is not readily apparent among entrainment losses because the majority of entrained fish are younger than age 1.
Thu Jan 10 14:29:33 MST 2002 ;Results; I Plant: jr.whiting.78.79 ; Units: equivalent.sums Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/I.equivalent.sums.jr.whiting.78.79.csv

Table H3-4: Annual Impingement of Fishery Species at J.R. Whiting, Without Net Expressed as Yield Lost to Fisheries (in pounds)

Year	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Freshwater Drum	Gizzard Shad	Sucker spp.	Sunfish spp.	Walleye	White Bass	Yellow Perch	Total
1978	22	93	42,282	8	2,219	463,399	21	1	1,455	4,280	334	514,113
1979	39	92	16,323	4	1,922	1,151,753	10	1	195	3,992	158	1,174,488
Mean	30	93	29,303	6	2,070	807,576	15	1	825	4,136	246	844,300
Minimum	22	92	16,323	4	1,922	463,399	10	1	195	3,992	158	514,113
Maximum	39	93	42,282	8	2,219	1,151,753	21	1	1,455	4,280	334	1,174,488
SD	12	1	18,356	3	210	486,740	8	0	891	204	124	466,956
Total	60	185	58,606	11	4,140	1,615,152	31	1	1,650	8,272	492	1,688,601

0 = Sampled, but none collected.
Thu Jan 10 14:29:40 MST 2002 ;Results; I Plant: jr.whiting.78.79 ; Units: yield Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/I.yield.jr.whiting.78.79.csv

Table H3-5: J.R. Whiting Annual Impingement Without Net, Expressed as Production Foregone (in pounds)

Year	Alewife	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	Wall-eye	White Bass	Yellow Perch	Total
1978	206	38	155	27,277	32	10,056	3,972	209,925	45	50	181	3	2,980	3,086	1,544	259,550
1979	21	67	154	10,530	15	8,477	3,440	521,757	34	4	84	3	399	2,878	731	548,596
Mean	114	52	155	18,904	23	9,267	3,706	365,841	40	27	133	3	1,689	2,982	1,138	404,073
Minimum	21	38	154	10,530	15	8,477	3,440	209,925	34	4	84	3	399	2,878	731	259,550
Maximum	206	67	155	27,277	32	10,056	3,972	521,757	45	50	181	3	2,980	3,086	1,544	548,596
SD	131	21	1	11,842	12	1,116	376	220,499	8	32	69	0	1,825	147	575	204,386
Total	227	105	309	37,807	47	18,533	7,412	731,682	79	54	266	6	3,379	5,964	2,276	808,146

0 = Sampled, but none collected.
Thu Jan 10 14:29:37 MST 2002 ;Results; I Plant: jr.whiting.78.79 ; Units: annual.prod.forg Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/I.annual.prod.forg.jr.whiting.78.79.csv

H3-4.2 Annual Entrainment Without the Net

Annual entrainment before net installation is presented in the following tables. Table H3-6 presents the annual number of entrained organisms without the net as estimated by J.R. Whiting, Table H3-7 presents these losses expressed as age 1 equivalents, Table H3-8 presents entrainment losses expressed as lost commercial and recreational fishery yields, and Table H3-9 presents entrainment losses expressed as production foregone. Details of these calculations are provided in Chapter A5 of Part A of this document.

H3-5 J.R. Whiting's Annual Impingement With the Net

Results of impingement monitoring after installation of the net indicate 92% reduction in impingement averaged over the years 1981-1991. The tables in this section present annual impingement rates after net installation. Table H3-10 presents annual impingement (numbers of organisms) with the net as estimated by J.R. Whiting, Table H3-11 presents these losses expressed as age 1 equivalents, Table H3-12 presents impingement losses with the net expressed as lost commercial and recreational fishery yields, and Table H3-13 presents losses with the net expressed as production foregone. Details of these calculations are provided in Chapter A5 of Part A of this document. No entrainment monitoring was conducted after net installation.

H3-6 Summary

Table H3-14 summarizes total I&E at J.R. Whiting before net installation in terms of raw losses, age 1 equivalents, fishery yield, and production foregone. Table H3-15 displays this information for impingement at J.R. Whiting after installation of the deterrent net. EPA estimates that without the net, baseline impingement damages at J.R. Whiting amount to 21,493,415 age 1 equivalent fish per year, representing 844,301 pounds of foregone fishery yield each year. With the net, lost fishery yield is reduced to 62,730 pounds per year. The following chapters discuss the estimated economic value of baseline I&E damages at J.R. Whiting without the net, the economic benefits of the deterrent net in reducing baseline impingement, and the potential economic benefits of various § 316(b) regulatory options.

Table H3-6: J.R. Whiting Annual Entrainment (numbers of organisms) Without Net, As Estimated by the Facility

Year	Bluntnose Minnow	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Logperch
1979	1,623,716	28,918	7,372,177	132,964	7,584,514	32,762,696	569,558,422	191,471

Thu Jan 10 14:21:34 MST 2002 Raw.losses. ENTRAINMENT; Plant:jr.whiting.78.79;
PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/raw.losses.ent.jr.whiting.78.79.csv

Table H3-6: J.R. Whiting Annual Entrainment (numbers of organisms) Without Net, As Estimated by the Facility (cont.)

Year	Others	Rainbow Smelt	Sucker spp.	Sunfish spp.	White Bass	Yellow Perch
1979	553,800,944	155,897	268,228	1,040,904	5,679,922	2,788,745

Thu Jan 10 14:21:34 MST 2002 Raw.losses. ENTRAINMENT; Plant:jr.whiting.78.79;
PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/raw.losses.ent.jr.whiting.78.79.csv

Table H3-7: J.R. Whiting Annual Entrainment Without Net, Expressed as Numbers of Age 1 Equivalents

Year	Bluntnose Minnow	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	White Bass	Yellow Perch	Total
1979	46,669	143	36,496	5,391	69,046	29,768	1,221,061	7,405	20,575	3,853	350,828	28,118	12,360	1,831,715

Thu Jan 10 14:29:31 MST 2002 ;Results; E Plant: jr.whiting.78.79 ; Units: equivalent.sums Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/E.equivalent.sums.jr.whiting.78.79.csv

Table H3-8: Annual Entrainment of Fishery Species at J.R. Whiting Without Net Expressed as Yield Lost to Fisheries (in pounds)

Year	Channel Catfish	Common Carp	Crappie spp.	Freshwater Drum	Gizzard Shad	Sucker spp.	Sunfish spp.	White Bass	Yellow Perch	Total
1979	4	17,636	45	1,581	48,198	48	127	2,377	29	70,045

Thu Jan 10 14:29:38 MST 2002 ;Results; E Plant: jr.whiting.78.79 ; Units: yield Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/E.yield.jr.whiting.78.79.csv

Table H3-9: J.R. Whiting Annual Entrainment Without Net, Expressed as Production Foregone (in pounds)

Year	Bluntnose Minnow	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	White Bass	Yellow Perch
1979	198	47	53,476	4,726	20,775	21,050	135,481	570	714	4,125	1,856	39,474	7,723

Thu Jan 10 14:29:35 MST 2002 ;Results; E Plant: jr.whiting.78.79 ; Units: annual.prod.forg Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.78.79/E.annual.prod.forg.jr.whiting.78.79.csv

Table H3-10: J.R. Whiting Annual Impingement (numbers of organisms) With Net, As Estimated by the Facility

Year	Alewife	Bull-head spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Fresh-water Drum	Gizzard Shad	Log-perch	Others	Rainbow Smelt	Sucker spp.	Sun-fish spp.	Wall-eye	White Bass	White Perch	Yellow Perch
1981	605	138	1,903	10,507	917	201,851	37,610	2,605,856	2,494	NA	723	154	2,090	441	19,421	0	34,044
1982	0	107	1,832	1,567	501	14,050	8,309	610,812	640	NA	8	38	646	283	5,612	0	4,864
1983	0	64	1,097	1,174	655	11,217	2,297	752,149	1,298	NA	22	29	1,025	83	2,815	0	3,431
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1986	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	0	67	250	122	181	5,604	886	72,428	0	177	0	0	290	9	269	1,697	892
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1989	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	0	21	578	405	58	354	4,254	300,253	0	356	0	0	395	2	686	8,698	515
Mean	121	79	1,132	2,755	462	46,615	10,671	868,300	886	266	151	44	889	164	5,761	2,079	8,749
Minimum	0	21	250	122	58	354	886	72,428	0	177	0	0	290	2	269	0	515
Maximum	605	138	1,903	10,507	917	201,851	37,610	2,605,856	2,494	356	723	154	2,090	441	19,421	8,698	34,044
SD	271	45	737	4,372	349	86,939	15,316	1,006,849	1,047	127	320	64	728	192	7,925	3,772	14,254
Total	605	397	5,660	13,775	2,312	233,076	53,356	4,341,498	4,432	533	753	221	4,446	818	28,803	10,395	43,746

NA = Not sampled.
0 = Sampled, but none collected.
Thu Jan 10 14:52:24 MST 2002 Raw.losses. IMPINGEMENT; Plant:jr.whiting.81.plus;
PATHNAME:P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.81.plus/raw.losses.imp.jr.whiting.81.plus.csv

Table H3-11: J.R. Whiting Annual Impingement With Net, Expressed as Numbers of Age 1 Equivalents

Year	Alewife	Bull-head spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Fresh-water Drum	Gizzard Shad	Log-perch	Rain-bow Smelt	Sucker spp.	Sun-fish spp.	Wall-eye	White Bass	White Perch	Yellow Perch
1981	695	160	2,453	11,517	1,110	238,880	43,393	4,550,566	3,333	973	184	3,483	507	26,039	0	40,123
1982	0	124	2,361	1,718	606	16,627	9,587	1,066,652	855	11	46	1,077	326	7,524	0	5,733
1983	0	74	1,414	1,287	793	13,275	2,650	1,313,466	1,735	30	35	1,708	95	3,774	0	4,044
184	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1986	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	0	78	322	134	219	6,632	1,022	126,480	0	0	0	483	10	361	2,263	1,051
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1989	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	0	24	745	444	70	419	4,908	524,327	0	0	0	658	2	920	11,597	607
Mean	139	92	1,459	3,020	560	55,167	12,312	1,516,298	1,185	203	53	1,482	188	7,724	2,772	10,312
Minimum	0	24	322	134	70	419	1,022	126,480	0	0	0	483	2	361	0	607
Maximum	695	160	2,453	11,517	1,110	238,880	43,393	4,550,566	3,333	973	184	3,483	507	26,039	11,597	40,123
SD	311	52	949	4,792	423	102,888	17,671	1,758,245	1,399	431	76	1,214	221	10,626	5,030	16,800
Total	695	462	7,295	15,099	2,799	275,834	61,561	7,581,491	5,923	1,013	265	7,410	941	38,619	13,860	51,558

Note: Impingement losses expressed as age 1 equivalents are larger than raw losses (the actual number of organisms impinged). This is because the ages of impinged individuals are assumed to be distributed across the interval between the start of year 1 and the start of year 2, and then the losses are normalized back to the start of year 1 by accounting for mortality during this interval (for details, see description of S*j in Chapter A5, Equation 4 and Equation 5). This type of adjustment is applied to all raw loss records, but the effect is not readily apparent among entrainment losses because the majority of entrained fish are younger than age 1.
NA = Not sampled.
0 = Sampled, but none collected.
Thu Jan 10 15:33:14 MST 2002 ;Results; I Plant: jr.whiting.81.plus ; Units: equivalent.sums Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.81.plus/I.equivalent.sums.jr.whiting.81.plus.csv

Table H3-12: Annual Impingement of Fishery Species at J.R. Whiting With Net Expressed as Yield Lost to Fisheries (in pounds)

Year	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Freshwater Drum	Gizzard Shad	Sucker spp.	Sunfish spp	Walleye	White Bass	White Perch	Yellow Perch
1981	2	77	5,565	9	2,305	179,621	2	1	89	2,201	0	95
1982	2	74	830	5	509	42,103	1	0	57	636	0	14
1983	1	44	622	7	141	51,845	0	1	17	319	0	10
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1986	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	1	10	65	2	54	4,992	0	0	2	30	1	2
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1989	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	0	23	215	1	261	20,696	0	0	0	78	5	1
Mean	1	46	1,459	5	654	59,852	1	1	33	653	1	24
Minimum	0	10	65	1	54	4,992	0	0	0	30	0	1
Maximum	2	77	5,565	9	2,305	179,621	2	1	89	2,201	5	95
SD	1	30	2,316	4	939	69,402	1	0	39	898	2	40
Total	7	228	7,296	23	3,270	299,258	3	3	165	3,264	6	122

NA = Not sampled.
0 = Sampled, but none collected.
Thu Jan 10 15:33:21 MST 2002 ;Results; I Plant: jr.whiting.81.plus ; Units: yield Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.81.plus/I.yield.jr.whiting.81.plus.csv

Table H3-13: J.R. Whiting Annual Impingement With Net, Expressed as Production Foregone (in pounds)

Year	Alewife	Bullhead spp.	Channel Catfish	Common Carp	Crappie spp.	Emerald Shiner	Freshwater Drum	Gizzard Shad	Log-perch	Rainbow Smelt	Sucker spp.	Sunfish spp.	Wall-eye	White Bass	White Perch	Yellow Perch
1981	41	4	128	3,590	38	2,935	4,127	81,370	17	7	20	6	182	1,587	0	438
1982	0	3	123	535	21	204	912	19,073	4	0	5	2	117	459	0	63
1983	0	2	74	401	27	163	252	23,487	9	0	4	3	34	230	0	44
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1985	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1986	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1987	0	2	17	42	7	81	97	2,262	0	0	0	1	4	22	8	11
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1989	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1990	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1991	0	1	39	138	2	5	467	9,376	0	0	0	1	1	56	39	7
Mean	8	2	76	941	19	678	1,171	27,113	6	1	6	3	68	471	9	113
Minimum	0	1	17	42	2	5	97	2,262	0	0	0	1	1	22	0	7
Maximum	41	4	128	3,590	38	2,935	4,127	81,370	17	7	20	6	182	1,587	39	438
SD	18	1	50	1,494	14	1,264	1,681	31,440	7	3	8	2	79	648	17	183
Total	41	12	380	4,707	95	3,389	5,855	135,567	30	7	28	13	338	2,353	47	563

NA = Not sampled.
0 = Sampled, but none collected.
Thu Jan 10 15:33:17 MST 2002 ;Results; I Plant: jr.whiting.81.plus ; Units: annual.prod.forg Pathname:
P:/Intake/Great_Lakes/GL_Science/scodes/jr.whiting/tables.output.81.plus/I.annual.prod.forg.jr.whiting.81.plus.csv

Table H3-14: Average Annual Impingement and Entrainment at J.R. Whiting Before Net Installation (sum of annual means of all species evaluated)

	Impingement	Entrainment
Raw losses (# of organisms)	12,588,366	1,182,989,518
Age 1 equivalents (# of fish)	21,493,215	1,831,713
Fishery yield (lbs of fish)	844,301	70,045
Production foregone (lbs of fish)	404,074	290,215

Table H3-15: Average Annual Impingement at J.R. Whiting Following Net Installation (sum of annual means of all species evaluated)

	Impingement
Raw losses (# of organisms)	949,124
Age 1 equivalents (# of fish)	1,612,966
Fishery yield (lbs of fish)	62,730
Production foregone (lbs of fish)	30,685

Note: Entrainment was not sampled after installation of the impingement deterrent net.