Briefing booklet for structured expert judgment questionnaire

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Asian Carps of the Genus *Hypophthalmichthys* (Pisces, Cyprinidae) — A Biological Synopsis and Environmental Risk Assessment

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A lack of information is available in peer-reviewed literature about the habitat use of juvenile Silver Carp in the United States because the invasion is recent and ongoing. Williamson and Garvey (*in press*), however, report an abundance of young-of-year Silver Carp in the backwaters of the middle Mississippi River. Some of the field biologists encountering juvenile Silver Carp in 2004 reported collecting this life stage in low velocity and off-channel habitats in the Missouri, Mississippi, Wabash, and lower Ohio rivers (Table 1). Young-of-year (<100 mm) and juvenile (100-500 mm) Silver Carp collected for the LTRMP (1992-2004) were found in similar proportions between main channel borders, side channel borders, and contiguous backwaters (Fig. 13).

Largescale Silver Carp

Largescale Silver Carp prefer slow-moving, plankton-rich open waters. This species is a nocturnal feeder and remains in deeper waters during daylight hours (Pearl River Fisheries Research Institute 1991). Chen (1998) noted that migrations into flowing water are associated with spawning behavior. He also noted that Largescale Silver Carp typically reside in slow-moving, open waters. The only information we found on local movements involved diurnal feeding movements of this species.

Biology and Natural History

Temperature Tolerance

Bighead Carp

Bighead Carp can tolerate extremes in water temperature, from cold temperate to tropical. In their native range in China, Bighead Carp spawn at different temperatures: in the Yangtze River, from 26 to 30°C in 1957 to a range of 18.3 to 23.5°C in 1953 and 1954 (Chang 1966) and as low as 18°C in the Han River (Chunsheng et al. 1980). Russian waters provide several other examples of temperature tolerance: in the delta region of the Lower Volga River, 3- to 4-day-old larvae were caught in early June 1972, and the water temperature at the time of spawning could not have been higher than 14-15°C according to calculations by Opuszynski and Shireman (1995). Negonovskaya (1980) reported that in the lakes of Russia's Pskov Region, the most active feeding activity occurs at 20-22°C, Bighead Carp fingerlings continued minimal feeding levels at 10°C and survived (albeit did not feed or respond to external stimuli) at temperatures as low as 5°C. In studies with archival tags implanted in adult Bighead Carp in the Missouri River in 2003 and 2004, DCC (unpublished data) found that the fish were inactive below 2°C, but that fish were usually active at temperatures above 4°C, and sometimes moved to the surface at night. DCC sometimes collected adult Bighead Carp with full guts at temperatures lower than 4°C, but gut evacuation rates in Bighead Carp at these temperatures are not known.

Experiments with thermal preferences conducted in Texas (Bettoli et al. 1985) indicated that young Bighead Carp (56-73 mm) acclimated to 23.0ºC selected a mean temperature of 25.4ºC. Their critical thermal maximum appeared to be 38.8ºC, and a preferred temperature range of 25.0 to 26.9ºC in the laboratory has been reported (Bettoli et al. 1985). We found no documentation of lower water temperature lethal limits. Nevertheless, the presence of Bighead Carp in rivers and reservoirs in the Manchurian Plain that remain frozen 4 to 6 months out of the year suggests that the species is quite cold tolerant.

Also significant is the finding that annual temperature fluctuations, which are characteristic in the natural range of Chinese carps, are not necessarily needed for natural reproduction. In the Pampanga River Basin of the Philippines, for example, where natural spawning occurs, the temperature does not change appreciably during the year. The average range in monthly air temperature is from 25.9 to 19.6°C (Opuszynski and Shireman 1995).

Silver Carp

As with Bighead Carp, the water temperature range at which larval Silver Carp can exist is broad: 16-40°C (Tripathi 1989), with optimum temperature reported as 26-30 (Panov and Khromov 1970, in Radenko and Alimov 1992), 39 (Opuszynski et al. 1989), and 33.5°C (Radenko and Alimov 1992). The ultimate upper lethal temperature of larval Silver Carp (aged 3 to 28 days) was 43.5-46.5°C (Opuszynski et al. 1989). Silver Carp are quite tolerant to low water temperatures. In Alberta, Canada, Silver Carp successfully overwinter in ponds that are near 0ºC from around the beginning of November through the end of April (B. MacKay, Alberta Department of Agriculture, Food and Rural Development, Lethbridge, Alberta, personal communication, 2004). Silver Carp are known to feed at water temperatures of 10 to 19°C in Israel (Leventer 1979, in Wrigley et al. 1988). When the water temperature dropped below 15°C, appetite of Silver Carp was reduced, and below 8-10°C, feeding almost ceased (FAO 1980; Tripathi 1989). In the Missouri River, Silver Carp caught by DCC sometimes had full guts at temperatures lower than 4°C. Bialokoz and Krzywosz (1981) found that gut evacuation rate of Silver Carp at 4°C was 108 hours. At water temperatures below 18°C or higher than 31°C, rates of ovulation and hatching of Silver Carp have been reported to be low with high rates of abnormal embryonic development (FAO 1980). Water temperatures for maximum growth of Silver Carp have been reported to be 24-31°C (Mahboob and Sheri 1997) and 30-34°C (Javed 1988, in Mahboob and Sheri 1997). Presence of this species in the Amur River Basin and absence of Bighead Carp (except where introduced) from that basin, suggests that the Silver Carp may be more cold tolerant than Bighead Carp.

Largescale Silver Carp

Although we found no information on temperature tolerance, the native range of this species (21-22º N) indicates that it is a subtropical to tropical species and may be intolerant of temperate climates. Nevertheless, hybrids between this species and Silver Carp are established in the middle Syr Dar’ya River (ca. 44-46º N) in Kazakstan (Payusova and Shubnikova 1986; Salikhov and Kamilov 1995), a clear indication that the hybrids are tolerant of a temperate climate.

Salinity Tolerance

Bighead Carp

Several studies have indicated that Bighead Carp can survive within a limited range of low salinities. Chervinski (1980) found that adult Bighead Carp, when transferred from fresh water to saltwater, were able to adjust to 15-20‰ saltwater concentrations. Fish that were kept in water at these concentrations for an additional 2 weeks remained alive. Fermin (1990) and Garcia et al. (1999) conducted studies of Bighead Carp fry in Laguna Lake, Philippines, which undergoes an annual intrusion of seawater. They concluded that Bighead Carp fry possess some degree of osmoregulatory capability, allowing them to survive and grow following direct exposure to a range of low salinities. In the Terek Region of Russia, Bighead Carp larvae and fingerlings migrate into the coastal areas of the Caspian Sea (salinity = 6-12‰), where they remain until reaching sexual maturity (Abdusamadov 1987).

Research has been conducted on salinity tolerances of Bighead Carp fry in the Philippines (Garcia et al. 1999). Most Bighead Carp culture in the Philippines occurs in Laguna Lake in lakeshore hatcheries of the 89,000-ha lake. During the dry season (March-June), seawater from Manila Bay enters the lake through the Pasig River. Bighead Carp fry were exposed to seawater for 96 hours at 11, 18, and 35 days post-hatch. There was 98.3% to 100% survival of all fry at salinities of 0% and 2‰. At a salinity of 4‰, all 11-day-old fry died but 98.9% of 18-day-old fry and 100% of 35-day-old fry survived. Only 56.7% of 18-day-old fry and 100% of 35-day-old fry survived at 6‰, and at 8‰ only 25% of the 35-day-old fry survived. At salinities above 2‰, food intake, absorption, and conversion efficiencies were reduced, slowing growth rate. Thus, the ability of Bighead Carp fry to osmoregulate increased with age and 6‰ appeared to be the critical maximum salinity.

Silver Carp

According to the FAO (1972), Silver Carp is a freshwater species that can live in slightly brackish waters. However, as in Bighead Carp, a limited range of salinity tolerances has been reported for this species. Zang et al. (1989) reported that Silver Carp fingerlings could withstand, at most, water at 1.5‰ salinity whereas Zabka (1983) bred Silver Carp in water with a salinity of 2.5‰. Waller (1985) also reported that salinity should be maintained below 4‰ to produce Silver Carp. Falk (1986) found that Silver Carp reared in water at 5.1‰ salinity increased in weight from 1.3 to 8.8 g/individual in 32 days. Tripathi (1989) reported that fry and fingerlings have a tolerance of 7.5‰ to 12.0‰ salinity. Abdusamadov (1987) reported that larvae and fingerlings of Silver Carp migrate into the coastal areas of the Caspian Sea where the salinity is 6‰ to 12‰, where they remain until reaching sexual maturity. Verbal reports of Silver Carp in low salinity backwater bays along the Gulf Coast of Louisiana have not been confirmed.

Largescale Silver Carp

No information was found on the salinity tolerance of Largescale Silver Carp. Considering that this species is most closely related to Silver Carp with which it hybridizes, its salinity tolerance is probably similar to that of Silver Carp.

Reproductive Biology

Fecundity

Bighead Carp

Bighead Carp have a notably high fecundity rate. Fertility of Bighead Carp increases with age and body weight and is directly related to growth rate (Verigin et al. 1990). In Russian waters, females spawning for the first time had an average stripped fecundity of 280,000 eggs (Vinogradov et al. 1966) whereas older spawners gave 478,000 to 549,000 eggs (Abdusamadov 1987). In the Terek Region of the Caspian Basin, absolute individual fecundity of introduced Bighead Carp ranged from 316,300 to 1,860,800 eggs (Sukhanova 1966). In the Yangtze River, China, fecundity of Bighead Carp weighing 18.5 kg (42 lbs) was 1.1 million eggs (Chang 1966). Fecundity of Bighead Carp from the lower Missouri River collected in 1998-1999 ranged from 11,588 to 769,964, with an average of 226,213 eggs (Schrank and Guy 2002).

High fecundity in fishes is usually accompanied by high mortality in early life stages and low fecundity with parental care or protection and lower mortality. However, as noted by de Iongh and Van Zon (1993), predation may be less intense in a nonnative habitat, giving a highly fecund nonindigenous fish such as the Bighead Carp an advantage over species with lower fecundity. Welcomme (1988) suggested this mechanism to explain the successful establishment of Common Carp beyond its native range.

Silver Carp

Fecundity of Silver Carp, like that of Bighead Carp, is high and well studied. Estimates of fecundity have differed among geographic regions and the size of fish examined: 315,000-1,340,500 eggs per female (for a 62 cm, 4.2 kg, and a 82 cm, 9.3 kg fish; Abdusamadov 1987), 299,000-5,400,000 eggs per female (Kamilov and Salikhov 1996), 145,000-2,000,000 eggs per female for fish 3.18-8.51 kg (Alikunhi et al. 1963, in Singh 1989), and 597,000-4,329,600 eggs per female for fish 6.4-12.1 kg (Singh 1989). Total fecundity of six Silver Carp from the middle Mississippi River in 2003 ranged from 57,283 to 328,538 (Williamson and Garvey, *in press*). As in other fishes, fecundity of Silver Carp increases with body size (Kamilov and Salikhov 1996). Dobriyal (1988) reports a linear relation between body length and fecundity and between body length and ovary weight. Kamilov and Komrakova (1999) found no significant association between relative fecundity and length or weight.

Largescale Silver Carp

We found no specific information regarding the fecundity of Largescale Silver Carp in the literature but expect fecundity would be similar to that of Silver Carp.

Sexual Maturity and Mating Behavior

Bighead Carp

Henderson (1979b) reported that sexual maturity of Bighead Carp was reached at 3 or 4 years, but Chang (1966), Huet (1970), and Bardach et al. (1972) noted that age at maturity varied significantly with environmental and climatic conditions. In southern China, for example, Bighead Carp males, usually maturing 1 year earlier than females (Jennings 1988), reached sexual maturity at 2 to 3 years; in central China, at 3 to 4 years; and in northeast China, at 5 to 6 years (Kuronuma 1968). Woynarovich and Horváth (1980) recorded the average age of Bighead Carp at first maturity in temperate climates to be 6 to 8 years, compared with 3 to 4 years in subtropical and tropical climates. A similar discrepancy existed for the average size of these fish at first maturity: in temperate climates, Bighead Carp matured at an average weight of 5 to 10 kg and 70 to 80 cm, and at a smaller size—an average of 3 to 7 kg—in subtropical and tropical climates (Woynarovich and Horváth 1980).

Mating activity of Bighead Carp generally takes place at the surface (Chang 1966) with males actively chasing females and sometimes leaping out of the water. Usually more than two males follow one female; like other carps, the Bighead Carp is promiscuous (Jennings 1988; Opuszynski and Shireman 1995). A male often prods its head against the belly of a female, sometimes causing both fish to flip over, swim upside down, and ultimately cast the eggs and milt into the air (Chang 1966). In an intensive 5-year study of 1,700 km of the Yangtze River, Yi et al. (1988b) found that Bighead and Silver carps used 36 specific spawning sites. The spawning sites were used by both species.

Silver Carp

Like male Bighead Carp, male Silver Carp usually mature 1 year earlier than females (Kuronuma 1968), and the age at which this species reaches sexual maturity was variable across systems. In the rivers of south China, Silver Carp matured at 3 to 4 years whereas further north in the Yangtze River, they did not mature until age 4 (Konradt 1965). Silver Carp matured even later in the Amur River (Makeeva 1963, in Konradt 1965), and not until at least age 5 for those raised in southern regions of the former USSR (Konradt 1965). All Silver Carp collected by Kamilov and Komrakova (1999) from Uzbekistan were mature at 4 years. Abdusamadov (1987) reported Silver Carp spawning at age 4 to 8 years in the Terek Region of the Caspian Basin. Berg (1964) stated that Silver Carp were mature by their sixth year of life, presumably in the former USSR. Kuronuma (1968) found that Silver Carp matured at 2 to 5 kg and 2 to 3 years in southern China, at 4 to 5 years in central China, and at 5 to 6 years in northern China.

Maturation rate of Silver Carp, as in Bighead Carp, has been found to be related to water temperature, requiring 1,000 degree days at 15°C and 500 degree days at 30°C (Jhingran and

Pullin 1985, in Laws and Weisburd 1990). In Guangxi, China, with a growing period of 12 months and water temperatures averaging 27.2°C, Silver Carp matured in 2 years; in Guangdong, China, with a 11-month growing season and average water temperature of 25°C, they matured in 2 to 4 years; in Jiangsu, China, with an 8-month growing season and water temperature of 24°C, they matured in 3 to 4 years, and in the Amur River with a 5.5-month growing season and average water temperature of 20.2°C, they matured in 5 to 6 years (FAO 1980). In the natural climatic conditions of Uzbekistan, gonadal development and growth of Silver Carp are positively correlated. Growth rate of Silver Carp in the first year of life is the determining factor for age of sexual maturation (Kamilov 1987). They have matured in farm ponds of Uzbekistan at 3 years when they have attained 17 cm and 100-120 g in the first year of life (Kamilov 1987).

When Silver Carp are ready to spawn, ripples have been seen on the water surface from spawners chasing each other. About 40 to 80 minutes later, males and females ascended close to the water surface, chasing each other and shedding eggs and sperm (Kuronuma 1968). Yi et al. (1988b) found that Silver Carp repeatedly used discrete spawning sites within the Yangtze River, and enumerated the number of sites. Thirty-six sites, used for Bighead and Silver carps for spawning, were found in 1,700 km of river.

Largescale Silver Carp

Largescale Silver Carp reach sexual maturity at a younger age than Bighead or Silver Carp. Pearl River Fisheries Research Institute (1991) and Chen (1998) reported that females reach maturity in 2 years and males in 1 year. No information was found on mating behavior other than spawning typically occurs in rivers during rains or floods in May and June, although spawning may be postponed until mid-August (Pearl River Fisheries Research Institute 1991; Chen 1998).

Spawning

Bighead Carp

In Asia, Bighead Carp generally spawn between April and June, peaking in late May (Chang 1966; Verigin et al. 1978). Spawning of Bighead Carp is initiated by rising water levels following the heavy rains that occur in the spring or, in China, during the monsoon season (Jennings 1988; Pflieger 1997). Yi et al. (1988b) found that eggs were collected mostly on the rising hydrograph, as opposed to after the peak. Bighead Carp migrate upstream to spawning grounds (Verigin et al. 1978). In an ongoing telemetry study, DCC has tracked Bighead Carp traveling long distances upriver, sometimes exceeding 80 km during periods of high water.

Spawning grounds of Bighead Carp are characterized by rapidly flowing (current velocity of 0.6 to 2.3 m/s) turbid water, 18-30°C, with suspended solids and a visibility of 10 to 15 cm (Chang 1966; Verigin et al. 1978). These sites are commonly found where there is a mixing of water, such as at a confluence of rivers, among the rocks of rapids, or behind sandbars, stonebeds, or islands (Breder and Rosen 1966; Chang 1966; Huet 1970). Chang (1966) documented these environmental conditions in his studies of Bighead Carp spawning sites in the Yangtze, Pearl, and Hwai river systems in their native China.

Although Asian and European populations of Bighead Carp have been studied extensively, the spawning characteristics and early life history of this species in North American river ecosystems have yet to be well documented. Nevertheless, results of preliminary studies of Bighead Carp in the United States indicate parallels in spawning conditions and behavior to populations in Asia and Europe. A study by Schrank et al. (2001), for example, found that increased water discharge and a temperature of 22°C initiated spawning of Bighead Carp in the lower Missouri River—similar to results reported from Asian literature.

When *Hypophthalmichthys* are introduced to a new environment, however, their reproductive requirements may undergo substantial changes (Opuszynski and Shireman 1995). For example, the successful spawning of three Chinese carps (Grass [*Ctenopharyngodon idella*], Silver, and Bighead carps) in the Kara Kum Canal, Turkmenistan, contradicts the belief that a rise in the water level is a basic precondition to spawning. The Kara Kum Canal is probably the only known example of natural reproduction of Asian carps in a human-made channel. Although it flows rapidly (0.9 to 1.2 m/s) and is turbid with suspended material from the Amu Dar'ya River, the water level in the canal is more or less stable and not subjected to substantial fluctuations in the spring-summer period when spawning occurs (Aliev 1976). Also, Tang (1960) reported that Bighead Carp spawned in a reservoir in Taiwan, but the details are unclear.

Silver Carp

In the Terek Region of the Caspian Basin, Abdusamadov (1987) reported the spawning migration of introduced Silver Carp started during the last 2 weeks of May and continued until the beginning of July. Other timings reported for Silver Carp vary slightly: mid-May through mid-June spawning in Arkansas (Freeze and Crawford 1983); May through July in the Terek River (Abdusamadov 1987); June through the end of July or the beginning of August in the Amur River where this species is native (Krykhtin and Gorbach 1981; Gorbach and Krykhtin 1989); late May or early June through June in Uzbekistan (Kamilov 1987), where it probably lasts for 8 to 10 weeks (Berg 1964); in April-July in its native China (Dobriyal 1988); and in June-July in Japan (Dobriyal 1988). Water temperatures reported during Silver Carp spawning include 18-19 (Abdusamadov 1987) and 22-26°C (Kaul and Rishi 1993). The introduced Silver Carp spawning grounds in the Syr Dar'ya River have been found to vary from year-to-year and be influenced by flood intensity and current velocity (Kamilov and Salikhov 1996). Large lakes connected to rivers often serve as nursery areas for Silver Carp (e.g., Poyang Lake, in the middle basin of the Yangtze River; Wang et al. 2003a).

As in Bighead Carp, Silver Carp often spawn after a sharp rise in the water level associated with the spring freshet (Verigin 1979). Krykhtin and Gorbach (1981) suggested that associating spawning with a rise in water level is adaptive because this decreases the possibility of egg mortality and helps larvae to enter floodwaters rich in the food they need, at the commencement of exogenous feeding. Konradt (1965) offered that the timing of spawning is determined by water level changes and that temperature plays a subordinate role. Jankovic (1992) believed that suspended alluvium (1.2 kg/m^3) was more important for successful spawning than water level increase. It is unclear if homing behavior exists in Silver Carp (Wang et al. 2003a).

Because Silver Carp eggs, like those of Bighead Carp, are semi-buoyant, spawning typically occurs in water of sufficient flow to keep the eggs from sinking to the bottom and dying (Laird and Page 1996). Reported current velocities required for successful spawning range from 0.3 to 3.0 m/s (Chang 1966; Holĉík 1976; Krykhtin and Gorbach 1981; Kamilov and Salikhov 1996). Abdusamadov (1987) found most eggs in the main river channel at current velocities 1.1-1.9 m/s. Total quantity of heat required for reproduction of Silver Carp is 2,685 degree days on average (Abdusamadov 1987). Silver Carp are known to spawn in one reservoir, the Gobindsagar Reservoir, in Himachal Pradesh, India (Sehgal 1989, 1999).

In the Amur River, specimens occur with asynchronous vitellogenesis indicating that the same female may spawn twice during one growing season (Makeeva 1963, in Konradt 1965). There is less information on the spawning activities of Silver Carp in the United States than for Bighead Carp.

Bighead and Silver Carps

As described above, Bighead and Silver carps are known to spawn in the spring and early summer after a rise in water levels. There are also several indications of spawning by Bighead and Silver carps in the wild in late summer or early fall in the United States. These indications are recent and most have not yet been reported in peer-reviewed literature. Therefore, we rely on personal communications and unpublished data to convey the early indications that Bighead and Silver carps have a prolonged spawning period in the United States.

Pflieger (1997) reported collecting a 7.6 cm (age 0) Bighead Carp in mid-August and a 2.5-cm (age 0) Bighead Carp in mid-September in the Missouri River, suggesting an extended spawning period or multiple spawning. Rasmussen (2002) noted multiple size classes of young-of-year *Hypophthalmichthys* in the Upper Mississippi River backwaters in 1999 and 2000. Diana Papoulias (U.S. Geological Survey, Columbia, Missouri, unpublished data), using histological analysis, found females and males of Bighead and Silver carps at late reproductive stages (V and VI) as late as October in 2003 and 2004. Kerry Reeves (U.S. Geological Survey Cooperative Fish and Wildlife Research Unit, University of Missouri, Columbia, Missouri, unpublished data) collected *Hypophthalmichthys* larvae from the lower Missouri River in late August or early to mid-September each year from 2002 to 2004. On October 3, 2004, young-of-year Silver Carp measuring 27 to 37mm were caught in floodplain wetlands of the lower Missouri River (A. Starostka, U.S. Fish and Wildlife Service Field Research Office, Columbia, Missouri, unpublished data). These wetlands had been connected to the river by overbank floods on August 31 and September 1, 2004. Silver Carp collected in July on the same wetland were more than 100 mm total length, evidently the result of spawns in spring 2004. Schrank and Guy (2002) found bimodal distribution of intraovarian egg diameters from Bighead Carp in the lower Missouri River. Taken together, these data provide strong evidence that *Hypophthalmichthys* in the United States have a potential spawning season that extends into late summer and early fall.

Largescale Silver Carp

In its native range (Red River, northern Vietnam, and Nandujiang River of Hainan), Largescale Silver Carp is reported to typically spawn in May and June, although spawning may be delayed until mid-August. Rains or floods stimulate spawning migrations into rivers (Pearl River Fisheries Research Institute 1991; Chen 1998). No additional information was found on the spawning habits of Largescale Silver Carp. Because Largescale Silver and Silver carps are closely related, we presume that spawning requirements are similar to those of Silver Carp.

Early Development

Bighead Carp

During spawning, eggs are released by Bighead Carp in rapids of rivers, on the downstream sides of sandbars, and in currents around islands (Jennings 1988). The eggs are semi-buoyant and must remain suspended in the water column by the turbulence of the moving water in order to hatch (Soin and Sukhanova 1972; Yi et al. 1988b; Pflieger 1997). Nevertheless, in 2004, many Bighead Carp eggs were inadvertently collected while sampling bedload sediment in a side channel of the Missouri River (DCC, unpublished data). They were held at room temperature in unaerated and unagitated plastic bags of water and sediment where they hatched and survived for 4 days, at which time they were sacrificed.

Soin and Sukhanova (1972) and Yi et al. (1988a) described the eggs, larvae, and fry of Bighead, Silver, Black (*Mylopharyngodon piceus*), and Grass carps. Yi et al. (1988a) provided elegant sketches of the eggs and larvae at small incremental changes in development. The water-hardened eggs of Bighead Carp were larger than those of Silver and Grass carps, usually ranging in size between 5.7 and 6.2 mm, but rarely as small as 4.9 mm. Fresh, unpreserved eggs of *Hypophthalmichthys* were clear in color, unlike those of Grass Carp with a slight yellow tint. Table 2 provides data on myomere counts that can be used to differentiate between the larvae of Bighead, Silver, Grass, and Black carps. Further diagnostic characteristics including pigmentation, fin shape, and morphometric differences of these carps at different larval stages can be found in Yi et al. (1988a).

Table 2. Myomere counts in three stages in the larval development of Bighead (*Hypophthalmichthys nobilis*), Silver (*H. molitrix*), Grass (*Ctenopharyngodon idella*), and Black carps (*Mylopharyngodon piceus*). Anterior = number of myomeres anterior to caudal fin, not including myomere directly under leading edge. Posterior = number of myomeres between anterior and vent, including myomere directly over vent. Translated from Yi et al. (1988a).

Species	Immediately posthatch				At first appearance of gas bladder				After two chambers of gas bladder visible			
	Trunk section		Caudal section	Total	Trunk section		Caudal section	Total	Trunk section		Caudal section	Total
	Anterior	Posterior			Anterior	Posterior			Anterior	Posterior		
Bighead Carp	6	17	15	38	8	15	16	39	11	12	16	39
Silver Carp	6	19	14	39	8	17	15	40	10	15	15	40
Grass Carp	8	22	13	43	9	21	15	45	12	18	15	45
Black Carp	7	19	14	40	9	17	15	41	11	15	15	41

In large river ecosystems, an increase in discharge coupled with rising water temperature provides good conditions for larval fish that depend on floodplains for development (Galat et al. 1996). One day after fertilization, if spawning occurs during periods of rising water level, the eggs and hatching Bighead Carp larvae are carried downstream to flooded lakes, creeks, and channels that serve as nursery areas (Nikolsky 1963; Huet 1970). Currents may carry larvae to quieter waters such as creeks, lakes, reservoirs, or flooded areas that become nursery areas (Nikolsky 1963). Under conditions of falling water levels, larvae migrate away from river channels to vegetated calm waters (Nikolsky 1963; Chang 1966). Nikolsky (1963) reported that if eggs and larvae descend during periods of falling water, the larvae actively migrate to nursery areas, out of the main channel, to seek refuge in vegetation and feeding grounds. Such behavior has not been studied in the United States.

Incubation of Bighead Carp eggs in soft water can cause premature and poor survival of the larvae (Chaudhuri 1979). The outer membranes of fertilized Bighead Carp eggs absorb water and swells rapidly. If the incubating medium has a lower ionic concentration than the egg, premature bursting of the egg from excessive water absorption may occur (Gonzal et al. 1987). Poor survival of Bighead Carp because of soft water has been a problem for fish farmers (Chaudhuri 1979). Although we found no information specific to Bighead Carp, a study examining the effect of water hardness on the survival of Silver Carp eggs (Gonzal et al. 1987) found that a water hardness of 300-500 mg/L calcium carbonate was optimal for the successful hatching of Silver Carp.

Silver Carp

Silver Carp also produce semi-buoyant eggs released during periods of flooding that are carried by currents through the hatching stage (Laird and Page 1996). Currents bring larvae to slow-flowing backwaters, creeks, reservoirs, or other flooded areas that become nursery areas (Nikolsky 1963). Gorbach and Krykhtin (1989) found that eggs and larvae of Silver Carp can be carried more than 500 km downstream from spawning grounds. Krykhtin and Gorbach (1981) stated that minimum flow requirements and developmental period to exogenous feeding necessitates >100 km of channel for successful reproduction of Silver Carp.

Soin and Sukhanova (1972) and Yi et al. (1988a) described the eggs and larvae of Silver Carp. The water-hardened eggs of Silver Carp ranged in diameter from 4.9 to 5.6 mm, similar to eggs of Grass Carp but smaller than those of Bighead Carp. Fresh eggs of Silver Carp were clear and could be distinguished from Grass Carp eggs that had a yellow tinge. Table 2 provides data on myomere counts than can be used to differentiate between the larvae of Bighead, Silver, Grass, and Black carps. Further diagnostic characteristics including pigmentation, fin shape, and morphometrics differences of these carps at different larval stages can be found in Yi et al. (1988a).

When incubated in soft water, eggs of Silver Carp can hatch or burst prematurely (Chaudhuri 1979). If the incubating medium has a lower ionic concentration than the egg, premature bursting occurs from excess water absorption. Highest hatching rates (22-29%) were reported at water hardness of 300, 400, and 500 mg/L calcium carbonate whereas low hatching rates (3-5%) were observed at 100 and 200 mg/L calcium carbonate (Gonzal et al. 1987).

Optimum total hardness was 382 mg/L calcium carbonate for hatchability and 423 mg/L for larval viability (Gonzal et al. 1987). Water softness is unlikely to limit reproduction of Bighead and Silver carps within the central United States where the water is usually hard, but may be important in some areas where *Hypophthalmichthys* are not yet established, for example, certain tributaries of the Great Lakes.

Largescale Silver Carp

No specific information was found. Nevertheless, because this species is most closely related to Silver Carp, early development of this species is probably similar.

Feeding Habits

Bighead Carp

Most literature cites the Bighead Carp as being predominantly zooplanktivorous (Borutskiy 1973; Lazareva et al. 1977; Cremer and Smitherman 1980; Burke et al. 1986; Dong and Li 1994), particularly when zooplankton biomass is high (Danchenko 1970; Lazareva et al. 1977). The youngest larvae (7-9 mm) have been found to eat primarily protozoa and zooplankton, including rotifers, the cladocerans *Bosmina* and young *Moina*, and copepod nauplii and copepodites (Chang 1966; Bardach et al. 1972; Marciak and Bogdan 1979). Ling (1967) found that 10-17 mm larvae consumed Cladocera. At lengths between 18 and 23 mm, larvae began to eat phytoplankton (mainly diatoms), and at 24 to 30 mm they readily consumed zooplankton and phytoplankton (Ling 1967). Lazareva et al. (1977) found that when zooplankton biomass was above 2 to 3 g/m^3, and the stocking rate was sufficiently low, that zooplankton constituted 14-25% of the food bolus weight of juvenile Bighead Carp. Borutskiy (1973) reported that adult Bighead Carp feed primarily on zooplankton in fish ponds in eastern regions of the former Soviet Union. Nikol’skiy and Aliyev (1974) reported that adult Bighead Carp in the Kara Kum Canal, former USSR, relied primarily on zooplankton (cladocerans, copepods, and to a lesser extent, rotifers) in the spring and early fall.

Larval, juvenile, and adult Bighead Carp exhibit highly opportunistic feeding habits, however, depending in part, on zooplankton abundance and biomass. Many studies have shown that when concentrations of zooplankton are low, Bighead Carp will switch to feeding on phytoplankton (blue-green algae, diatoms, and green algae). Lazareva et al. (1977) found that larval Bighead Carp in ponds with low zooplankton biomass switched from primarily zooplankton to phytoplankton (blue-green and euglenoid algae). They also reported a lower incidence of zooplankton in the stomachs of juvenile Bighead Carp from ponds with lower zooplankton biomass (0.7-5.5% of food bolus weight when zooplankton was 1 g/ m^3, increasing to 14-25% of food bolus weight at 2-3 g/ m^3 zooplankton). Nikol'skiy and Aliyev (1974), Danchenko (1970), Lazareva et al. (1977), and Burke et al. (1986) found that Bighead Carp fed primarily on zooplankton during May and June and switched to colonial algae in July and August, when standing stocks of algae were high and zooplankton was scarce. Bighead Carp sometimes consume large quantities of detritus, as well; other studies have found an average of 69.3% of their diets and as much as 87% to 97% of the weight of food they consumed was comprised of organic substances and mineral particles (Moskul 1977; Cremer and Smitherman 1980; Opuszynski 1981).

The feeding adaptability of Bighead Carp is related to the morphology of its comb-like gill rakers and epibranchial organ. Dong and Li (1994) described a large number of taste buds in the epithelium of the filtering organ, which may aid Bighead Carp in identifying areas with a high density of zooplankton. Food selectivity also depends on plankton density and particle size: if plankton biomass is sufficient (5 mg/L) and a size differential exists within the plankton community, the fish tend to selectively filter the larger food items. When plankton biomass has been sufficient, without a size differential, food selectivity has not been observed (Jennings 1988). Consumption of larger food particles, usually 50-100 µm but up to 3,000 µm, has been reported (Cremer and Smitherman 1980; Spataru et al. 1983; Opuszynski and Shireman 1991). Although the gape of Bighead Carp is large, foregut size may limit the particle size that can be consumed. Expansion of the foregut to accommodate larger particles appears to be limited by the structure of the pharyngeal teeth and the grinding plate (DCC, personal observation). Bighead Carp also ingest particles up to four times smaller than gill raker width, particularly in times of zooplankton scarcity (Opuszynski et al. 1991). Although the mechanism used for this small-particle food capture is not entirely clear, it is possible that a mucous coating on the gill rakers facilitates this by trapping smaller particles and aiding their passage to the esophagus (Jennings 1988).

Filter feeding by Bighead Carp influences the composition and size structure of the plankton community by reducing concentrations of zooplankton and large phytoplankters (Stone et al. 2000), although little research has been done on the effect of filter feeding by Bighead Carp on phyto- and zooplankton communities independent from that of Silver Carp. The combined stocking of Bighead and Silver carps has resulted in reduced cladocerans and copepods in a shallow, eutrophic lake in China where the fishes were not native (Yang et al. 1999), a decline in the abundance of cladocerans in a subtropical lake in China where the fishes were not native (Shao et al. 2001), cladocerans and copepods were severely reduced, and rotifers were reduced by more than 80% in a 0.8-ha pond in Colorado (Lieberman 1996).

There are two primary forms of filter-feeding in fishes: pump feeders and ram suspension feeders (Sanderson et al. 1994). Pump feeders (e.g., Gizzard Shad) use the buccal pump to push water through the filtering gill rakers (Sanderson et al. 2001). Lu and Xie (2001) considered Bighead Carp to be pump filter feeders. Dong and Li (1994) stated that juvenile Bighead Carp in aquaria functioned as pump filter feeders, and although they selected areas of high zooplankton abundance, they did not snap at individual prey or move towards individual zooplankters swimming in front of them. Ram suspension feeders (e.g., Paddlefish) hold their mouths open and swim through the water, forcing water through the filtering gill rakers (Sanderson et al. 1994). DCC has observed Bighead Carp in the field using a variety of feeding behaviors, including those resembling both types of filter feeding. Bighead Carp have been often observed hanging nearly vertically in the water with their heads toward the surface (Fig. 14), apparently using their buccal pump to feed on plankton or other food particles in the surface film or near the surface. Bighead Carp also exhibit ram feeding, or possibly a combination of ram suspension and pump feeding. In this behavior, the fish swims at a moderate speed in a mostly horizontal position holding their mouth open and forcing water through the gills, with intermittent gulps.

This behavior occurs below the surface or on the surface (Fig. 15). When Bighead Carp feed at or near the surface, the white lower lip forms a distinct crescent shape that is visible at a distance and very diagnostic of the presence of surface-feeding fish. Surface feeding by Bighead Carp has been observed in the Missouri River most often during the night and evening. Adult Bighead Carp have been observed taking larger food items into the mouth and blowing them out again repeatedly, apparently in an attempt to dislodge particles small enough to ingest. These observations are offered in the absence of available literature on feeding behavior of Bighead Carp. Bighead Carp may have other feeding behaviors in addition to these that have been observed, and the relative importance of different feeding behaviors is not known.

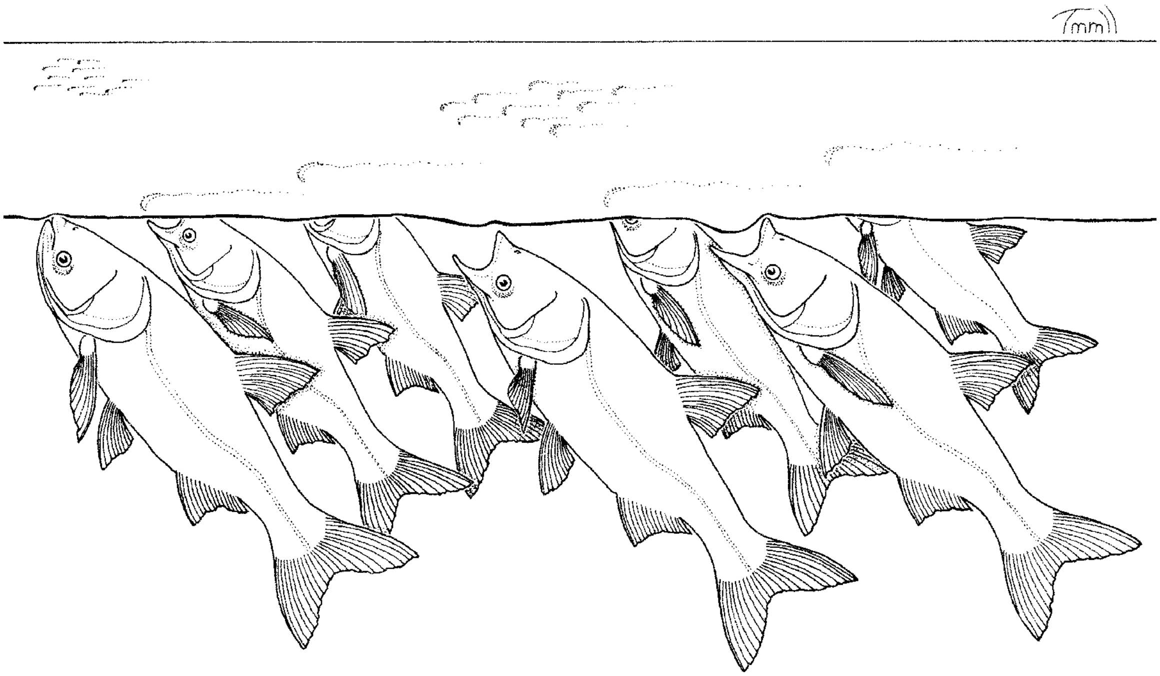


Figure 14. Bighead Carp, *Hypophthalmichthys nobilis*, pump-feeding at water surface. Illustration by Susan Trammell.

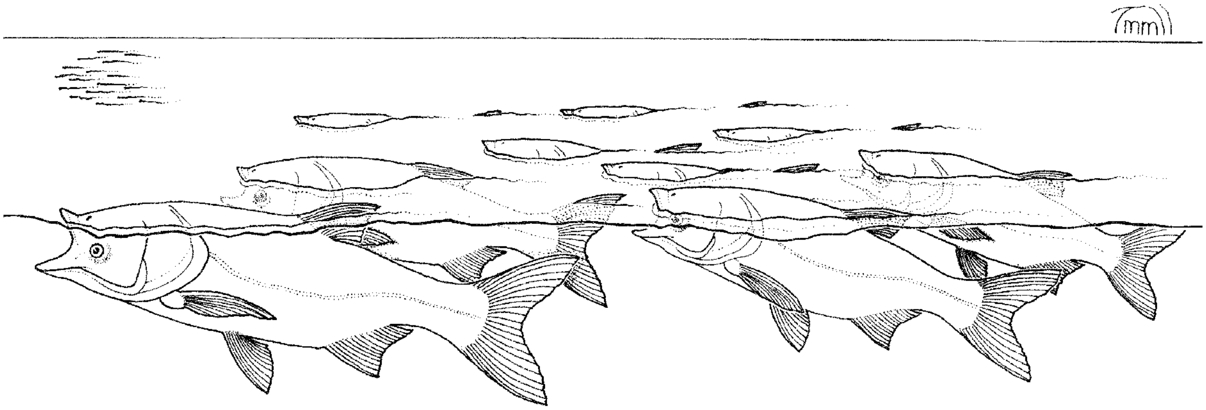


Figure 15. Bighead Carp, *Hypophthalmichthys nobilis*, ram feeding at the water surface. Illustration by Susan Trammell.

Although Bighead Carp are considered to be filter feeders, they can be caught with hook and line by using sweet smelling pasty baits that break down slowly (Hangzhou Rongchan Sporting Products Co., Ltd. 2003; Barth 2004), chunks of fish flesh (Angling Direct Holidays 2003), aquatic weeds, bread, potatoes, mollusks, and earthworms (Thai Fishing Guide Co., Ltd. 2004; Fig. 16). Sport angling for Bighead Carp generally relies on a "suspension method" in which dough bait is suspended in the water with tackle that facilitates hooking the fish, even though the bait is not consumed directly from the hook (Fig. 17).

Figure 16. Bighead Carp, *Hypophthalmichthys nobilis*, caught on hook and line, in Thailand. Photograph courtesy of Jean-Francois Helias, Fishing Adventures Thailand.

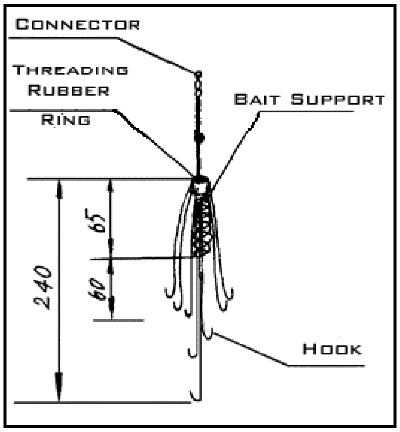


Figure 17. Tackle required for the 'suspension method' of sport angling for Bighead, *Hypophthalmichthys nobilis*, and Silver, *H. molitrix*, carps (modified from Hangzhou Rongchan Sporting Products Co., Ltd. 2003).

Bighead Carp in captivity have been reported to feed readily on pelleted trout food whereas Silver Carp will not (Shelton and Smitherman 1984). Bighead Carp also feed at a wide range of temperatures. In China, the optimum temperature for feeding was recorded as 20 to 30°C (Ling 1977); similarly, in small lakes of the former USSR, Negonovskaya (1980) found that Bighead Carp fed most actively at water temperatures of 20 to 22°C, but will continue levels of minimal feeding at 10°C. Preliminary research on the behavior of Bighead and Silver carps in the Missouri River indicates that the fish are active during cold weather and sometimes had full guts at water temperatures as low as 2.5°C (Chapman 2003), although gut evacuation rate is likely to be low at such low temperatures (Bialokoz and Krzywosz 1981).

While data pertaining to the consumption rate of Bighead Carp are limited, it is known that this fish, like other Asian carps, is a voracious feeder. Jennings (1988) noted that the daily ration (relation of total food weight taken in one day to the weight of the fish) for Bighead Carp was found to be 6.6% whereas Opuszynski and Shireman (1993) determined that the mean daily food ration of Bighead Carp ranged from 7.2% to 11.3% of fish body weight in ponds in Florida. Opuszynski et al. (1991) determined that the filtration rate ranged from 185 to 256 mL/h/g for 34- to 2,242-g fishes.

Silver Carp

Silver Carp consume plankton and other particles that are harvested by filtration, but can effectively filter and consume smaller particles than Bighead Carp (Table 3). They are thought to be pump filter feeders (Lu and Xie 2001). Silver Carp have gill rakers that are highly modified into a sponge-like filtering apparatus (Fig. 5; Jirasek et al. 1981). Ingested food is ground by blunt pharyngeal teeth against a cartilaginous plate (Robison and Buchanan 1988). They can remove smaller particles than would be expected based on the spaces between their gill rakers (Barthelmes 1977, in Adamek and Spittler 1984) because of an epibranchial organ (also called suprabranchial organ by some authors) that consolidates filtered materials by production of copious amounts of mucus (Spataru 1977). The epibranchial organ in Silver Carp is much smaller than that of the Bighead Carp. Silver Carp have been found to remove *Chlorella* (algae) at 3.2 µm (De-Shang and Shuang-Lin 1996), particles 4 µm (Omarov 1970), 5-10 µm (Kucklentz 1985), 10 µm, and larger (Smith 1989). Vörös et al. (1997) found that Silver Carp could not take in algae smaller than 10 µm based on comparison of gut contents with natural food assemblages. Cremer and Smitherman (1980) reported that food particles in the intestine were 8-100 µm, and Kaul and Rishi (1993) reported larval Silver Carp consumed particles 50-300 µm. Xie (1999) found 90-g Silver Carp removed particles 4.5-10 µm. Leventer and Teltsch (1990) found a maximum particle size of up to 100 µm. Spittler (1978) found that Silver Carp, 3-35 mg, chose particles 160-180 µm from a wide range offered. Silver Carp have been found to be ineffective at removing nannoplankton and picoplankton from the water (Sieburth et al. 1978). Although the gape of Silver Carp is large, foregut size may limit the particle size that can be consumed. Expansion of the foregut to accommodate larger particles appears to be limited by the structure of the pharyngeal teeth and the grinding plate (DCC, personal observation).

Many studies have found Silver Carp to feed primarily on phytoplankton (Ghosh et al. 1973; Cremer and Smitherman 1980; Kaushal et al. 1980; Spataru et al. 1983; Maheshwari et al. 1992). Ghosh et al. (1973), and Kirilenko and Chigrinzkaya (1983), and Vybornov (1989) considered Silver Carp to be important consumers of Cyanophyta (blue-green algae). Several studies have found that the cyanobacteria *Microcystis* may, depending on the season, constitute 20-98% of the food bolus of Silver Carp (Borutskiy 1973; Tarasova et al. 1977; Gorobets 1979; Tarasova 1979, in Kirilenko and Chigrinzkaya 1983; Shapiro 1985). Some controversy exists over whether Silver Carp can select certain taxa or particle sizes from the water that they filter.

Table 3. Comparison of the feeding habits of Bighead (*Hypophthalmichthys nobilis*) and Silver (*H. molitrix*) carps.

	Bighead carp	**Silver carp**
Type of feeder	Primarily a zooplanktivore, but highly opportunistic.	Primarily a phytoplanktivore, but highly opportunistic.
Food items consumed	Zooplankton; phytoplankton; detritus. Will bite on dough balls used as bait.	Phytoplankton; zooplankton; bacteria (planktonic and in aggregations); detritus. Can filter smaller particles than Bighead Carp. Will bite on bread paste and dough balls used as bait.
Morphological characteristics specific to feeding	Long, comb-like gill rakers coated with mucus to help trap smaller particles. Many taste buds on filtering organ aid detection of zooplankton.	Special filtering apparatus on gill bars allows removal of small particles. Suprabranchial organ consolidates ingested materials by producing large amounts of mucus.
Consumption rate	High; voracious feeder	High, but widely variable
Feeding temperatures	Most active at 20-22°C. Will continue levels of feeding at 10°C or as low as 2.5°C.	Most active at 15-30°C. Will continue feeding as low as 4°C. More cold-tolerant than Bighead Carp.
Ecological niche for feeding	Often at the water surface, but also feed throughout water column, including bottom.	Do not commonly feed at the surface.
Dietary overlap with indigenous species?	Yes	Yes

Cremer and Smitherman (1980) found phytoplankton in the guts of Silver Carp in the same proportion as in water samples, indicating no selectivity.

Efficiency of digestion of algae by Silver Carp has been found to vary by algal species: *Chloroella pyrenoidosa* 23%, *Scenedesmus obliquus* 22%, *Glenodinium* sp. 50%, *Pediastrum* sp. 48%, *Pandorin morum* 76%, pine pollen 91%, and *Brachionus calyciflorus* 100% (Dong et al. 1992). Xie (1999) suggested that the variable digestibility of algae is because of differential crushing of algae in the esophagus since little is lysed in the intestine. It has also been suggested that Silver Carp may not be able to meet energy requirements consuming phytoplankton alone (Bitterlich 1985c). Silver Carp fed only *Scenedesmus* showed 80% mortality after 5 weeks whereas those fed a mixed algae culture showed 25% mortality (Tarifeno-Silva et al. 1982). On the basis of stable carbon isotopes in fish muscle and algae and observations of stomach and intestinal contents, more than 90% of Silver Carp yield in the organically manured ponds was based on food webs originating with algal carbon (Schroeder et al. 1990). Miura and Wang (1985, in Leventer 1987) found 35% of the chlorophyll did not decompose in the digestive system and is excreted into the water.

Even though isotope techniques have indicated that Silver Carp digest green algae and cyanobacteria efficiently (Iwata 1976; Zhu and Deng 1983), whether Silver Carp are primarily phytoplanktivorous has been questioned. The gut fluids of Silver Carp lack cellulase, indicating difficulty in breaking down cellulose by means of enzymatic digestion (Ni and Chaing 1954, in Xie 1999; Bitterlich 1985a,b,c). As a result, a high proportion of algal cells in the hindgut or after excretion seem intact or remain live (e.g., Spataru 1977 observed live *Euglena* and *Phacus*, *Rotaria*, and *Brachionus*; Henebry et al. (1988) observed live *Chlamydomonas* in the hindgut or feces of Silver Carp). Not only are Silver Carp unable to obtain nutrition when algae passes through their system intact, but the growth of some algae is actually stimulated by passing through the intestine of the Silver Carp (Barthelmes 1977, in Adamek and Spittler 1984). Bitterlich (1985b) reported much undigested algal matter in the gut of Silver Carp, and differential digestion among algal taxa.

Filter feeding by Silver Carp has been shown to affect the abundance and structure of the phytoplankton community. The effect of filter feeding by Silver Carp on the biomass of phytoplankton appears inconsistent. Some studies (e.g., Kajak et al. 1975; Leventer 1987; Lieberman 1996; Lu et al. 2002) have shown that Silver Carp cause a decline in algal biomass. Others, however, have shown that algal biomass increases as a result of filter feeding by Silver Carp (e.g., Opuszynski 1981; Spataru et al. 1983; Milstein et al. 1985a). Regardless of their effect on the abundance of phytoplankton, studies have consistently shown that filter feeding by Silver Carp shifts the species composition of the phytoplankton community to smaller species (Kucklentz 1985; Leventer 1987; Milstein et al. 1988; Smith 1989; Costa-Pierce 1992; Laws and Weisburd 1990; Vörös et al. 1997).

Silver Carp also have been shown to consume zooplankton, especially when phytoplankton abundance is low (Spataru and Gophen 1985; Burke et al. 1986). Rotaria are important food for larval Silver Carp (Krykhtin and Gorbach 1981; Kouril et al. 1982). Dabrowski and Bardega (1984) found that from the third day of feeding, larval Silver Carp consumed zooplankton 300-400 µm. Sobolev (1970) found that Silver Carp fed on zooplankton at 2 weeks (12-14 mm), but that they switched to primarily phytoplankton after 18 days. Opuszynski (1979b) observed ontogenetic diet shift from being a general planktonic feeder to being selectively phytophagous in Lake Kinneret, Israel. Spataru and Gophen (1985) found that Silver Carp in Lake Kinneret consumed a high biomass of cyclopoid copepods and that zooplankton constituted 50% or more of Silver Carp diets in fall and winter. Domaizon et al. (2000) found zooplankton to be the major contributor to the diet of age 1+ Silver Carp (90.5% ingested biomass) whereas the diet of those 3+ years contained zooplankton (44.8% ingested biomass) and phytoplankton (55.2%). Using photosynthetic pigment ratios and photosynthetic rates of gut materials, Takamura et al. (1993) concluded that the occurrence of phaeophorbide *a* in feces of Silver Carp indicated consumption of herbivorous zooplankton, even though zooplankton was rarely observed in feces (perhaps because of rapid digestion; Bitterlich and Gnaiger 1984). Their results also showed that Silver Carp preferred Chlorococcales and Euglenophyceae over blue-green algae. These two types of phytoplankton, however, were observed in the feces of Silver Carp. Algae of these groups remained undigested and were still photosynthesizing after passage through the intestine. Gu et al. (1996) found using stable carbon and nitrogen isotope values that conventional diet analysis might have underestimated nutritional importance of zooplankton in Silver Carp because of their inability to determine dietary components incorporated into fish tissue and to determine dietary changes over time.

Filter feeding by Silver Carp has been shown to affect the structure and abundance of the zooplankton community. Studies have consistently shown that the presence of Silver Carp results in a zooplankton community dominated by smaller individuals. Fukushima et al. (1999), for instance, found that that the zooplankton community in Lake Kasumiguara (Japan) shifted toward smaller individual zooplankters in the presence of Silver Carp, regardless of fish density. In one of the two experiments, rotifers bloomed in the fishless enclosure and not in any of the different densities of fish. In enclosures in Lake Donghu, China, Lu et al. (2002) found that crustacean zooplankton biomass decreased with increasing fish biomass. They found that small-bodied crustacean zooplankton survived in the presence of fish, but large-bodied cladocerans and copepods were abundant only in enclosures without fish. Interestingly, they reported that calanoid copepods, which are evasive as adults, did not develop in enclosures with high densities of Silver Carp because of predation on nauplii. Domaizon and Devaux (1999) also found an inverse relation between Silver Carp density and zooplankton abundance. Many studies have attributed reduced abundance in zooplankton in response to the presence of Silver Carp (e.g., Milstein et al. 1985b; Burke et al. 1986; Wu et al. 1997; Radke and Kahl 2002). Silver Carp can also affect the population growth characteristics of zooplankters. Radke and Kahl (2002), for example, found that the presence of Silver Carp resulted in a rapid decline in the size and age at maturity of the cladoceran *Daphnia galeata*. The mechanism of the effect of Silver Carp on the zooplankton community has been debated. In a pond experiment, Burke et al. (1986) speculated that the reduction in zooplankton abundance in the presence of Silver Carp was due to competition for food resources (phytoplankton) because few zooplankters were found in the stomachs of Silver Carp. In another pond experiment, Milstein et al. (1985b) concluded that the relation between Silver Carp and the zooplankton community was complex—not only did Silver Carp prey on zooplankton, but they also competed with them for food resources.

Several studies have found that Silver Carp consume considerable amounts of bacteria, both planktonic and in aggregations (Kuznetsov 1978, 1980; Balasubramanian et al. 1993). Kuznetsov (1978) found that juvenile Silver Carp (6-10 g) consumed large quantities of bacterial aggregates, which were often surrounded by slime produced by the fish. Voropayev (1969) showed that Silver Carp filtered aggregates of bacteria ranging from 21 to 60 µm; Schroeder (1979) considered bacterial aggregates >37 µm to be a principal food for Silver Carp. Some authors have also found detritus in the intestine of Silver Carp (e.g., Bitterlich 1985c). Detritus has been reported to be >90% of Silver Carp diets in the Amur River in spring and 60-100% in fall (Borutskiy 1973, in Opuszynski 1981), 89-94% from Silver Carp in ponds (Borutskiy 1973), 90-99% (Vovk 1974), and >99% (Nabereznii et al. 1972). Large amounts of detritus in the intestine of Silver Carp suggested to Bitterlich (1985a) that these stomachless fish are omnivorous, not primarily herbivorous. Henebry et al. (1988) suggested that bacterial grown in the gut may be important in the nutrition of Silver Carp; bacteria increased in concentration between the foregut and midgut of the fish and decreased in concentration between the midgut and hindgut, indicating that bacteria were being grown and then digested.

Williamson (2004) found that Silver Carp from the middle Mississippi River selected for phytoplankton and against zooplankton in August and September 2003, but as phytoplankton abundance decreased, Silver Carp selected for zooplankton and against phytoplankton. He suggested that avoidance of zooplankton was driven by a high abundance of more difficult-to-capture copepods.

Although considered to be planktivorous in the literature, Silver Carp are successfully caught by hook and line using bread, bread paste waterproofed with salt-free butter and flavored with aromatic attractants such as “smelly” cheese, Aniseed oil, rotten bananas (Dias 2004), or sticky dough (Hangzhou Rongchan Sporting Products Co. Ltd. 2003) using specialized tackle (Fig. 17) and the “suspension method”.

Silver Carp are thought to be pump filter feeders (Lu and Xie 2001). Dong and Li (1994) stated that juvenile Silver Carp in aquaria functioned as pump filter feeders, and although they selected areas of high zooplankton abundance, they did not snap at individual prey or move towards individual zooplankton swimming in front of them. Despite the fact that both Silver and Bighead carps are abundant in the lower Missouri River, DCC has often observed Bighead Carp feeding but has never observed Silver Carp feeding behavior in the wild. The reason is unclear, but may be because Silver Carp are more difficult to approach, or perhaps because they do not share the surface-feeding behaviors of Bighead Carp.

Food consumption rates estimated for Silver Carp have been quite variable. Fry at the smallest size class consumed up to 140% of their body weight daily, declining to just more than 30% by 63 mg and rising up to 63% for fingerlings 70-166 mg (Wang et al. 1989). According to Moskul (1977, in Leventer 1979), Silver Carp consumed about 20% of their body weight per day. Kuznetsov (1980) found that juvenile Silver Carp consumed 0.15-0.18 g/m^3 bacteria (dry weight) per 1 g of weight in water without algae and 0.09-0.23 g/m^3 per 1 g in water with algae. Bialokoz and Krzywosz (1981) estimated annual food consumption of adult Silver Carp to be 8.8 kg, with 90% of consumption occurring during the three warmest months in Paproteckie Lake, Poland. Balasubramanian et al. (1993) found that filtration rate increased with the size of Silver Carp. Smith (1989) found a maximum filtering rate of Silver Carp to be 18.25 L/hour/fish. Removal rate of food particles by Silver Carp decreases with increasing particle size (Dong and Li 1994). Dong et al. (1992) found suction volumes (mL/mouth) increased with fish size and water temperature: 0.28 mL at 15°C and 0.17 mL at 25°C for a 5.6-cm fish, and 1.14 mL at 15°C and 1.34 mL at 25°C for a 11-cm fish.

Evacuation rates have been estimated for a variety of sizes and ages of Silver Carp at different water temperatures. Using food labeling, Omarov (1970) estimated the time of food passage through the intestine of a 2-year old Silver Carp (320-370 g) to be 4 hours at 23°C and 4.23 mg/L dissolved oxygen. Bialokoz and Krzywosz (1981) estimated evacuation rates to be 10 hours at 22.6°C and 108 hours at 4.0°C. Henebry et al. (1988) found a food retention time for 20.7-25.7 cm Silver Carp of 4 to 5 hours at 28.5°C. Okoniewska and Kruger (1979, in Bialokoz and Krzywosz 1981) found that gut passage time for Silver Carp (200-500 g) fluctuated between 5.5 and 10.2 hours at 20 to 22°C. Alimentary tracts containing more food emptied 30% slower than those that were less full (Bialokoz and Krzywosz 1981).

Largescale Silver Carp

Pearl River Fisheries Research Institute (1991) and Chen (1998) noted that Largescale Silver Carp feed on phytoplankton. Because this species is most closely related to Silver Carp, their food and feeding habits are probably much the same. Chen (1998) reported that Largescale

Silver Carp are nocturnal feeders, remaining in deeper water during daylight hours. No other information on feeding habits of this species was found.

Growth Rate and Longevity

Bighead Carp

Age and growth of Bighead Carp remain somewhat poorly understood because aging of this species has met with varied success. Nuevo et al. (2004a) found otoliths and cleithra to be unsuitable structures for age determination of Bighead Carp from the Mississippi River. However, Morrision et al. (2004) successfully used otoliths and scales in the aging of Bighead Carp caught from Lake Erie. Accuracy of age assessment of known-age fish in the Nuevo et al. (2004a) study was 69% using pectoral ray cross sections and 78% using scales. Nuevo et al. (2004b), using the pectoral ray cross-section method, found that Bighead Carp grew rapidly in the Mississippi River, reaching 1 kg in weight by age 2. Given their rapid growth rates, high fecundity, adaptable feeding behavior, and tolerance of a variety of environmental conditions, one could conclude that Bighead Carp is a hardy species with the potential to reproduce and persist as large, fluctuating populations in U.S. rivers and lakes.

Bighead Carp are capable of amazingly fast growth rates. In fertile waters with temperatures above 13.9 ºC, Bighead Carp can attain 2.7 kg in less than 1 year (Waterman 1997). After reaching 0.45 to 0.68 kg, they can gain 0.45 kg or more per month (Stone et al. 2000), are capable of reaching 18 to 23 kg in 4 to 5 years (Henderson 1978), and can grow up to 1.5 m or more in length. Maximum weight of Bighead Carp is around 40 kg (Baltadgi 1979). The U.S. record is a 40.8-kg Bighead Carp that was caught in a Texas lake in 1999 (Howells 2001). In culture systems, Bighead Carp show a high growth potential and outperform Silver and Grass carps in terms of net production (Woynarovich 1968; Newton 1980; Opuszynski 1981).

Three-year-old Bighead Carp collected from the lower Missouri River in 1998-1999 averaged 550 mm in length; 5-year-old Bighead Carp averaged 700 mm (Schrank and Guy 2002). The growth of Bighead Carp in the lower Missouri River during this time peaked between 2 and 3 years of age, declining after age 3 (Schrank and Guy 2002). Mean back-calculated lengths of Bighead Carp from the lower Missouri River were larger than those of Bighead Carp from populations stocked into reservoirs in Poland (Schrank and Guy 2002; Fig. 18). Nuevo et al. (2004b) reported that fish of the same ages, collected from the Mississippi River in the same years, were much larger than those collected by Schrank and Guy (2002) from the Missouri River; 3-year-old fish from the Mississippi River ranged from 757 to 852 mm, and 5-year-old fish ranged from 807 to 909 mm.

Survival of Bighead Carp in aquaculture has been reported to be high. Maddox et al. (1978) studied productivity of Bighead Carp, Silver Carp, and tilapias in a polyculture system in the United States, and reported that Bighead Carp survival was 92% during the 52-day study. Newton et al. (1978) combined five species at the rates (per hectare) of 250 Bighead Carp (1.39 kg), 1,250 Silver Carp (566 g), 50 Grass Carp (542 g), 50 Largemouth Bass (*Micropterus salmoides*; 184 g), and 3,150 Channel Catfish (*Ictalurus punctatus*; 36 g) in a low-intensity polyculture system in the United States. They reported that Bighead Carp survival averaged

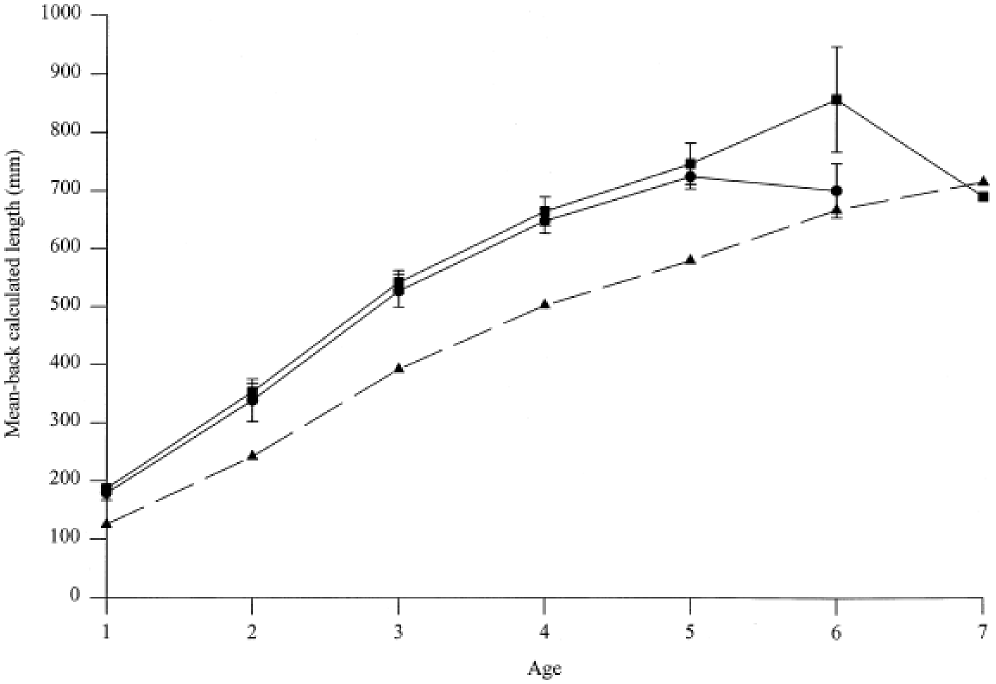


Figure. 18. Mean back calculated length (mm) by age using dorsal fin rays of male (*circles*) and female (*squares*) Bighead Carp (*Hypophthalmichthys nobilis*) collected in the lower Missouri River (May-August 1998, January-May 1999). Bars represent one standard error. Dashed line represents mean back calculated length of Bighead Carp stocked into lakes in Poland (Jennings 1988). Taken from Schrank and Guy (2002).

98% after 140 days. Green and Smitherman (1984) reported survival of Bighead Carp from eggs to larvae, with high quality spawn and normal incubation conditions, of not <70% to 80%. Furthermore, they reported survival of Bighead Carp fry stocked at 370,500 fry/ha to be 95% in ponds and 100% in tanks after 42 days.

As noted by Jennings (1988), there is a lack of specific information on longevity and mortality of naturalized or indigenous populations of Bighead Carp. Recently, the maximum age of Bighead Carp was reported to be 16 years (J. Yang, Kunming Institute of Zoology, Kunming, China, personal communication to P. Chen, Museum of Zoology, University of Kansas, 2004). The oldest Bighead Carp that have been aged in the United States, to our knowledge, was by Morrison et al. (2004). They aged two Bighead Carp that were caught from Lake Erie, Ontario, and reported that both fish were 8-10 years old, were in excellent health, and displayed recent growth at the time of capture. Because the biology of Grass Carp and that of Bighead Carp are similar, it is possible that the latter may have similar longevity. Although little is known about the longevity of Grass Carp, three specimens of Grass Carp were collected from Spiritwood Lake, North Dakota, in 2004 that must have been stocked into the lake by the North Dakota Department of Game and Fish in 1972, making these Grass Carp 32 to 33 years old (G. Van Eeckhout, North Dakota Department of Game and Fish, personal communication, 2004). These data suggest that Bighead Carp may be quite long lived.

Silver Carp

Like Bighead Carp, Silver Carp can grow quickly. In culture, the following growth rates have been reported: 1 kg in 55 days (Newton 1980), 1 kg in 5 months (Ghosh et al. 1973), a 17-fold increase in weight in 78 days for 7.6 cm Silver Carp (Stott and Buckley 1978), 5.4 kg in 1 year (Henderson 1979a), 2-2.5 kg in 2 years (Leventer 1987), and 18-23 kg at 4-5 years (Henderson 1979a). Silver Carp can also grow quickly in reservoirs and natural waters: 20+ kg in 5 years (Leventer 1987) in a wastewater reservoir. In Lake Kinneret, Israel, fish achieved 20 to 30 kg in 5 to 8 years (Leventer 1987). Kamilov and Salikhov (1996) reported Silver Carp up to a maximum total length of 1.26 m from the Syr Dar'ya River. Liang et al. (1999) grew six fish species in ponds for 2 years and found that Silver Carp had the highest increase in biomass (522 kg/ha/year). Net yield was 940 kg/ha; Silver Carp grew to marketable size (0.5-1.0 kg) in less than 1 year (Liang et al. 1999). In 2003, Silver Carp from the middle Mississippi River attained mean total lengths (back calculated from fin rays) of 318 mm by the end of the first year, and 650 mm by age 3 (Williamson and Garvey, *in press*).

Documented daily growth rates for Silver Carp include 0.003 g/day in mesocosm experiments (Starling 1993) and juveniles increased an average of 4.19 g/day (FAO 1980). At 400/ha in polyculture, Silver Carp grew 8.8 g/day (Leventer 1987), and grew 5.8 g/day in pen culture in reservoirs in Nepal (Rai 2000). During the first spring after they were stocked in Lake Kinneret, Israel, Silver Carp grew 4-5 g/day, and their growth rate increased to 8 g/day as temperature rose (Shefler and Reich 1977). During the next year when fish weighed 2+ kg, growth was about 10 g/day with some intervals at 15 g/day (Shefler and Reich 1977). The following percent increases have been reported: 6,000-9,000% in 180 days in Taiwan (Chien and Tsai 1985, in Smith 1994), 15,000% in 10 months in Taiwan (Sin and Chiu 1987, in Smith 1994); 11,000-15,000% in 12 months in Arkansas (Henderson 1983), and 2,000% in 6 months in Alabama (Cremer and Smitherman 1980, in Smith 1994). Silver Carp (age 1 through age 5) collected from the middle Mississippi River in 2003 grew substantially faster than those from Gobindsagar Reservoir, India, and those from the Amur River, Russia (Williamson and Garvey, *in press*).

Growth of Silver Carp is influenced primarily by food availability (Tripathi 1989; Hagiwara and Mitsch 1994, in Liang et al. 1999). However, Cremer and Smitherman (1980) found that growth of juvenile Silver Carp was not affected by phytoplankton densities in ponds and did not differ in ponds receiving fertilizer or feed (2.7 g/day for 159 days). Density dependent growth, however, has also been documented (Murty et al. 1978; Leventer 1987; Opuszynski 1980).

Shefler and Reich (1977) reported that Silver Carp did not cease growing in winter in Lake Kinneret, Israel. But Wrigley et al. (1988) found that Silver Carp decreased in weight during winter at a rate of 0.2-0.3% per day. Tripathi (1989) showed a weight loss of 21-32% in 30 days in Silver Carp (1.2-45.8 g) at 15-18°C, suggesting that overwintering of fry and fingerlings is more hazardous than that of juveniles and adults because of the higher metabolic rates of fry and fingerlings.

Survival of Silver Carp in aquaculture has been reported to be high. Ghosh et al. (1973) reported that Silver Carp cultured in ponds had almost 91% survival. Survival of Silver Carp at various stocking density rates (100,000-250,000/ha) was 74.4% to 99.3% (Murty et al. 1978) and 59.8% in a polyculture experiment (Liang et al. 1999). The annual mortality of Silver Carp in the middle Mississippi River, however, was lower than anticipated (64%) on the basis of literature values, given only limited commercial harvest of this species (Williamson and Garvey, *in press*).

Longevity data for Silver Carp are scarce largely because Silver Carp are difficult to age. It is clear from ponds with Silver Carp of known ages that one annulus forms on the scales in a year. Peculiarities of the scales of Silver Carp (the diffused expression of annuli) and opaque otoliths, however, make it difficult to use them for aging (Kamilov 1985). Sysoeva (1958, in Kamilov 1985) reported fan-shaped divergent circuli of the new year laid down after the annulus in all ages of Silver Carp from the Amur River. Aging of Silver Carp using other body parts has met with varied success. Johal et al. (2000) reported that the postcleithrum was a good aging structure for Silver Carp. Johal et al. (2001) stated that the body-cleithrum relation can be used for aging. Shefler and Reich (1977) reported aging Silver Carp using scales from the pectoral fin region. Kamilov (1985) found that the first ray of the pectoral fin, vertebrae, and pterygiophore of the first ray of the dorsal fin were suitable for aging whereas the operculum and otoliths were not.

Reports of maximum ages of Silver Carp indicate that the species is long lived. Kamilov and Salikhov (1996) found Silver Carp up to 10 years old in the Syr Dar'ya River in Uzbekistan, but this information probably applies to hybrids of Silver and Largescale Silver carps. Silver Carp in China have been reported to reach a maximum of 40 kg and live up to 15 years (J. Yang, Kunming Institute of Zoology, Kunming, China, personal communication to P. Chen, Museum of Zoology, University of Kansas, 2004). Berg (1964) reported that Silver Carp can reach an age of 20 years and that the 17+ year class dominated a particular catch. Because the biology of Grass Carp and that of Silver Carp are similar, it is possible that the latter may have similar longevity. Although little is known about the longevity of Grass Carp, three specimens of Grass Carp were collected from Spiritwood Lake, North Dakota, in 2004 that must have been stocked into the lake by the North Dakota Department of Game and Fish in 1972, making these Grass Carp 32 to 33 years (G. Van Eeckhout, North Dakota Department of Game and Fish, personal communication, 2004).

Largescale Silver Carp

Chan and Fan (1988) indicated that the Largescale Silver Carp has a slightly higher growth rate than Silver Carp and that the growth rate for hybrids between these two species is intermediate. They reported mean growth rate for 20 individuals each in culture in northern Vietnam as 511 g for Largescale Silver Carp and 370 g for Silver Carp in 1985. No information was found on longevity. Pearl River Fisheries Research Institute (1991) stated that a 1-year-old fish can reach 500 mm and weigh 3 kg; a 2-year-old fish, more than 600 mm and 6 kg; and a 3-year-old fish, 700 mm and 8 kg. Some large adults reach weights of 20 to 25 kg. Berg (1964) reported that Silver Carp can live 20 years. This suggests the possibility of a similar longevity in the closely related Largescale Silver Carp.

Response to Physical Stimuli

Over the past few years, Silver Carp have received considerable attention in the United States because of their physical and psychological impact on boaters. These fish become agitated by the sound and vibration of boat motors and react by leaping out of the water. Often they jump high into the air and hit boats and their passengers. Bighead Carp have also occasionally been reported to leap from the water in response to boat traffic, but this activity is either rare or possibly the reports are the result of misidentification of Silver Carp or hybrids of Silver and Bighead carps. Of hundreds of fishes that have leaped into the boat of one author (DCC), all of the fish have been Silver Carp or hybrid Bighead Carp × Silver Carp. Bighead Carp will occasionally leap a short distance out of the water when electrofished or when spawning.

Bighead Carp

Vinogradov (1979) described the Bighead Carp as a “quiet schooling fish, easily caught from lakes and reservoirs.” U.S. Fish and Wildlife Service (2003) reported that Bighead Carp submerged at the sound of an outboard motor in the Missouri River below Gavins Point Dam, South Dakota and Nebraska. During a telemetry study in the Missouri River, DCC has had many opportunities to observe the behavioral responses of *Hypophthalmichthys* spp. to motor boats. Tagged Bighead Carp were sometimes observed to react strongly to the presence of a running outboard or even an electric trolling motor, requiring that locations of the fish be established through triangulation from a distance. Tagged Bighead Carp occasionally left a wing-dike pool when the research vessel entered.

DCC has observed that Bighead and Silver carps are susceptible to being driven by a boat or other noise-generating methods useful in their capture. Nevertheless, Bighead Carp are more lethargic than Silver Carp and do not often jump from the water. Bighead Carp are easily caught from culture ponds using a seine. Green and Smitherman (1984) found that 75% to 99% of Bighead Carp were caught from a pond with a single seine haul, compared to 38% for Silver Carp.

Silver Carp

Silver Carp is a pelagic, schooling species (Mukhamedova 1977). Man and Hodgkiss (1981) reported that they usually swim just beneath the water surface. However, winter data from archival tags implanted in Silver Carp by DCC in the Missouri River indicated that these fish generally stayed between 1 and 5 m deep and were rarely located near the bottom. Unlike Bighead Carp, Silver Carp in the Missouri River or its tributaries are rarely observed on the surface until disturbed. DCC has observed that once disturbed, Silver Carp often swim rapidly near the surface creating a characteristic large wake. Silver Carp regularly jump out of the water when disturbed (Tarifeno-Silva et al. 1982; Skelton 1993), particularly in response to outboard motors (Fig. 19). Brian Todd (Missouri Department of Conservation, Kirksville, Missouri, personal communication, 2003) stated that this response is more pronounced with higher RPMs and greater motor noise.

Figure 19. Jumping Silver Carp, *Hypophthalmichthys molitrix*. Photograph courtesy of R.D. Nelson, U.S. Department of Agriculture, Natural Resources Conservation Service, Lincoln, Nebraska.

Reports of large jumping Silver Carp seriously injuring boaters and water-skiers and severely damaging watercraft are becoming more frequent (Beattie 2002; Deardorff 2002; Kilborn 2002; Perea 2002; Lien 2003; Myhre 2003; Williams 2003). Occurrences of Silver Carp landing in boats and hitting boaters are commonplace. With boat speeds of more than 32 km/hour and fish that sometimes exceed 9 kg, results can be disastrous (Chapman 2003). One day of sampling fish in the Missouri River by DCC resulted in more than 100 kg of Silver Carp jumping into a research vessel. Fishery biologists working in areas with Silver Carp are often hit by jumping fish (Perea 2002; M. Pegg, Illinois Natural History Survey, Havana, Illinois, personal communication, 2003). As reported by Meersman (2004), boater Marcy Poplett was on the Illinois River in October 2003 on a personal watercraft when a Silver Carp struck her in the face. The impact knocked her off the watercraft and she fell, unconscious, into the river. She revived to find herself bleeding and then passed out a second time. A passing boater rescued her. Her injuries included a broken nose, concussion, injured back, black eye, and a broken foot.

In addition to personal injury, Silver Carp also cause property damage and leave a mess for boaters to clean. One author (DCC) has observed damage to recreational boats on the Missouri River, including a broken windshield and a broken Plexiglas faring. Other reports of damage from jumping Silver Carp include a broken generator (B. Canaday, Missouri Department of Conservation, Jefferson City, Missouri, personal communication, 2003), and broken radios and depth finders (M. Pegg, Illinois Natural History Survey, Havana, Illinois, personal communication, 2003). When a Silver Carp lands in a boat, even if it does not break anything of value, it leaves slime, scales, and feces for boaters to contend with. Some fisheries professionals, including one author (DCC), who work in areas where Silver Carp are common, have added screens or netting to their vessels to deflect carp and thus reduce injuries and equipment damage.

The specific dynamics of this behavior—the reason that boat motors prove to be such a strong stimulus for Silver Carp—have yet to be thoroughly investigated. It has been suggested that the jumping is a method of avoiding predators (Perea 2002), but this has not been proven.

While now widely publicized because of the magnitude of its effects, this behavior actually was recorded at least as early as 1928 when V.K. Soldatov reported that Silver Carp, frightened by the noise of his boat, would leap out of water and fall into the boat (Berg 1964). Clearly, the jumping behavior of Silver Carp presents a physical danger to recreational boaters and water-skiers. Injuries to humans from jumping fish will continue and may increase with Silver Carp populations, and human deaths may possibly occur. Risk to humans is highest when there are two boats, both moving at high speeds in the same direction (DCC, personal observation). At such speeds, Silver Carp jump out of the water behind the first boat, placing the following boat and its occupant(s) in jeopardy of being struck. Water-skiers face the same risk.

Silver Carp are difficult to capture from culture ponds with a seine because of their jumping behavior. Not only do Silver Carp escape the seine by jumping over it, but the large jumping fish create a hazardous situation for persons in or near the water (M. Freeze, Keo Fish Farm, Keo, Arkansas, personal communication, 2004).

Largescale Silver Carp

No information on the response of Largescale Silver Carp to physical stimuli was found. Because Chen (1998) noted that Largescale Silver Carp remain deep in the water column during daylight hours and swim toward the surface at night to feed on plankton may indicate that they are less prone to jumping than Silver Carp in response to sounds of boat engines during daytime.

Associated Diseases and Parasites

Bighead Carp

Originally compiled by Jennings (1988), Table 4 provides an updated, annotated list of disease-causing agents that reportedly infect Bighead Carp, mostly in high-density culture situations. Also from Jennings (1988) is a summary of Bauer et al.'s (1973) discussion of several of these diseases. The information provided is based on citations from the literature. We cannot verify the taxonomic accuracy of the organisms listed or discussed.

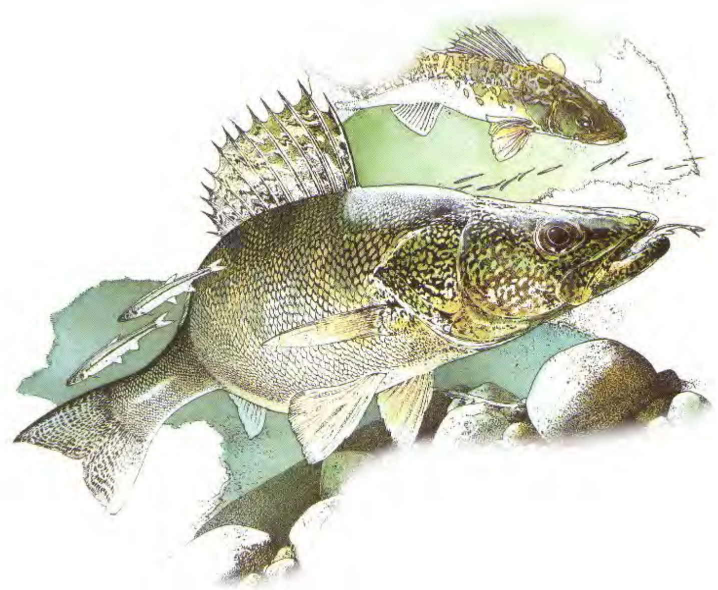
“White-skin disease” of Bighead Carp is caused by the bacterium *Pseudomonas dermoalba* and is recognized by a whitening of the skin at the base of the dorsal and caudal fins. Mortality results if the fish are not treated. The most infectious disease is caused by *Saprolegnia*, characterized by a cotton-like growth that develops on the epidermis as a result of the fish being stressed.

Bighead Carp are also susceptible to many diseases caused by parasitic protozoans. *Eimeria* sp. caused coccidial enteritis, a disease that is widespread in fish ponds in the Russian Federation and Hungary (Mólnar 1976). All developmental stages of this disease occur in any part of the gut, but intensive infection usually affects the foregut and midgut. The fish becomes sluggish and emaciated, the abdomen becomes soft and swollen, and yellowish strands of mucus,

Report for 2011 by the

LAKE ERIE WALLEYE TASK GROUP

March 2012



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Great Lakes Fishery Commission
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***Note**: Data and management summaries contained in this report are provisional. Every effort has been made to insure their correctness. Contact individual agencies for complete state and provincial data.*

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Charges to the Walleye Task Group, 2011-2012

The charges from the Lake Erie Committee's (LEC) Standing Technical Committee (STC) to the Walleye Task Group (WTG) for the period from March 2011 to February 2012 were to:

1. Maintain and update centralized time series of datasets required for population models and assessment including;
    a. Tagging and population indices (abundance, growth, maturity).
    b. Fishing harvest and effort by grid.
2. Improve existing population models to produce the most scientifically-defensible method for estimating and forecasting abundance, recruitment, and mortality. Continue to explore data pooling, catchability blocks, lambdas, and alternate selectivities to improve the existing model.
3. Report Recommended Allowable Harvest (RAH) levels for 2012.
4. Review jaw and PIT tagging study results and provide guidance/recommendations for future tagging strategies to the LEC.
5. Assist the STC with potential development of a new walleye exploitation strategy and with updating the Walleye Management Plan.

Review of Walleye Fisheries in 2011

Fishery effort and walleye harvest data were combined for all fisheries, jurisdictions and Management Units (Figure 1) to produce lake-wide summaries. The 2011 total estimated lake-wide harvest of walleye was 1.798 million walleye (Tables 1 and 2), with a total of 1.691 million walleye harvested in the total allowable catch (TAC) area. This harvest represents 58% of the 2011 TAC (2.919 million walleye) and includes walleye harvested in commercial and sport fisheries in Management Units 1, 2, and 3. An additional 105,748 walleye (6% of the lake-wide total) were harvested outside of the TAC area in Management Units 4 and 5 (referred to as Unit 4 in the Tables). The sport fish harvest of 0.593 million walleye in 2011 represents a 49% decrease from the 2010 harvest of 1.152 million, or a level of harvest that is 75% below the long-term (1975-2011) average of 2.407 million. The 2011 Ontario commercial harvest was approximately 1.208 million walleye lake-wide, with 1.179 million caught in the TAC area (Table 2). Ontario does not conduct angler creel surveys on an annual basis, thus recent estimates of harvest and effort for this fishery component are not available for Ontario waters. The most recent Ontario creels were completed in 2008, 2004, and 2003 in walleye MUs 1, 2 - 3, and 4 - 5, respectively. If the 2011 Ontario sport harvest was comparable to these earlier reference years, then Ontario lake-wide sport harvest would be approximately 48 thousand walleye, with 46 thousand harvested within the TAC area. Combined with reported commercial walleye harvest in the TAC area, this total harvest would remain unchanged at 97% of the Ontario TAC allocation of 1.256 million walleye. The Ontario commercial harvest was 26% higher than in 2010, and the 2011 harvest is 42% below the long-term average (1978-2011; Table 2, Figure 2).

Sport fishing effort decreased 33% in 2011 from 2010, to a total of 1.89 million angler hours (Table 3, Figure 3). Compared to 2010, sport effort in 2011 decreased in Management Units 1, 2 and 4, and was similar to the effort reported in Management Unit 3 in 2010. Lake-wide commercial gill net effort in 2011 (6,591 km) increased 34% from 2010 and is the 5th lowest observed effort since 1975 (Table 3, Figure 4).

Sport harvest per unit of effort (HUE, walleye/angler hour) decreased across all Management Units in 2011 compared to 2010. Management Unit 1 (0.27 walleye/angler hour), Management Unit 2 (0.30 walleye/angler hour), Management Unit 3 (0.41 walleye/angler hour) and Management Unit 4 (0.26 walleye/angler hour) decreased by 31%, 23%, 21% and 7%, respectively. In Management Unit 1, the sport harvest rate was 41% below the long-term average (0.46 walleye per angler hour; Table 4, Figure 5). The sport harvest rates in Management Unit 2 was slightly (6%) below the long-term mean of 0.32 walleye/angler hour, while Management Unit 3 (14%) and Management Unit 4 (24%) were both above the long-term means in 2011. The 2011 lake-wide average sport HUE of 0.29 walleye/angler hours was 33% lower than the long-term mean of 0.43 walleye/angler hour.

In 2011, total commercial gill net harvest per unit effort (HUE; 183.3 walleye/kilometer of net) decreased 6% relative to 2010, and was 50% above the long-term lake-wide average (122.2 walleye/kilometer; Table 4, Figure 5). When compared with 2010 commercial gill net harvest rates, they decreased in 2011 for Management Unit 1 (12%) and Management Unit 4 (38%) and increased in Management Unit 2 (3%) and Management Unit 3 (10%).

For the commercial and recreational fisheries, the harvest was dominated by walleye originating from the 2007 (age 4) and 2003 (age 7 and older) year classes. Ages 7-and-older walleye comprised 57% of the lake-wide sport fishery harvest and 38% of the total commercial fishery harvest (Tables 5 and 6). The 2007 year class (age 4 walleye) represented 22.0% of the total sport harvest and 26% of the total commercial harvest (Table 6). Lake-wide, ages 7-and-older fish accounted for 44% of the harvest, while the 2007 year class contributed 25%. The low contributions from the age 5, 6, and 7 cohorts (2006, 2005, and 2004 year classes, respectively) is an indication of their relatively lower abundance.

Across all jurisdictions, the mean age of walleye in the 2011 harvest ranged from 5.7 to 8.1 years old in the sport fishery, and from 4.9 to 8.3 years old in Ontario's commercial fishery (Table 7, Figure 6). In 2011, the mean age of walleye harvested increased in both the sport and commercial fishery. The mean age in the sport fishery was 6.7 years, above the long-term (1975-2011) mean of 4.2 years, and the highest recorded since 1975. In the commercial fishery, the mean age was 5.3 years, higher than the long-term (1975-2011) mean of 3.7 years, and is the highest value in the time series (1975-2011). The mean age of the total harvest (sport and commercial fisheries) in 2011 (5.8 years) was the highest in the time series (1975-2011). This reflects the continued dependence of the fisheries on the 2003 (age-7) and 2007 (age-4) year classes, with little contribution to the fisheries from any other cohort in 2011.

Catch-at-Age Population Analysis and Abundance

The WTG continued to use the Automatic Differentiation Model Builder (ADMB) statistical catch-at-age (SCAA) analysis to estimate walleye population abundance from 1978 to 2011 (Walleye Task Group 2001). The model includes fishery data from the Ontario commercial fishery (west and central basins) and sport fisheries in Ohio (west and central basins) and Michigan (west basin). Since 2002, the standard WTG model has included 3 index gill net surveys. Over the years, evidence mounted that pooling the Michigan and Ohio gill net surveys had both a logical and statistical basis. In 2012, the Walleye Task Group continued the use the standard model configuration that was adopted in 2010 which uses the combined MI and OH index gill net survey data sets.

The model assumes log-normal distributions for catch-at-age (ages 2 through 7+, i.e., seven and older) and fishing effort. Natural mortality (M) is fixed in the model for all ages and years at 0.32. The key parameters, including age-2 recruitment and population size in the first year of the model, fisheries catchability, and selectivity, are estimated using a maximum likelihood approach with a concentrated likelihood configuration. The abundances-at-age were derived from the estimated parameters using an exponential survival equation. Since 2010, lambdas have been derived based on an expert opinion approach described in the ***Review of Lambda Weightings*** section of the 2010 Walleye Task Group Report (WTG 2010)**.**

The 2011 west-central population estimate from the 2012 WTG model was 20.4 million age 3 and older walleye (Table 8, Figure 7). The 2012 model estimate of age 2 fish in 2011 (2009 year class) was 13.575 million fish. The ADMB estimate of age-2 abundance in the last year of the model is known to have the highest error bounds, since the model contains little data about this year class. In 2010, the Quantitative Fisheries Center (QFC) at Michigan State University recommended that the WTG utilize the regression estimate of abundance derived from the age-0 interagency trawl catch rate for that cohort as the age-2 estimate. By consensus the WTG adopted that recommendation and will continue to use the regression estimate for the age-2 estimated abundance in the latest year of the fishery. See ***Recruitment Estimator for Incoming Age 2 Walleye and 2012 Population Size Projection*** section below for details on methodology. The regression estimate of age 2 fish in 2011 was 3.850 million fish (Table 9). The total 2011 west-central population estimate (age 2 regression estimate for the 2009 cohort plus age 3 and older walleye estimate from 2012 WTG model) was 24.3 million walleye (Table 8). Abundance of age-4 fish (2007 year class) was estimated at 7.97 million fish, while age 7 and older fish (mainly 2003 year class) abundance was estimated at 5.9 million. There were an estimated 14.8 million age 4 and older walleye in 2011.

Recruitment Estimator for Incoming Age-2 Walleye and 2012 Population Size Projection

A linear regression model was used to estimate age-2 walleye recruitment for 2011 and 2012. This regression utilizes estimates of age-2 walleye abundance from the catch-at-age analysis of the WTG model and walleye catches from pooled Ontario and Ohio bottom trawling reported as number of young-of-the-year walleye per hectare (Table 9, Figure 8). Linear regression used by the WTG to predict the abundance of these cohorts excludes the most recent ADMB age-2 estimate (the 2009 year class), as it has the widest estimation error due to the presence of only a single estimate of age in the model time series. The 2012 age-2 population estimate (2010 year class) from linear regression was 9.723 million walleye (Table 9, Figure 9).

Hypoxic conditions were observed present during the last three years of interagency bottom trawl assessment at a few of the sampling sites in the west basin. Due to concerns about the potential effects of hypoxia on the distribution of juvenile percids and other species, representatives from task groups, the Standing Technical Committee, researchers from the Quantitative Fisheries Center at Michigan State University and Ohio State University (OSU) developed an interim policy for the assignment of bottom trawl status. Informed by literature (Eby and Crowder 2002, Craig and Crowder 2005) and field study (Ohio DNR / OSU) concerning fish avoidance of hypoxic waters, an interim policy was agreed upon whereby bottom trawls that occurred in waters with dissolved oxygen less than or equal to 2 mg per liter would be excluded from analyses applied retroactively from 2009. This interim policy will be revisited in the future following an improved understanding of the relationship between dissolved oxygen and the distribution of fish species and their various among life stages in Lake Erie.

The standard process for projecting age-3 and older abundance for the year in which RAH is reported (i.e., 2012 in this case) involves applying statistical catch-age analyses (SCAA) survival estimates from the last year in the ADMB model to the abundance estimate of age-2 and older walleye in the last year (2011). Estimated age-specific survival is a function of estimated instantaneous fishing mortality (F), selectivity, and assumed natural mortality (M, 0.32) during 2011.

The 2012 estimated abundance of age-2 and older walleye is approximately 26.1 million (Table 10, Figure 10). It is projected that the 2003 year class (age-7) and older cohorts will represent 17% (4.382 million), whereas the 2007 year class will comprise 20% (5.319 million) of the population in 2012. Based on the projected abundance in 2012, walleye spawner abundance (ages-4 and older) in 2012 is estimated to be 13.6 million fish. This is in the 65th percentile of spawner abundance values for the time series 1978-2012. However, the spawner-recruit relationship for Lake Erie walleye is poorly understood, with recruitment likely influenced by a combination of abiotic and biotic factors. Thus, it is difficult to predict how many recruits (young-of-year) will be produced in 2012 based solely on abundance of spawning adults.

Harvest Policy and Recommended Allowable Harvest for 2012

The RAH is determined by the harvest policy, along with population and parameter estimates produced by the WTG 2012 model. The harvest management policy adopted by the LEC in the Walleye Management Plan (WMP; Locke et al. 2005) is a sliding F-scale that has a feedback or state-dependent approach, and varies targeted fishing mortality rate based on population abundance (Figure 11). The policy stipulates that when walleye abundance is 20-40 million walleye, the targeted fishing mortality rate should be between F=0.20 and F=0.35, and when abundance is between 15-20 million walleye, the fishing rate should be between F=0.1 and F=0.2 (Figure 11; Locke et al. 2005). Using results from the WTG 2012 model, the estimated abundance of 26.1 million walleye in 2012, and the sliding-F harvest policy of F=0.246, the calculated mean RAH for 2012 is 3.487 million walleye, with a range from 2.191 (minimum) to 5.326 (maximum) million walleye (Table 11).

East Basin Walleye Assessment

1) Mixed adult walleye populations

During past years, the WTG attempted a broad-based assessment of the walleye resource in the east basin using a cohort-based stock assessment model, i.e. statistical catch-at-age analysis (SCAA) using the AD Model Builder platform, similar to the walleye assessment in the west and central basin. The assessment provided abundance estimates of the east basin walleye population from 1993 to 2009. These previous efforts were especially helpful for assembling walleye fishery and survey data from all east basin jurisdictions to support a more comprehensive assessment than had previously been possible. Additionally, the east-basin SCAA model was expected to provide a coarse scale for describing east basin walleye abundance relative to the resource in the quota management area.

The SCAA model depends on the catch-at-age information collected from fisheries and surveys and assumes the same cohorts are tracked through time. However, many studies have shown the walleye resource in the east basin during harvest season is a mixture of walleye sub-populations from both west basin and east basin (Einhouse and MacDougall 2010). In a recent study, Zhao et al (2011) used a mark-recapture analysis to quantify the contribution of both sources. They estimated that, on average, about 90% of walleyes harvested in the east basin were seasonal migrants from the west basin. However, there exists a large amount of uncertainty and variation associated with the annual age and size structure of the walleye population migrating from the west basin. Further, it is unlikely that this migration occurs in a consistent way by exactly the same segment of the population each year. The study suggests that catch-at-age information cannot track the same cohort of walleye from year to year in the east basin and the core assumption of tracking cohorts in a cohort-based model is likely violated. Therefore, beginning with the report for 2010, the WTG removed the East Basin ADMB abundance estimates from the WTG report.

The WTG member agencies from the east basin continue assessment surveys to track changes in the abundance of walleye population, and walleye fisheries are closely monitored and regulated in the east basin. In the future, WTG members will continue to examine the walleye resource inhabiting eastern Lake Erie to develop a multi-jurisdictional assessment that recognizes both expansive seasonal movements from the west-central quota management area, as well as the dynamics of smaller and localized east basin spawning stocks. This may necessarily include a stock assessment approach that does not utilize a catch-at-age modeling of absolute abundance.

2) Basin-Wide Juvenile Walleye

A preliminary consideration of the dynamics, production and relative abundance of localized east basin stocks was undertaken in 2011 by utilizing data from comparable components of Ontario (ON Partnership) New York (NYDEC warmwater) and Ohio (ODNR) gillnet assessment programs. Based on the assumption that young walleye do not undertake large migrations from their point of origin, the abundance and location of yearling walleye in the eastern basin was plotted and considered relative to yearling walleye from other basins (Figure 12). This approach allows us to consider recruitment success between basins (e.g. west basin and east basin had large densities of yearlings compared to that of the central basin in 2011) and within the east basin (e.g. highest densities along the south and far eastern shorelines in 2011). This approach has notable limitations (lack of suspended gillnet data in NY; evidence for suspended yearling catches in Ontario waters; difficulty standardizing / incorporating data from other jurisdictions in the lake) however we present this as another step toward assessment of the eastern basin walleye resource. We will continue to explore ways of standardizing assessment data, modifying methodologies, and examining historic data in the coming year.

Other Walleye Task Group Charges

Centralized Databases

Walleye Task Group members currently manage several databases. These databases consist of harvest and population assessment surveys conducted by the respective agencies that manage the walleye population in Lake Erie. Annually, information from these surveys is compiled to assist WTG members in the decision-making process regarding recommended harvest levels and current status and trends of the walleye population. Use of WTG databases by non-members is only permitted following a specific protocol established in 1994, described in the 1994 WTG Report, and reprinted in the 2003 WTG Report (Walleye Task Group 2003).

The Lake Erie Walleye Tagging database consists of biological information collected from walleye tagged in the tributaries and main lake areas of Lake Erie. The tagging program dates back to 1986, and has been maintained at the Lake St. Clair Fisheries Research Station of the MDNR. Annually, agencies submit information regarding tagging activities in their jurisdictions. In addition to updating the database with new tagging information, the database also maintains a record of the tagged walleye which are reported as harvested in a given year. The information is used to estimate the movements of different spawning stocks within the lake proper and connecting waters of Lake Erie. Estimates of survival and exploitation are also generated with this information. The Lake Erie Walleye Tagging database is maintained at the Sandusky office of the Ohio Department of Natural Resources, Division of Wildlife.

Fishery harvest and population assessment survey information are annually compiled by the WTG and are used for estimating the population abundance of walleye in Lake Erie via SCAA analysis (Deriso et al. 1985). A spatially-explicit version of agency-specific harvest data (e.g., harvest-at-age and fishery effort by management unit) and population assessment (e.g., the interagency trawl program and gill net surveys) databases are maintained by the WTG. Annual population abundance estimates are used to assist LEC members with setting TACs for the upcoming year as well as to evaluate past harvest policy decisions.

Walleye Spatial Ecology Study

In 2010, an inter-lake walleye spatial ecology study was initiated between the Michigan Department of Natural Resources, Ohio Department of Natural Resources, United States Geological Survey, Carlton University, and Great Lakes Fishery Commission. The objectives of the study are to 1) determine the proportion of walleyes spawning in the Tittabawasse River or in the Maumee River that reside in the Lake Huron main basin population, move into and through the Huron-Erie-Corridor, and reside in Lake Erie, 2) identify the environmental characteristics associated with the timing and extent of walleye movement from riverine spawning grounds into Lake Huron and back again, 3) determine whether walleye demonstrate spawning site fidelity, and 4) compare unbiased estimates of mortality parameters of walleyes from Saginaw Bay and the Maumee River.

Acoustic telemetry tags, 200 tags per river, were implanted into walleye spawning in the Tittabawassee River, Lake Huron, and Maumee River, Lake Erie, during the spring of 2010. In addition to the internal acoustic tags, each walleye was tagged with an external orange tag and a $100US reward is being offered for reporting and returning the acoustic tag. In the event one of these fish is harvested, individuals are encouraged to report this to the Hammond Bay Biological Station at 989-734-4768 or contact the Ontario Ministry of Natural Resources or Ohio Department of Natural Resources.

Walleye Management Plan and Lake Erie Percid Advisory Group

In 2005, the Lake Erie Walleye Task Group and LEC completed the Lake Erie Walleye Management Plan (WMP; Locke et al. 2005). Within this plan, it was recommended that the actions, and the outcomes of these actions, be reviewed on a five-year basis in order to measure the success of the plan and evaluate its objectives. In 2010-2011, a review was completed which concluded that the performance of the WMP varied. While some fishery catch rate objectives were achieved, other factors such as instability in harvest and TAC, due in part to recruitment patterns, caused concern for fisheries managers and stakeholders.

In order to move forward with updating the WMP, the LEC formed the Lake Erie Percid Management Advisory Group (LEPMAG). This group consists of stakeholder groups from all jurisdictions surrounding Lake Erie , Lake Erie managers, agency staff, and is being facilitated by Michigan State University's Quantitative Fisheries Center. The LEPMAG forum offers an opportunity for stakeholders to have direct input into the LEC process. The purpose of this group is to discuss fishery objectives, options, and uncertainties around the management of Lake Erie fisheries, and advise Lake Erie managers on potential exploitation policies for walleye. In 2011-2012, LEPMAG members were involved in a series of five facilitated workshops in order to determine fisheries objectives for the Lake Erie walleye population, examined variations of the walleye assessment model, and considered several types of management options for the fishery. The QFC has progressed with the technical work on developing management strategy evaluation (MSE) models incorporating input from the LEPMAG workshops. The MSE will help LEPMAG develop, test, and compare performance of various harvest policies while recognizing key uncertainties. Ultimately a new harvest policy for walleye will be developed for the 2013 season. The future of the WMP is dependent on the LEPMAG process and LEC review.

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The WTG would also like to thank the members of the Habitat Task Group for their work addressing the walleye habitat charge.

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Table 1. Annual Lake Erie walleye total allowable catch (TAC, top) and measured harvest (Har; bottom, bold), in numbers of fish from 1980 to 2011. TAC allocations for 2010 are based on water areas: Ohio, 51.11%; Ontario, 43.06%; and Michigan, 5.83%. New York and Pennsylvania do not have assigned quotas but are included in annual total harvest.

		TAC Area (MU-1, MU-2, MU-3)				Non-TAC Area (MUs 4&5)				All Areas
Year		Michigan	Ohio	Ontario [a]	Total	NY	Penn.	Ontario	Total	Total
1980	TAC	261,700	1,558,600	1,154,100	2,974,400				0	2,974,400
	Har	**183,140**	**2,169,800**	**1,049,269**	**3,402,209**				**0**	**3,402,209**
1981	TAC	367,400	2,187,900	1,620,000	4,175,300				0	4,175,300
	Har	**95,147**	**2,942,900**	**1,229,017**	**4,267,064**				**0**	**4,267,064**
1982	TAC	504,100	3,001,700	2,222,700	5,728,500				0	5,728,500
	Har	**194,407**	**3,015,400**	**1,260,852**	**4,470,659**				**0**	**4,470,659**
1983	TAC	572,000	3,406,000	2,522,000	6,500,000				0	6,500,000
	Har	**145,847**	**1,864,200**	**1,416,101**	**3,426,148**				**0**	**3,426,148**
1984	TAC	676,500	4,028,400	2,982,900	7,687,800				0	7,687,800
	Har	**351,169**	**4,055,000**	**2,178,409**	**6,584,578**				**0**	**6,584,578**
1985	TAC	430,700	2,564,400	1,898,800	4,893,900				0	4,893,900
	Har	**460,933**	**3,730,100**	**2,435,627**	**6,626,660**				**0**	**6,626,660**
1986	TAC	660,000	3,930,000	2,910,000	7,500,000				0	7,500,000
	Har	**605,600**	**4,399,400**	**2,617,507**	**7,622,507**				**0**	**7,622,507**
1987	TAC	490,100	2,918,500	2,161,100	5,569,700				0	5,569,700
	Har	**902,500**	**4,433,600**	**2,688,558**	**8,024,658**				**0**	**8,024,658**
1988	TAC	397,500	3,855,000	3,247,500	7,500,000				0	7,500,000
	Har	**1,996,788**	**4,890,367**	**3,054,402**	**9,941,557**	**85,282**			**85,282**	**10,026,839**
1989	TAC	383,000	3,710,000	3,125,000	7,218,000				0	7,218,000
	Har	**1,091,641**	**4,191,711**	**2,793,051**	**8,076,403**	**129,226**			**129,226**	**8,205,629**
1990	TAC	616,000	3,475,500	2,908,500	7,000,000				0	7,000,000
	Har	**747,128**	**2,282,520**	**2,517,922**	**5,547,570**	**47,443**			**47,443**	**5,595,013**
1991	TAC	440,000	2,485,000	2,075,000	5,000,000				0	5,000,000
	Har	**132,118**	**1,577,813**	**2,266,380**	**3,976,311**	**34,137**			**34,137**	**4,010,448**
1992	TAC	329,000	3,187,000	2,685,000	6,201,000				0	6,201,000
	Har	**249,518**	**2,081,919**	**2,497,705**	**4,829,142**	**14,384**			**14,384**	**4,843,526**
1993	TAC	556,500	5,397,000	4,546,500	10,500,000				0	10,500,000
	Har	**270,376**	**2,668,684**	**3,821,386**	**6,760,446**	**40,032**			**40,032**	**6,800,478**
1994	TAC	400,000	4,100,000	3,500,000	8,000,000				0	8,000,000
	Har	**216,038**	**1,468,739**	**3,431,119**	**5,115,896**	**59,345**			**59,345**	**5,175,241**
1995	TAC	477,000	4,626,000	3,897,000	9,000,000				0	9,000,000
	Har	**107,909**	**1,435,188**	**3,813,527**	**5,356,624**	**26,964**			**26,964**	**5,383,588**
1996	TAC	583,000	5,654,000	4,763,000	11,000,000				0	11,000,000
	Har	**174,607**	**2,316,425**	**4,524,639**	**7,015,671**	**38,728**	**89,087**		**127,815**	**7,143,486**
1997	TAC	514,000	4,986,000	4,200,000	9,700,000				0	9,700,000
	Har	**122,400**	**1,248,846**	**4,072,779**	**5,444,025**	**29,395**	**88,682**		**118,077**	**5,562,102**
1998	TAC	546,000	5,294,000	4,460,000	10,300,000				0	10,300,000
	Har	**114,606**	**2,303,911**	**4,173,042**	**6,591,559**	**34,090**	**124,814**	**47,000**	**205,904**	**6,797,463**
1999	TAC	477,000	4,626,000	3,897,000	9,000,000				0	9,000,000
	Har	**140,269**	**1,033,733**	**3,454,250**	**4,628,252**	**23,133**	**89,038**	**87,000**	**199,171**	**4,827,423**
2000	TAC	408,100	3,957,800	3,334,100	7,700,000				0	7,700,000
	Har	**252,280**	**932,297**	**2,287,533**	**3,472,110**	**28,599**	**77,512**	**67,000**	**173,111**	**3,645,221**
2001	TAC	180,200	1,747,600	1,472,200	3,400,000				0	3,400,000
	Har	**159,186**	**1,157,914**	**1,498,816**	**2,815,916**	**14,669**	**52,796**	**39,498**	**106,963**	**2,922,879**
2002	TAC	180,200	1,747,600	1,472,200	3,400,000				0	3,400,000
	Har	**193,515**	**703,000**	**1,436,000**	**2,332,515**	**18,377**	**22,000**	**36,000**	**76,377**	**2,408,892**
2003	TAC	180,200	1,747,600	1,472,200	3,400,000				0	3,400,000
	Har	**128,852**	**1,014,688**	**1,457,014**	**2,600,554**	**27,480**	**43,581**	**32,692**	**103,753**	**2,704,307**
2004	TAC	127,200	1,233,600	1,039,200	2,400,000				0	2,400,000
	Har	**114,958**	**859,366**	**1,419,237**	**2,393,561**	**8,400**	**19,969**	**29,864**	**58,233**	**2,451,794**
2005	TAC	308,195	2,988,910	2,517,895	5,815,000				0	5,815,000
	Har	**37,599**	**610,449**	**2,933,393**	**3,581,441**	**27,370**	**20,316**	**17,394**	**65,080**	**3,646,521**
2006	TAC	523,958	5,081,404	4,280,638	9,886,000				0	9,886,000
	Har	**305,548**	**1,868,520**	**3,494,551**	**5,668,619**	**37,161**	**151,614**	**68,774**	**257,549**	**5,926,168**
2007	TAC	284,080	2,755,040	2,320,880	5,360,000				0	5,360,000
	Har	**165,551**	**2,160,459**	**2,159,965**	**4,485,975**	**29,134**	**116,671**	**37,566**	**183,371**	**4,669,346**
2008	TAC	209,530	1,836,893	1,547,576	3,594,000				0	3,594,000
	Har	**121,072**	**1,082,636**	**1,574,723**	**2,778,431**	**29,017**	**74,250**	**34,906**	**138,173**	**2,916,604**
2009	TAC	142,835	1,252,195	1,054,970	2,450,000				0	2,450,000
	Har	**94,048**	**967,476**	**1,095,500**	**2,157,024**	**13,727**	**42,422**	**27,725**	**83,874**	**2,240,898**
2010	TAC	128,260	1,124,420	947,320	2,200,000				0	2,200,000
	Har	**55,248**	**958,366**	**983,397**	**1,997,011**	**36,683**	**54,056**	**23,324**	**114,063**	**2,111,074**
2011	Tac	170,178	1,491,901	1,256,921	2,919,000				0	2,919,000
	Har	**50,490**	**417,314**	**1,224,057**	**1,691,861**	**31,506**	**45,369**	**28,873**	**105,748**	**1,797,609**

[a] Ontario sport harvest values were estimated from the most recent creel surveys in each basin; 2008 in Unit 1, 2004 in Units 2 and 3, and 2003 in Unit 4. These values are included in Ontario's total walleye harvest, but are not used in catch-at-age analysis.

Table 2. Annual harvest (thousands of fish) of Lake Erie walleye by gear, management unit, and agency. Means contain data from 1975 to 2011.

	Sport Fishery															Commercial Fishery					
	Unit 1				Unit 2			Unit 3			Units 4 & 5					Unit 1	Unit 2	Unit 3	Unit 4		Grand
Year	OH	MI	ON[a]	Total	OH	ON[a]	Total	OH	ON[a]	Total	ON[a]	PA	NY	Total	Total	ON	ON	ON	ON	Total	Total
1975	77	4	7	88	10	--	10	--	--	--	--	--	--	0	98	--	--	--	--	0	98
1976	605	30	50	685	35	--	35	--	--	--	--	--	--	0	720	113	44	--	--	157	877
1977	2,131	107	69	2,307	37	--	37	--	--	--	--	--	--	0	2,344	235	67	--	--	302	2,645
1978	1,550	72	112	1,734	37	--	37	--	--	--	--	--	--	0	1,771	274	60	--	--	334	2,106
1979	3,254	162	79	3,495	60	--	60	--	--	--	--	--	--	0	3,555	625	30	--	--	655	4,211
1980	2,096	183	57	2,336	49	--	49	24	--	24	--	--	--	0	2,409	953	40	--	--	993	3,402
1981	2,857	95	70	3,022	38	--	38	48	--	48	--	--	--	0	3,108	1,037	119	3	--	1,159	4,268
1982	2,959	194	49	3,202	49	--	49	8	--	8	--	--	--	0	3,259	1,077	134	2	--	1,213	4,470
1983	1,626	146	41	1,813	212	--	212	26	--	26	--	--	--	0	2,051	1,129	167	80	--	1,376	3,427
1984	3,089	351	39	3,479	787	--	787	179	--	179	--	--	--	0	4,445	1,639	392	108	--	2,139	6,584
1985	3,347	461	57	3,865	294	--	294	89	--	89	--	--	--	0	4,248	1,721	432	225	--	2,378	6,627
1986	3,743	606	52	4,401	480	--	480	176	--	176	--	--	--	0	5,057	1,651	558	356	--	2,565	7,622
1987	3,751	902	51	4,704	550	--	550	132	--	132	--	--	--	0	5,386	1,611	622	405	--	2,638	8,024
1988	3,744	1,997	18	5,759	584	--	584	562	--	562	--	--	85	85	6,990	1,866	762	409	--	3,037	10,026
1989	2,891	1,092	14	3,997	867	35	902	434	80	514	--	--	129	129	5,542	1,656	621	386	--	2,663	8,206
1990	1,467	747	35	2,249	389	14	403	426	23	449	--	--	47	47	3,148	1,615	529	302	--	2,446	5,595
1991	1,104	132	39	1,275	216	24	240	258	44	302	--	--	34	34	1,851	1,446	440	274	--	2,160	4,011
1992	1,479	250	20	1,749	338	56	394	265	25	290	--	--	14	14	2,447	1,547	534	316	--	2,397	4,844
1993	1,846	270	37	2,153	450	26	476	372	12	384	--	--	40	40	3,053	2,488	762	496	--	3,746	6,800
1994	992	216	21	1,229	291	20	311	186	21	207	--	--	59	59	1,806	2,307	630	432	--	3,369	5,176
1995	1,161	108	32	1,301	159	7	166	115	27	141	--	--	27	27	1,635	2,578	681	489	--	3,748	5,384
1996	1,442	175	17	1,634	645	8	653	229	27	256	--	89	39	128	2,671	2,777	1,107	589	--	4,473	7,143
1997	929	122	8	1,059	188	2	190	132	5	138	--	89	29	118	1,505	2,585	928	544	--	4,057	5,563
1998	1,790	115	34	1,939	215	5	220	299	5	304	19	125	34	178	2,641	2,497	1,166	462	28	4,153	6,793
1999	812	140	34	986	139	5	144	83	5	88	19	89	23	131	1,349	2,461	631	317	68	3,477	4,827
2000	674	252	34	961	165	5	170	93	5	98	19	78	29	125	1,354	1,603	444	196	48	2,291	3,645
2001	941	160	34	1,135	171	5	176	46	5	51	19	53	15	87	1,449	1,004	310	141	20	1,475	2,924
2002	516	194	34	744	141	5	146	46	5	51	19	22	18	59	1,000	937	309	146	17	1,409	2,409
2003	715	129	34	878	232	5	237	68	5	73	2	44	27	73	1,261	948	283	182	14	1,427	2,688
2004	515	115	34	664	272	2	274	72	0	72	2	20	8	30	1,040	866	334	175	11	1,386	2,426
2005	374	38	27	438	110	2	112	126	0	126	2	20	27	49	725	1,878	625	401	15	2,920	3,645
2006	1,194	306	27	1,526	503	2	505	170	0	170	2	152	37	191	2,392	2,137	784	545	66	3,532	5,924
2007	1,414	166	27	1,607	578	2	580	169	0	169	2	116	29	147	2,502	1,348	450	333	35	2,167	4,669
2008	524	121	44	689	333	2	335	225	0	225	2	74	29	105	1,354	954	335	241	35	1,565	2,919
2009	553	94	44	691	287	2	289	128	0	128	2	42	14	58	1,166	705	212	135	28	1,079	2,244
2010	587	55	44	686	257	2	259	114	0	114	2	54	37	93	1,152	607	184	147	23	962	2,115
2011	224	50	44	318	104	2	106	89	0	89	2	45	32	79	593	736	262	181	29	1,208	1,801
Mean	1,594	280	40	1,913	278	10	284	168	13	178	8	69	36	56	2,407	1,434	444	291	31	2,083	4,490

[a] Ontario sport harvest values were estimated from the most recent creel surveys in each basin; 2008 in Unit 1, 2004 in Units 2 and 3, and 2003 in Unit 4. These values are included in Ontario's total walleye harvest, but are not used in catch-at-age analysis.

Table 3. Annual fishing effort for Lake Erie walleye by gear, management unit, and agency. Means contain data from 1975 to 2011.

	Sport Fishery [a]															Commercial Fishery [b]				
	Unit 1				Unit 2			Unit 3			Units 4 & 5					Unit 1	Unit 2	Unit 3	Unit 4	
Year	OH	MI	ON[c]	Total	OH	ON[c]	Total	OH	ON[c]	Total	ON[c]	PA	NY	Total	Total	ON	ON	ON	ON	Total
1975	486	30	46	562	61	--	61	--	--	--	--	--	--	0	623	--	--	--	--	--
1976	1,356	84	98	1,538	163	--	163	--	--	--	--	--	--	0	1,701	1,796	1,933	--	--	3,729
1977	2,768	171	130	3,069	151	--	151	--	--	--	--	--	--	0	3,220	4,282	1,572	--	--	5,854
1978	2,880	176	148	3,204	154	--	154	--	--	--	--	--	--	0	3,358	5,253	436	--	--	5,689
1979	4,179	257	97	4,533	169	--	169	--	--	--	--	--	--	0	4,702	5,798	1,798	--	--	7,596
1980	3,938	624	92	4,654	237	--	237	187	--	187	--	--	--	0	5,078	6,229	1,565	--	--	7,794
1981	5,766	447	138	6,351	264	--	264	382	--	382	--	--	--	0	6,997	6,881	2,144	622	--	9,647
1982	5,928	449	108	6,484	223	--	223	114	--	114	--	--	--	0	6,821	10,531	2,913	689	--	14,133
1983	4,168	451	118	4,737	568	--	568	128	--	128	--	--	--	0	5,433	11,205	5,352	5,814	--	22,371
1984	4,077	557	82	4,716	1,322	--	1,322	392	--	392	--	--	--	0	6,430	11,550	6,008	2,438	--	19,996
1985	4,606	926	84	5,616	1,078	--	1,078	464	--	464	--	--	--	0	7,158	7,496	2,800	2,983	--	13,279
1986	6,437	1,840	107	8,384	1,086	--	1,086	538	--	538	--	--	--	0	10,008	7,824	5,637	3,804	--	17,265
1987	6,631	2,193	84	8,908	1,431	--	1,431	472	--	472	--	--	--	0	10,811	6,595	4,243	3,045	--	13,883
1988	7,547	4,362	87	11,996	1,677	--	1,677	1,081	--	1,081	--	--	462	462	15,216	7,495	5,794	3,778	--	17,067
1989	5,246	3,794	81	9,121	1,532	77	1,609	883	205	1,088	--	--	556	556	12,374	7,846	5,514	3,473	--	16,833
1990	4,116	1,803	121	6,040	1,675	33	1,708	869	83	952	--	--	432	432	9,132	9,016	5,829	5,544	--	20,389
1991	3,616	440	144	4,200	1,241	79	1,320	724	155	880	--	--	440	440	6,840	10,418	5,055	3,146	--	18,619
1992	3,955	715	105	4,775	1,169	81	1,249	640	145	786	--	--	299	299	7,109	9,486	6,906	6,043	--	22,435
1993	3,943	691	125	4,759	1,349	70	1,418	1,062	125	1,187	--	--	305	305	7,669	16,283	11,656	7,420	--	35,359
1994	2,808	788	125	3,721	1,025	65	1,090	599	130	729	--	--	355	355	5,894	16,698	9,968	6,459	--	33,125
1995	3,188	277	125	3,589	803	65	868	355	130	485	--	--	259	259	5,201	20,521	12,113	7,850	--	40,484
1996	3,060	521	125	3,706	1,132	65	1,197	495	130	625	--	316	256	572	6,101	19,976	15,685	10,990	--	46,651
1997	2,748	374	88	3,210	864	45	909	492	91	583	--	388	273	661	5,363	15,708	11,588	9,094	--	36,390
1998	3,010	374	103	3,487	635	51	686	409	55	464	217	390	280	887	5,524	19,027	19,397	13,253	818	52,495
1999	2,368	411	--	2,779	603	--	603	323	--	323	--	397	171	568	4,699	21,432	10,955	7,630	1,444	41,461
2000	1,975	540	--	2,516	540	--	540	281	--	281	--	244	177	421	3,757	22,238	11,049	7,896	1,781	43,054
2001	1,952	362	--	2,314	697	--	697	261	--	261	--	241	163	404	3,676	9,372	5,746	5,021	639	20,778
2002	1,393	606	--	1,999	444	--	444	246	--	246	--	130	132	262	2,951	4,431	4,212	4,427	445	13,515
2003	1,719	326	--	2,045	675	--	675	236	--	236	30	159	162	351	3,307	4,476	3,946	3,725	365	12,512
2004	1,257	504	--	1,761	736	27	763	178	7	185	--	88	101	189	2,898	3,875	2,977	2,401	240	9,493
2005	1,180	212	40	1,392	573	--	573	261	--	261	--	109	142	251	2,477	7,083	4,174	4,503	174	15,934
2006	1,757	587	--	2,344	899	--	899	260	--	260	--	239	137	376	3,879	5,689	4,008	3,589	822	14,107
2007	2,076	448	--	2,524	1,147	--	1,147	321	--	321	--	232	135	367	4,358	4,509	2,927	2,665	383	10,484
2008	1,027	392	63	1,419	809	--	809	356	--	356	--	187	156	343	2,927	4,990	3,193	1,909	497	10,590
2009	1,063	310	--	1,373	777	--	777	289	--	289	--	124	100	224	2,663	3,537	2,164	1,746	478	7,925
2010	1,403	226	--	1,629	652	--	652	219	--	219	--	188	140	328	2,828	1,918	1,371	1,401	247	4,937
2011	862	165	--	1,026	346	--	346	217	--	217	--	156	145	301	1,891	2,646	1,884	1,572	489	6,591
Mean	3,148	741	102	3,959	781	60	799	429	114	469	124	224	241	260	5,434	9,281	5,681	4,675	630	19,235

[a] Sport units of effort are thousands of angler hours.

[b] Estimated Standard (Total) Effort in kilometers of gill net = (walleye targeted effort x walleye total harvest)/ walleye targeted harvest.

[c] Ontario sport fishing effort was estimated from the most recent creel surveys in each basin; 2008 in Unit 1, 2004 in Units 2 and 3, and 2003 in Unit 4.

Table 4. Annual catch per unit effort for Lake Erie walleye by gear, management unit, and agency. Means contain data from 1975 to 2011.

	Sport Fishery [a]															Commercial Fishery [b]				
	Unit 1				Unit 2			Unit 3			Units 4 & 5					Unit 1	Unit 2	Unit 3	Unit 4	
Year	OH	MI	ON[c]	Total	OH	ON[c]	Total	OH	ON[c]	Total	ON[c]	PA	NY	Total	Total	ON	ON	ON	ON	Total
1975	0.16	0.13	0.16	0.16	0.17	--	0.17	--	--		--	--	--		0.16					
1976	0.45	0.36	0.50	0.45	0.22	--	0.22	--	--		--	--	--		0.42	63.0	22.9			42.2
1977	0.77	0.62	0.53	0.75	0.24	--	0.24	--	--		--	--	--		0.73	54.9	42.6			51.6
1978	0.54	0.41	0.76	0.54	0.24	--	0.24	--	--		--	--	--		0.53	52.2	138.2			58.8
1979	0.78	0.63	0.81	0.77	0.36	--	0.36	--	--		--	--	--		0.76	107.9	16.7			86.3
1980	0.53	0.29	0.62	0.50	0.21	--	0.21	0.13	--	0.13	--	--	--		0.47	153.0	25.3			127.3
1981	0.50	0.21	0.51	0.48	0.14	--	0.14	0.12	--	0.12	--	--	--		0.44	150.7	55.4	4.9		120.1
1982	0.50	0.43	0.45	0.49	0.22	--	0.22	0.07	--	0.07	--	--	--		0.48	102.2	45.9	2.8		85.8
1983	0.39	0.32	0.34	0.38	0.37	--	0.37	0.20	--	0.20	--	--	--		0.38	100.7	31.2	13.7		61.5
1984	0.76	0.63	0.48	0.74	0.60	--	0.60	0.46	--	0.46	--	--	--		0.69	141.9	65.3	44.4		107.0
1985	0.73	0.50	0.68	0.69	0.27	--	0.27	0.19	--	0.19	--	--	--		0.59	229.6	154.5	75.6		179.1
1986	0.58	0.33	0.49	0.52	0.44	--	0.44	0.33	--	0.33	--	--	--		0.51	211.0	99.0	93.7		148.6
1987	0.57	0.41	0.61	0.53	0.38	--	0.38	0.28	--	0.28	--	--	--		0.50	244.2	146.5	133.1		190.0
1988	0.50	0.46	0.21	0.48	0.35	--	0.35	0.52	--	0.52	--	--	0.18	0.18	0.46	249.0	131.4	108.2		177.9
1989	0.55	0.29	0.17	0.44	0.57	0.45	0.56	0.49	0.39	0.47	--	--	0.23	0.23	0.45	211.1	112.7	111.2		158.3
1990	0.36	0.41	0.29	0.37	0.23	0.42	0.24	0.49	0.28	0.47	--	--	0.11	0.11	0.34	179.1	90.7	54.5		120.0
1991	0.31	0.30	0.27	0.30	0.17	0.30	0.18	0.36	0.28	0.34	--	--	0.08	0.08	0.27	138.8	87.0	87.1		116.0
1992	0.37	0.35	0.19	0.37	0.29	0.69	0.32	0.41	0.18	0.37	--	--	0.05	0.05	0.34	163.1	77.3	52.3		106.8
1993	0.47	0.39	0.30	0.45	0.33	0.37	0.34	0.35	0.09	0.32	--	--	0.13	0.13	0.40	152.8	65.4	66.8		106.0
1994	0.35	0.27	0.17	0.33	0.28	0.31	0.28	0.31	0.16	0.28	--	--	0.17	0.17	0.31	138.2	63.2	66.9		101.7
1995	0.36	0.39	0.25	0.36	0.20	0.12	0.19	0.32	0.21	0.29	--	--	0.10	0.10	0.31	125.7	56.2	62.2		92.6
1996	0.47	0.34	0.13	0.44	0.57	0.13	0.55	0.46	0.21	0.41	--	0.28	0.15	0.22	0.44	139.0	70.6	53.6		95.9
1997	0.34	0.33	0.10	0.33	0.22	0.04	0.21	0.27	0.06	0.24	--	0.23	0.11	0.17	0.28	164.6	80.1	59.8		111.5
1998	0.59	0.31	0.33	0.56	0.34	0.10	0.32	0.73	0.08	0.65	0.09	0.32	0.12	0.18	0.48	131.3	60.1	34.8	34.2	79.1
1999	0.34	0.34	--	0.34	0.23	--	0.23	0.26	--	0.26	--	0.22	0.14	0.22	0.27	114.8	57.6	41.6	47.4	83.9
2000	0.34	0.47	--	0.37	0.31	--	0.31	0.33	--	0.33	--	0.32	0.16	0.32	0.34	72.1	40.2	24.8	27.1	53.2
2001	0.48	0.44	--	0.48	0.25	--	0.25	0.18	--	0.18	--	0.22	0.09	0.22	0.38	107.1	54.0	28.1	32.1	71.0
2002	0.37	0.32	--	0.36	0.32	--	0.32	0.19	--	0.19	--	0.17	0.14	0.17	0.32	211.5	73.4	33.0	37.4	104.3
2003	0.42	0.40	--	0.41	0.34	--	0.34	0.29	--	0.29	0.07	0.28	0.17	0.21	0.37	211.8	71.7	48.9	38.4	114.1
2004	0.41	0.23	--	0.36	0.37	0.06	0.36	0.40	--	0.40	--	0.23	0.08	0.15	0.35	223.5	112.2	73.0	45.3	146.0
2005	0.32	0.18	0.67	0.31	0.19	--	0.19	0.48	--	0.48	--	0.18	0.19	0.19	0.29	265.2	149.8	89.1	86.4	183.2
2006	0.68	0.52	--	0.64	0.56	--	0.56	0.65	--	0.65	--	0.63	0.27	0.50	0.61	375.7	195.6	151.9	80.8	250.4
2007	0.68	0.37	--	0.63	0.50	--	0.50	0.53	--	0.53	--	0.50	0.21	0.40	0.57	298.9	153.8	124.9	91.4	206.7
2008	0.51	0.31	--	0.45	0.41	--	0.41	0.63	--	0.63	--	0.40	0.19	0.30	0.45	191.2	104.9	126.2	70.4	147.8
2009	0.52	0.30	--	0.47	0.37	--	0.37	0.44	--	0.44	--	0.34	0.14	0.25	0.42	199.2	97.9	77.1	58.0	136.1
2010	0.42	0.24	--	0.39	0.39	--	0.39	0.52	--	0.52	--	0.29	0.26	0.28	0.39	316.7	134.5	105.0	94.5	194.9
2011	0.26	0.31	--	0.27	0.30	--	0.30	0.41	--	0.41	--	0.29	0.22	0.26	0.29	278.3	138.9	115.0	59.0	183.3
Mean	0.48	0.37	0.40	0.46	0.32	0.27	0.32	0.37	0.19	0.36	0.08	0.31	0.15	0.21	0.43	174.16	86.74	69.81	57.31	122.19

[a] Sport CPE = Number/angler hour

[b] Commercial CPE = Number/kilometer of gill net

[c] Ontario sport fishing CPE was estimated from the most recent creel surveys in each basin; 2008 in Unit 1, 2004 in Units 2 and 3, and 2003 in Unit 4.

Table 5. Catch at age of walleye harvest by management unit, gear, and agency in Lake Erie during 2011.
Units 4 and 5 are combined in Unit 4.

		Commercial	Sport					All Gear
Unit	Age	Ontario	Ohio	Michigan	New York	Pennsylvania	Total	Total
1	1	34,608	0	3	--	--	3	34,611
	2	79,176	12,221	7,397	--	--	19,618	98,794
	3	147,538	27,609	14,563	--	--	42,172	189,710
	4	210,112	70,483	16,844	--	--	87,327	297,439
	5	8,367	5,784	159	--	--	5,943	14,310
	6	25,800	6,405	1,546	--	--	7,951	33,751
	7+	230,786	101,009	9,977	--	--	110,986	341,772
	Total	736,387	223,511	50,490	--	--	274,001	1,010,388
2	1	14,178	0	--	--	--	0	14,178
	2	35,699	5,885	--	--	--	5,885	41,584
	3	39,087	4,622	--	--	--	4,622	43,709
	4	51,655	16,710	--	--	--	16,710	68,365
	5	4,630	1,718	--	--	--	1,718	6,348
	6	6,270	3,814	--	--	--	3,814	10,084
	7+	110,271	71,700	--	--	--	71,700	181,971
	Total	261,790	104,449	--	--	--	104,449	366,239
3	1	429	0	--	--	--	0	429
	2	883	815	--	--	--	815	1,698
	3	4,140	2,453	--	--	--	2,453	6,593
	4	49,831	10,383	--	--	--	10,383	60,214
	5	9,159	1,047	--	--	--	1,047	10,206
	6	15,668	3,728	--	--	--	3,728	19,396
	7+	100,770	70,929	--	--	--	70,929	171,699
	Total	180,880	89,355	--	--	--	89,355	270,235
4	1	0	--	--	0	0	0	0
	2	0	--	--	239	997	1,236	1,236
	3	53	--	--	4,786	1,246	6,032	6,085
	4	1,558	--	--	1,994	3,241	5,235	6,793
	5	3,520	--	--	4,707	997	5,704	9,224
	6	5,008	--	--	1,276	1,745	3,021	8,029
	7+	18,734	--	--	18,504	37,143	55,647	74,381
	Total	28,873	--	--	31,506	45,369	76,875	105,748
All	1	49,215	0	3	0	0	3	49,218
	2	115,758	18,921	7,397	239	997	27,554	143,312
	3	190,818	34,684	14,563	4,786	1,246	55,279	246,097
	4	313,156	97,576	16,844	1,994	3,241	119,655	432,811
	5	25,676	8,549	159	4,707	997	14,412	40,088
	6	52,746	13,947	1,546	1,276	1,745	18,514	71,260
	7+	460,561	243,638	9,977	18,504	37,143	309,262	769,823
	Total	1,207,930	417,315	50,490	31,506	45,369	544,680	1,752,610

[a] Ontario sport harvest values were not estimated from creel surveys in 2011; they are not used in catch-at-age analysis.

Table 6. Age composition (in percent) of walleye harvest by management unit, gear, and agency in Lake Erie during 2011. Units 4 and 5 are combined in Unit 4.

		Commercial	Sport					All Gears
Unit	Age	Ontario	Ohio	Michigan	New York	Pennsylvania	Total	Total
1	1	4.7	0.0	0.0	--	--	0.0	3.4
	2	10.8	5.5	14.7	--	--	7.2	9.8
	3	20.0	12.4	28.8	--	--	15.4	18.8
	4	28.5	31.5	33.4	--	--	31.9	29.4
	5	1.1	2.6	0.3	--	--	2.2	1.4
	6	3.5	2.9	3.1	--	--	2.9	3.3
	7+	31.3	45.2	19.8	--	--	40.5	33.8
	Total	100.0	100.0	100.0	--	--	100.0	100.0
2	1	5.4	0.0	--	--	--	0.0	3.9
	2	13.6	5.6	--	--	--	5.6	11.4
	3	14.9	4.4	--	--	--	4.4	11.9
	4	19.7	16.0	--	--	--	16.0	18.7
	5	1.8	1.6	--	--	--	1.6	1.7
	6	2.4	3.7	--	--	--	3.7	2.8
	7+	42.1	68.6	--	--	--	68.6	49.7
	Total	100.0	100.0	--	--	--	100.0	100.0
3	1	0.2	0.0	--	--	--	0.0	0.2
	2	0.5	0.9	--	--	--	0.9	0.6
	3	2.3	2.7	--	--	--	2.7	2.4
	4	27.5	11.6	--	--	--	11.6	22.3
	5	5.1	1.2	--	--	--	1.2	3.8
	6	8.7	4.2	--	--	--	4.2	7.2
	7+	55.7	79.4	--	--	--	79.4	63.5
	Total	100.0	100.0	--	--	--	100.0	100.0
4	1	0.0	--	--	0.0	0.0	0.0	0.0
	2	0.0	--	--	0.8	2.2	1.6	1.2
	3	0.2	--	--	15.2	2.7	7.8	5.8
	4	5.4	--	--	6.3	7.1	6.8	6.4
	5	12.2	--	--	14.9	2.2	7.4	8.7
	6	17.3	--	--	4.1	3.8	3.9	7.6
	7+	64.9	--	--	58.7	81.9	72.4	70.3
	Total	100.0	--	--	100.0	100.0	100.0	100.0
All	1	4.1	0.0	0.0	0.0	0.0	0.0	2.8
	2	9.6	4.5	14.7	0.8	2.2	5.1	8.2
	3	15.8	8.3	28.8	15.2	2.7	10.1	14.0
	4	25.9	23.4	33.4	6.3	7.1	22.0	24.7
	5	2.1	2.0	0.3	14.9	2.2	2.6	2.3
	6	4.4	3.3	3.1	4.1	3.8	3.4	4.1
	7+	38.1	58.4	19.8	58.7	81.9	56.8	43.9
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 7. Annual mean age (years) of Lake Erie walleye by gear, management unit, and agency. Means include data from 1975 to present.

	Sport Fishery															Commercial Fishery					All Gears
	Unit 1				Unit 2			Unit 3			Units 4 & 5					Unit 1	Unit 2	Unit 3	Unit 4		
Year	OH	MI	ON	Total	OH	ON	Total	OH	ON	Total	ON	PA	NY	Total	Total	ON	ON	ON	ON	Total	Total
1975	2.53	2.53	3.26	2.59	1.53	--	1.53	--	--	--	--	--	--	--	2.48	--	--	--	--	--	2.42
1976	2.49	2.49	2.35	2.48	2.05	--	2.05	--	--	--	--	--	--	--	2.46	1.51	1.51	--	--	1.51	2.29
1977	3.29	3.29	2.64	3.27	2.44	--	2.44	--	--	--	--	--	--	--	3.26	2.74	2.74	--	--	2.74	3.21
1978	3.50	3.62	3.07	3.48	3.33	--	3.33	--	--	--	--	--	--	--	3.48	2.69	2.69	--	--	2.69	3.37
1979	2.71	2.71	2.67	2.71	2.29	--	2.29	--	--	--	--	--	--	--	2.70	2.83	2.83	--	--	2.83	2.72
1980	3.00	3.00	2.84	3.00	2.92	--	2.92	2.65	--	2.65	--	--	--	--	2.99	2.96	2.96	--	--	2.96	2.98
1981	3.61	2.97	3.47	3.59	2.62	--	2.62	2.72	--	2.72	--	--	--	--	3.56	3.00	3.00	2.99	--	3.00	3.41
1982	3.25	3.25	2.76	3.24	2.58	--	2.58	2.51	--	2.51	--	--	--	--	3.23	2.81	2.81	2.81	--	2.81	3.12
1983	3.03	3.03	3.17	3.03	2.25	--	2.25	2.07	--	2.07	--	--	--	--	2.94	3.47	3.47	3.47	--	3.47	3.15
1984	2.64	2.64	2.90	2.64	2.61	--	2.61	2.68	--	2.68	--	--	--	--	2.64	2.89	2.89	2.89	--	2.89	2.72
1985	3.36	3.36	3.17	3.36	3.24	--	3.24	3.58	--	3.58	--	--	--	--	3.35	3.04	3.04	3.04	--	3.04	3.24
1986	3.73	3.61	3.54	3.71	3.69	--	3.69	4.08	--	4.08	--	--	--	--	3.72	3.61	3.70	4.22	--	3.71	3.72
1987	3.83	3.32	3.78	3.73	3.68	--	3.68	4.10	--	4.10	--	--	--	--	3.73	3.71	3.47	3.40	--	3.61	3.69
1988	3.97	3.43	4.58	3.78	3.81	--	3.81	5.37	--	5.37	--	--	4.87	4.87	3.93	3.27	3.15	3.89	--	3.32	3.74
1989	4.48	3.75	4.29	4.28	4.65	4.29	4.64	5.13	4.29	5.00	--	--	5.59	5.59	4.44	3.49	3.51	4.22	--	3.60	4.16
1990	4.44	4.64	5.00	4.52	5.31	5.41	5.31	6.41	5.41	6.36	--	--	5.70	5.70	4.90	3.91	3.90	4.60	--	3.99	4.49
1991	4.91	5.29	5.01	4.95	6.22	6.03	6.20	6.70	5.91	6.58	--	--	6.36	6.36	5.41	4.21	4.63	5.14	--	4.41	4.85
1992	4.60	3.49	3.45	4.43	4.89	6.72	5.15	5.67	6.42	5.73	--	--	6.35	6.35	4.71	4.03	4.23	5.49	--	4.27	4.46
1993	4.60	4.41	4.09	4.57	5.79	6.45	5.83	5.98	6.17	5.99	--	--	6.15	6.15	4.96	3.64	4.38	5.21	--	4.00	4.42
1994	4.53	4.19	5.84	4.49	5.38	6.41	5.45	6.22	6.85	6.28	--	--	6.49	6.49	4.93	3.65	4.36	5.60	--	4.03	4.32
1995	4.04	3.55	4.74	4.02	6.07	7.29	6.12	6.08	7.17	6.33	--	--	6.80	6.80	4.48	3.38	4.63	5.92	--	3.94	4.08
1996	3.98	3.46	4.31	3.93	4.22	7.22	4.26	6.06	7.57	6.22	--	--	6.47	6.47	4.35	3.57	3.36	5.21	--	3.73	3.91
1997	4.21	3.99	4.21	4.18	5.30	5.30	5.30	6.27	6.27	6.22	--	--	6.25	6.25	4.67	3.87	3.68	4.83	--	3.96	4.11
1998	3.74	3.13	3.15	3.69	4.66	8.09	4.74	4.64	7.81	4.69	9.55	--	10.13	9.92	4.32	3.26	4.00	5.26	7.00	3.72	3.82
1999	3.72	3.16	3.43	3.63	5.35	9.17	5.48	5.95	10.00	6.18	8.15	--	10.29	9.32	4.55	3.41	4.29	5.28	6.76	3.81	3.89
2000	3.94	3.27	--	3.76	4.12	--	4.12	6.36	--	6.36	--	--	9.75	9.75	4.55	3.69	4.67	5.65	6.46	4.11	4.12
2001	3.66	3.02	--	3.57	4.09	--	4.09	6.14	--	6.14	--	7.70	9.09	8.01	3.99	3.19	3.77	5.52	6.00	3.57	3.75
2002	3.80	3.83	--	3.81	4.57	--	4.57	5.46	--	5.46	--	6.59	8.05	7.25	4.21	3.22	3.50	5.37	5.80	3.54	3.78
2003	4.67	4.16	--	4.59	4.67	--	4.67	5.87	--	5.87	3.35	7.50	10.01	8.31	4.90	3.68	4.36	5.58	6.59	4.09	4.46
2004	4.77	4.41	--	4.70	5.11	6.56	5.12	6.42	--	6.42	--	5.86	11.11	7.41	5.01	2.96	2.59	3.49	6.07	2.96	3.82
2005	5.33	4.26	3.35	5.12	4.21	--	4.21	5.53	--	5.53	--	6.61	6.72	6.68	5.15	3.61	3.16	4.64	4.70	3.66	3.96
2006	3.86	3.24	--	3.73	3.68	--	3.68	4.57	--	4.57	--	4.10	6.38	4.55	3.85	3.19	3.19	3.44	4.82	3.26	3.50
2007	4.64	4.42	--	4.62	4.79	--	4.79	4.89	--	4.89	--	4.89	6.80	5.27	4.71	4.20	4.29	4.25	6.55	4.26	4.50
2008	5.42	5.60	--	5.46	5.90	--	5.90	5.21	--	5.21	--	5.67	7.21	6.10	5.57	5.21	5.38	5.06	8.28	5.29	5.42
2009	5.39	4.78	--	5.30	6.14	--	6.14	6.43	--	6.43	--	6.47	6.84	6.56	5.70	4.67	5.17	5.40	7.45	4.93	5.33
2010	5.72	5.38	--	5.69	6.37	--	6.37	7.30	--	7.30	--	7.16	7.16	7.16	6.12	4.11	4.82	6.14	7.79	4.64	5.44
2011	5.98	4.35	--	5.68	7.79	--	7.79	8.03	--	8.03	--	8.40	7.76	8.13	6.74	4.86	5.26	6.73	8.33	5.31	5.78
Mean	4.04	3.70	3.66	3.98	4.28	6.58	4.30	5.22	6.72	5.24	7.02	6.45	7.43	6.89	4.23	3.49	3.70	4.67	6.61	3.66	3.90

Table 8. Estimated abundance at age, survival (S), fishing mortality (F) and exploitation (u) for Lake Erie walleye, 1980-2011 (from ADMB WTG 2012 catc at age analysis, M=0.32). 2011 and 2012 age-2 are from the regression of pooled trawl YOY data and ADMB age-2 walleye abundance (see Table 9). Projected 2012 ages 3 to 7+ population is based on survival from 2011.

	Age							Ages 2+		
Year	2	3	4	5	6	7+	Total	S	F	u
1980	10,224,900	9,824,780	725,880	1,235,440	374,283	79,437	22,464,720	0.586	0.215	0.166
1981	6,920,460	6,695,790	5,190,710	382,755	651,448	239,801	20,080,964	0.470	0.435	0.305
1982	11,583,900	4,150,020	2,692,330	2,081,970	153,521	359,102	21,020,843	0.537	0.301	0.224
1983	7,572,000	7,148,580	1,825,140	1,180,900	913,183	227,715	18,867,518	0.590	0.208	0.162
1984	54,584,400	4,996,620	3,882,780	987,420	638,879	620,571	65,710,670	0.637	0.130	0.105
1985	5,246,740	35,905,100	2,684,770	2,079,050	528,718	682,260	47,126,638	0.618	0.161	0.128
1986	20,072,100	3,597,260	21,882,400	1,633,140	1,264,680	741,973	49,191,553	0.614	0.167	0.132
1987	19,314,800	13,475,300	2,072,130	12,569,900	938,127	1,160,760	49,531,017	0.615	0.166	0.131
1988	46,242,400	12,978,500	7,807,590	1,198,030	7,267,490	1,223,260	76,717,270	0.617	0.163	0.129
1989	11,589,400	30,498,900	7,169,990	4,302,890	660,255	4,690,500	58,911,935	0.591	0.207	0.161
1990	9,711,350	7,741,680	17,422,000	4,086,100	2,452,170	3,092,250	44,505,550	0.620	0.158	0.126
1991	5,512,620	6,612,170	4,669,800	10,485,300	2,459,170	3,365,520	33,104,580	0.631	0.141	0.113
1992	13,930,900	3,793,480	4,092,800	2,882,970	6,473,240	3,632,900	34,806,290	0.624	0.151	0.120
1993	19,728,700	9,425,760	2,234,140	2,402,590	1,692,390	5,979,960	41,463,540	0.594	0.201	0.157
1994	3,739,560	12,922,600	5,040,400	1,188,480	1,278,090	4,195,530	28,364,660	0.571	0.240	0.184
1995	13,865,500	2,479,540	7,171,960	2,782,570	656,105	3,106,290	30,061,965	0.587	0.213	0.165
1996	15,327,900	9,048,810	1,310,540	3,765,770	1,461,040	2,049,760	32,963,820	0.530	0.315	0.233
1997	2,049,630	9,488,760	4,085,730	586,247	1,684,550	1,630,070	19,524,987	0.525	0.325	0.239
1998	14,027,200	1,321,370	4,840,710	2,069,090	296,887	1,720,550	24,275,807	0.551	0.275	0.207
1999	6,284,800	8,709,950	601,434	2,184,440	933,710	956,773	19,671,107	0.545	0.288	0.215
2000	5,647,790	4,022,680	4,349,430	298,041	1,082,500	962,011	16,362,452	0.546	0.285	0.214
2001	17,518,000	3,605,800	2,002,470	2,149,400	147,286	1,034,350	26,457,306	0.625	0.150	0.120
2002	1,430,490	11,596,700	1,989,610	1,100,310	1,181,040	665,576	17,963,726	0.617	0.162	0.129
2003	13,661,500	979,205	7,090,910	1,213,270	670,970	1,133,590	24,749,445	0.629	0.144	0.115
2004	293,806	9,175,680	564,255	4,070,130	696,406	1,053,190	15,853,467	0.628	0.145	0.116
2005	72,989,000	206,523	5,751,460	352,895	2,545,530	1,104,230	82,949,638	0.663	0.091	0.075
2006	2,068,520	49,371,500	116,215	3,218,490	197,479	2,066,070	57,038,274	0.638	0.129	0.104
2007	3,589,460	1,462,750	31,364,300	73,706	2,041,230	1,450,310	39,981,756	0.631	0.141	0.113
2008	1,205,880	2,522,570	913,517	19,544,600	45,930	2,189,270	26,421,767	0.621	0.156	0.124
2009	17,299,900	844,176	1,559,110	563,178	12,049,100	1,401,370	33,716,834	0.672	0.077	0.064
2010	7,867,380	12,219,100	537,145	990,253	357,696	8,553,920	30,525,494	0.668	0.083	0.068
2011	3,849,756	5,590,530	7,966,310	349,716	644,718	5,853,690	24,254,720	0.677	0.071	0.059
2012	9,723,235	2,734,667	3,739,957	5,318,660	233,486	4,381,851	26,131,857			

Table 9. Data used to estimate the recruitment of age-2 walleye by linear regression. Y is the ADMB WTG 2012 model estimate of age-2 walleye and X is the mean catch per hectare of age-0 walleye for combined OH and ON August trawls. Values in bold are the regression estimates and are used for RAH projections in 2012 and forecast estimates of recruits in 2012 and 2013. Regression statistics are given at the bottom of the page.

Year Class	Year of Recruitment to Fisheries	OH+ONT Trawl Age-0 CPHa	ln (OH+ONT Trawl CPHa)	ADMB-estimated Age-2 walleye recruits (in millions)	ln (ADMB-estimated Age-2 walleye recruits in millions)
1988	1990	18.280	2.906	9.711	2.273
1989	1991	6.094	1.807	5.513	1.707
1990	1992	39.432	3.675	13.931	2.634
1991	1993	59.862	4.092	19.729	2.982
1992	1994	6.711	1.904	3.740	1.319
1993	1995	108.817	4.690	13.866	2.629
1994	1996	63.921	4.158	15.328	2.730
1995	1997	2.965	1.087	2.050	0.718
1996	1998	85.340	4.447	14.027	2.641
1997	1999	24.185	3.186	6.285	1.838
1998	2000	14.313	2.661	5.648	1.731
1999	2001	44.189	3.788	17.518	2.863
2000	2002	4.113	1.414	1.430	0.358
2001	2003	28.499	3.350	13.662	2.615
2002	2004	0.139	-1.973	0.294	-1.225
2003	2005	183.015	5.210	72.989	4.290
2004	2006	5.402	1.687	2.069	0.727
2005	2007	12.665	2.539	3.589	1.278
2006	2008	2.051	0.718	1.206	0.187
2007	2009	25.408	3.235	17.300	2.851
2008	2010	7.238	1.979	7.867	2.063
2009 [1]	2011	7.107	1.961	**3.850**	
2010 [2]	2012	26.260	3.268	**9.723**	
2011 [3]	2013	6.502	1.872	**3.614**	

[1] The latest ADMB age-2 estimate has the widest error bounds and is not used in the recruitment estimator.

[2] This regression estimate is for 2012 age-2 recruitment projection.

[3] This regression estimate is for 2013 age-2 recruitment projection.

Note: The regression equation, with standard errors in parentheses, was,

$\ln(Y) = 0.7089\ (0.0580)\ \ln(X) - 0.0422\ (0.1817)$

with $n = 21$, $F = 149$, $p < 0.0001$ and $r^2 = 0.887$.

Table 10. Estimated population of Lake Erie walleye for 2012 based on fishing mortality (F) and survival (S) at age from ADMB WTG 2012 model. Age-2 walleye estimates for 2011 and 2012 are from regressions presented in Table 9.

	2011 Parameters			Rate Functions					2012 Parameters			
	Stock Size (numbers)			Mortality Rates				Survival		2012 Stock Size (mils of fish)		
Age	**Mean**	**Min.**	**Max.**	**(F)**	**(Z)**	**(A)**	**(u)**	**(S)**	**Age**	**Mean**	**Min.**	**Max.**
2	3.850	2.865	5.174	0.022	0.342	0.290	0.019	0.710	2	9.723	6.706	14.097
3	5.591	4.273	6.908	0.082	0.402	0.331	0.068	0.669	3	2.735	2.035	3.675
4	7.966	6.365	9.567	0.084	0.404	0.332	0.069	0.668	4	3.740	2.859	4.621
5	0.350	0.286	0.414	0.084	0.404	0.332	0.069	0.668	5	5.319	4.250	6.388
6	0.645	0.533	0.756	0.084	0.404	0.332	0.069	0.668	6	0.233	0.191	0.276
7+	5.854	4.930	6.777	0.073	0.393	0.325	0.060	0.675	7+	4.382	3.684	5.080
Total	24.255	19.252	29.596	0.071	0.391	0.323	0.059	0.677	Total	26.132	19.725	34.137
(3+)	20.405	16.388	24.422	0.080	0.400	0.330	0.066	0.670	(3+)	16.409	13.018	20.040

Table 11. Estimated harvest of Lake Erie walleye for 2012 and population projection for 2013. Fishing mortality for the fully-selected age groups is derived from the regression equation described in the Harvest Policy section of this report. Abundance of age 2 and older walleye is from ADMB WTG 2012 model catch-age results, and trawl regressions. Stock size and catch in numbers are in millions of fish.

	2012 Stock Size (millions)					Rate Functions					2012 RAH (millions of fish)			Projected 2013 Stock Size (millions)
Age	**Min**	**Mean**	**Max**	**F**	**sel(age)**	**(F)**	**(Z)**	**(S)**	**(u)**		**Min**	**Mean**	**Max**	**Mean**
2	6.706	9.723	14.097		0.258	0.063	0.383	0.681	0.053		0.282	0.513	0.918	3.614
3	2.035	2.735	3.675		0.980	0.241	0.561	0.571	0.185		0.304	0.505	0.821	6.626
4	2.859	3.740	4.621		1.000	0.246	0.566	0.568	0.188		0.436	0.703	1.051	1.560
5	4.250	5.319	6.388		1.000	0.246	0.566	0.568	0.188		0.648	0.999	1.453	2.124
6	0.191	0.233	0.276		1.000	0.246	0.566	0.568	0.188		0.029	0.044	0.063	3.020
7+	3.684	4.382	5.080		0.867	0.213	0.533	0.587	0.165		0.493	0.724	1.020	2.703
Total	19.725	26.132	34.137	0.246					0.133	**RAH 2+**	2.191	3.487	5.326	19.648
(3+)	13.018	16.409	20.040							**RAH 3+**	1.910	2.974	4.408	16.033
										F	0.195	0.246	0.306	

	2013 Stock Size (millions)			Rate Functions				Projected 2013 RAH (millions of fish)	Projected 2014 3+ Stock Size (millions)
Age	**Mean**	**F**	**sel(age)**	**(F)**	**(Z)**	**(S)**	**(u)**	**Mean**	**Mean**
2	3.614		0.258	0.050	0.370	0.691	0.042	0.150	*
3	6.626		0.980	0.189	0.509	0.601	0.148	0.982	2.497
4	1.560		1.000	0.193	0.513	0.599	0.151	0.236	3.983
5	2.124		1.000	0.193	0.513	0.599	0.151	0.321	0.934
6	3.020		1.000	0.193	0.513	0.599	0.151	0.456	1.271
7+	2.703		0.867	0.167	0.487	0.614	0.132	0.358	3.469
Total	19.648	0.193					0.127	2.503	--
(3+)	16.033								12.154

* No estimate of the 2012 cohort recruiting in 2014 is available.

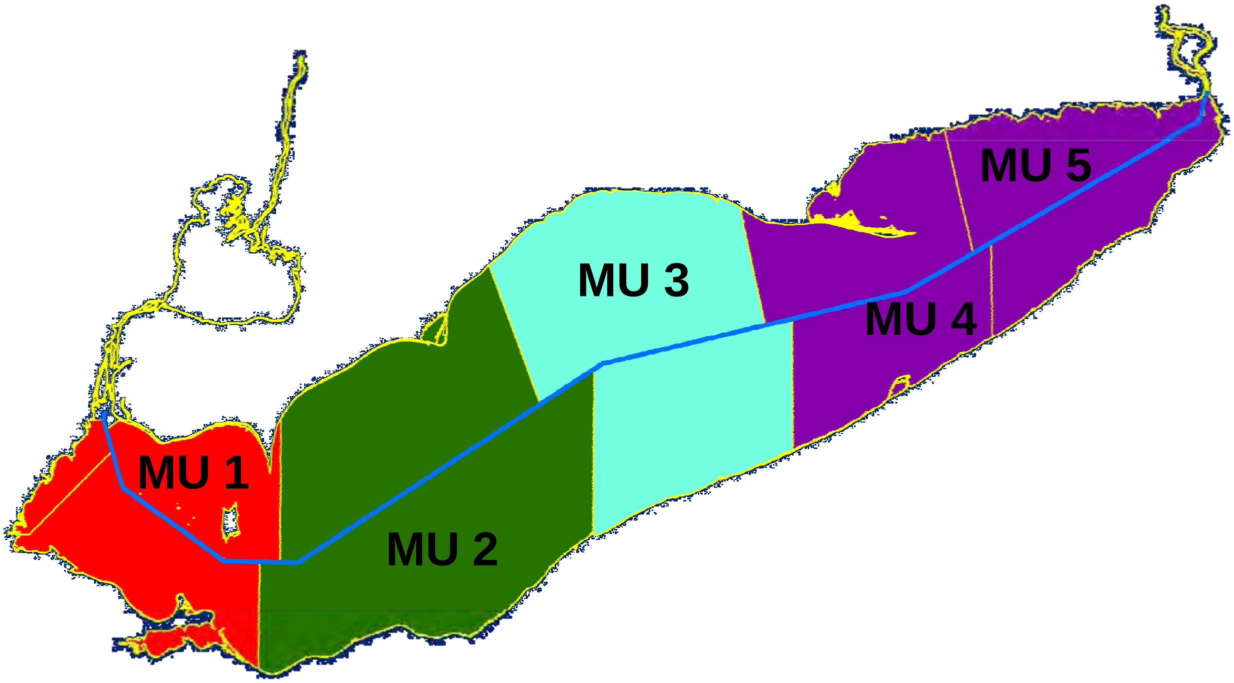


Figure 1. Map of Lake Erie with management units recognized by the Walleye Task Group for interagency management of walleye.

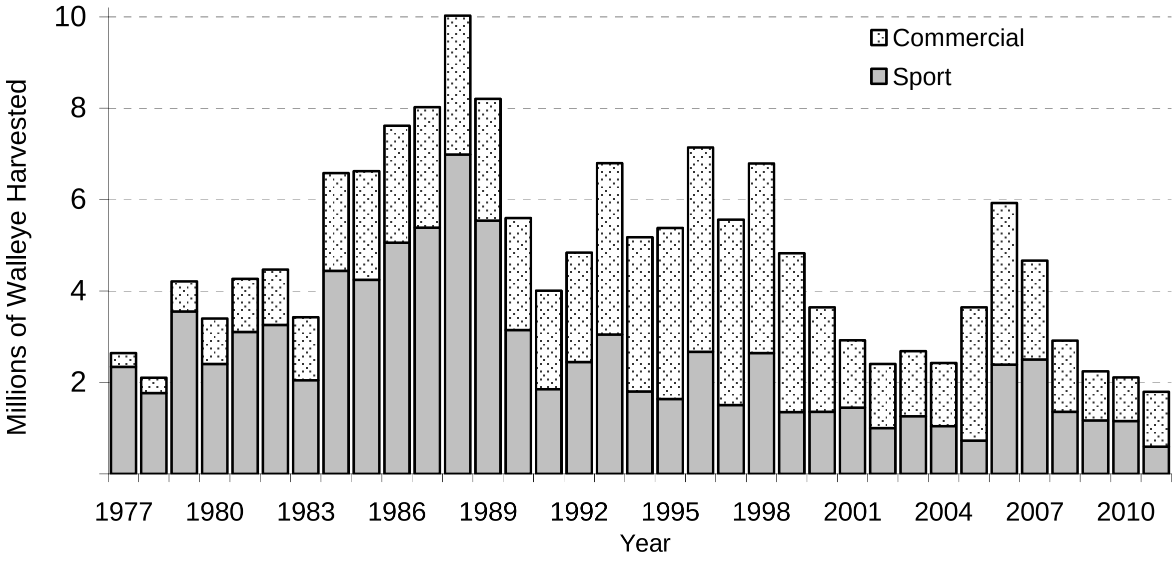


Figure 2. Lake-wide harvest of Lake Erie walleye by sport and commercial fisheries, 1977-2011.

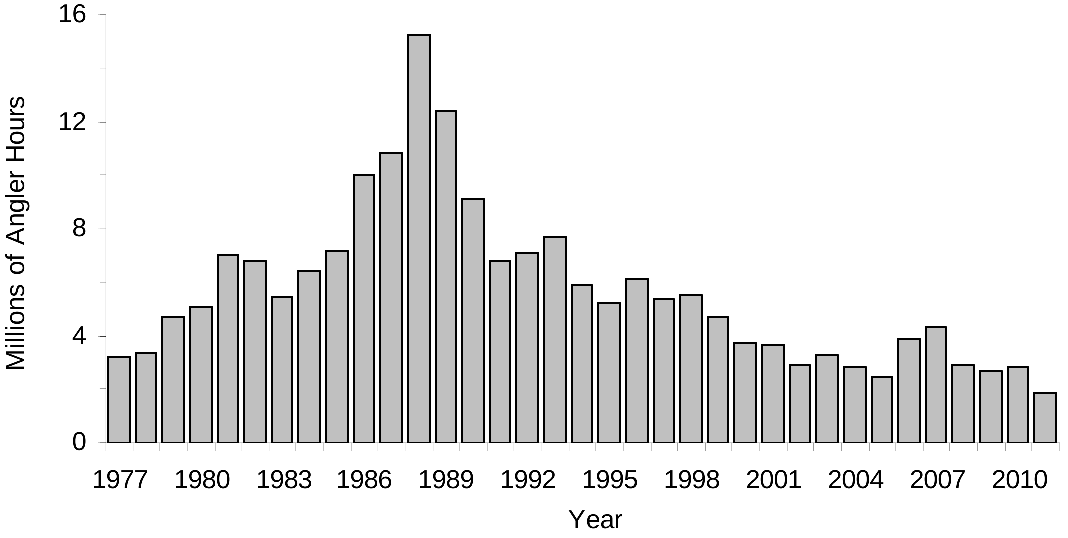


Figure 3. Lake-wide total effort (angler hours) by sport fisheries for Lake Erie walleye, 1977-2011. Years 1999-2011 exclude Ontario sport effort.

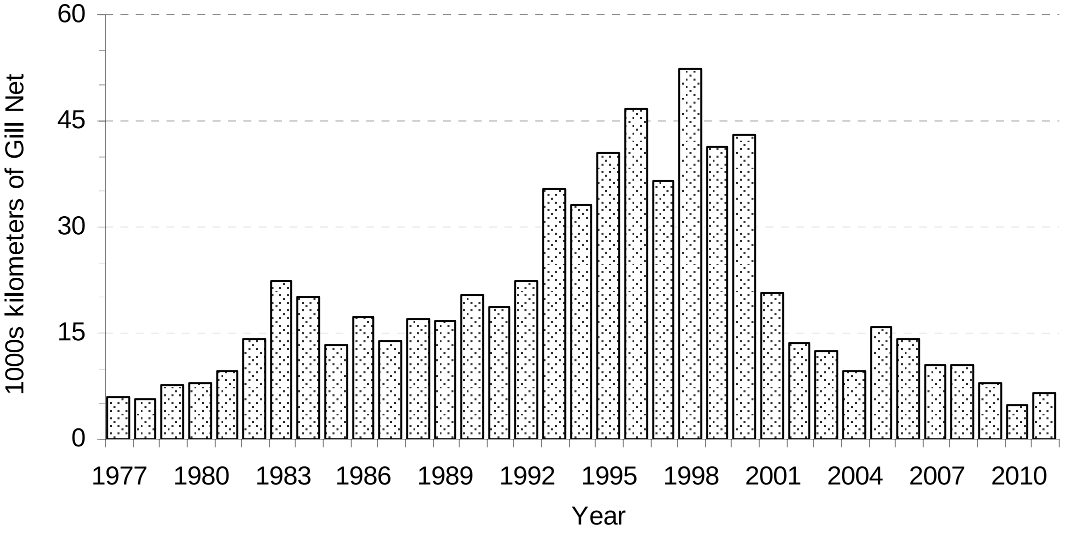


Figure 4. Lake-wide total effort (kilometers of gill net) by commercial fisheries for Lake Erie walleye, 1977-2011.

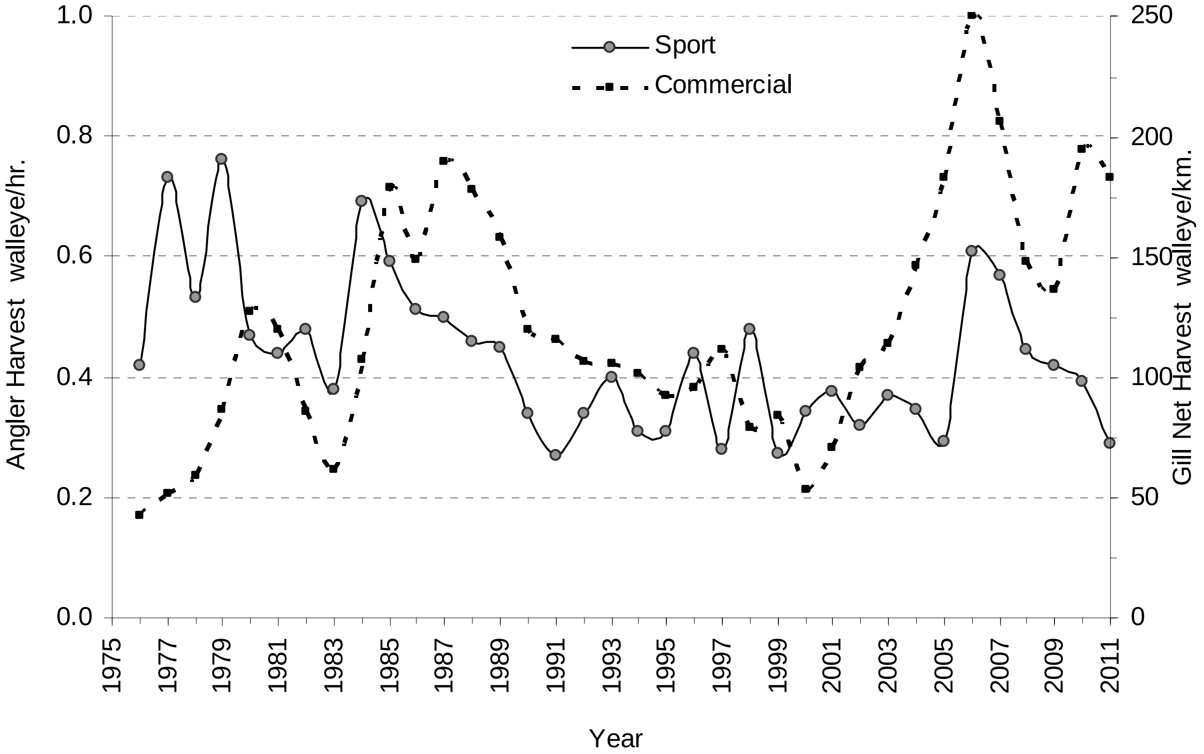


Figure 5. Lake-wide harvest per unit effort (HPE) for Lake Erie sport and commercial walleye fisheries, 1975-2011.

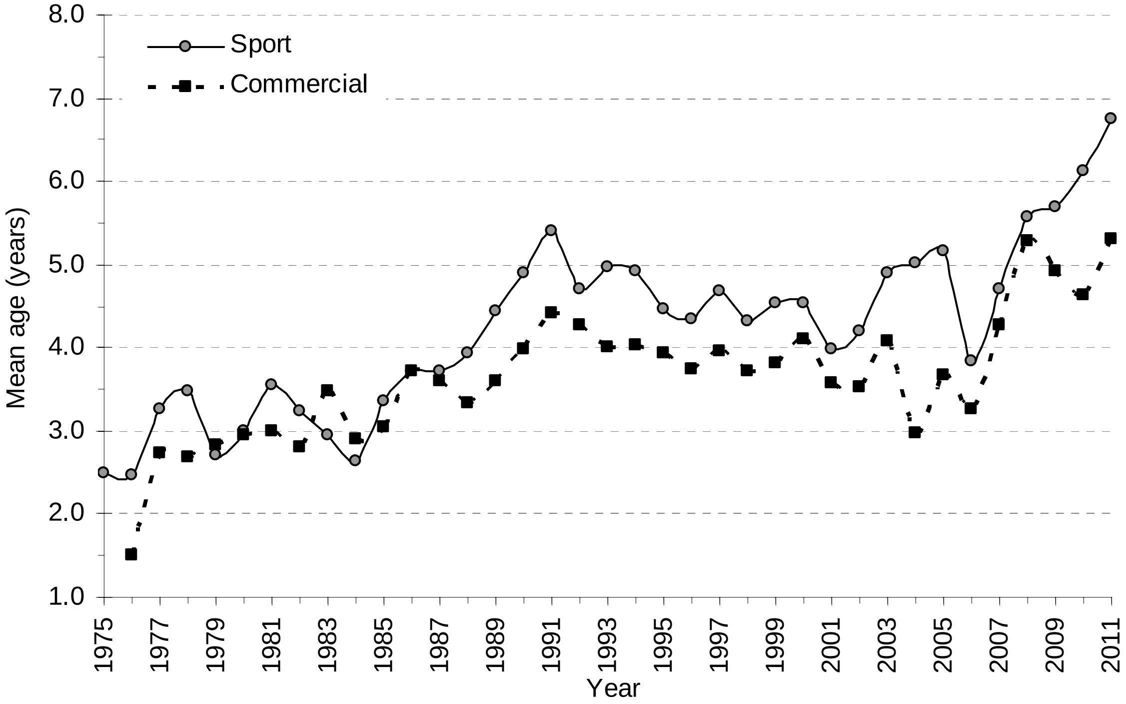


Figure 6. Lake-wide mean age of Lake Erie walleye in sport and commercial harvests, 1975-2011.

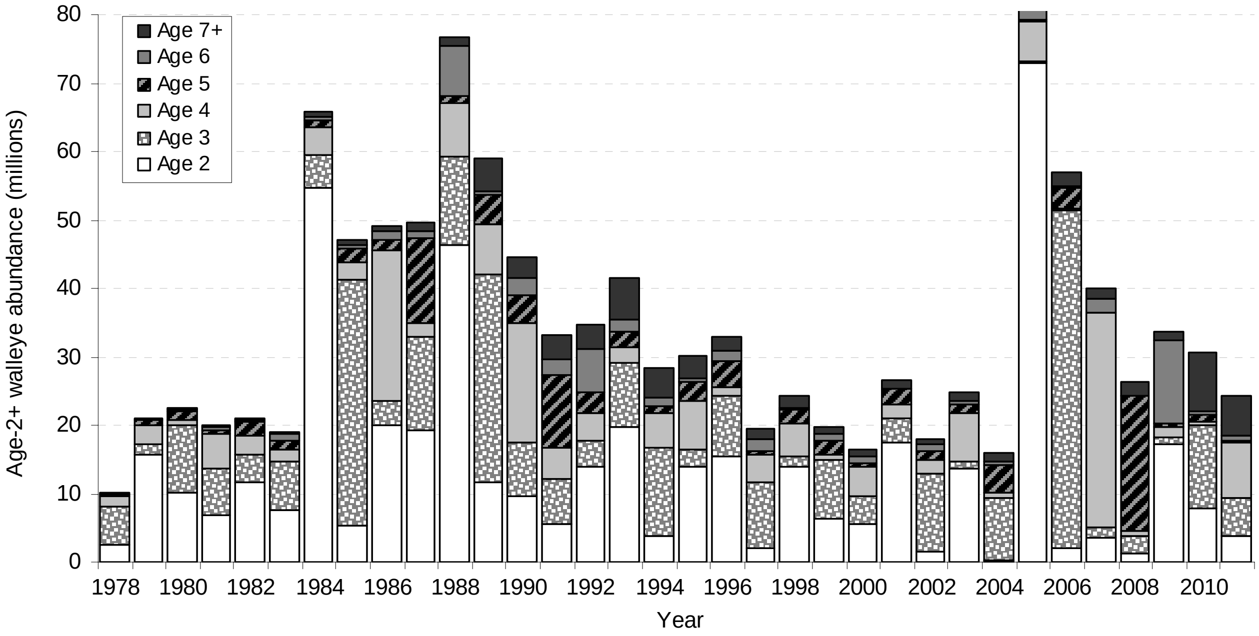


Figure 7. Estimates of abundance by age of Lake Erie walleye 1978-2011. Age-2 estimate in 2011 from regression. Data are from Table 8.

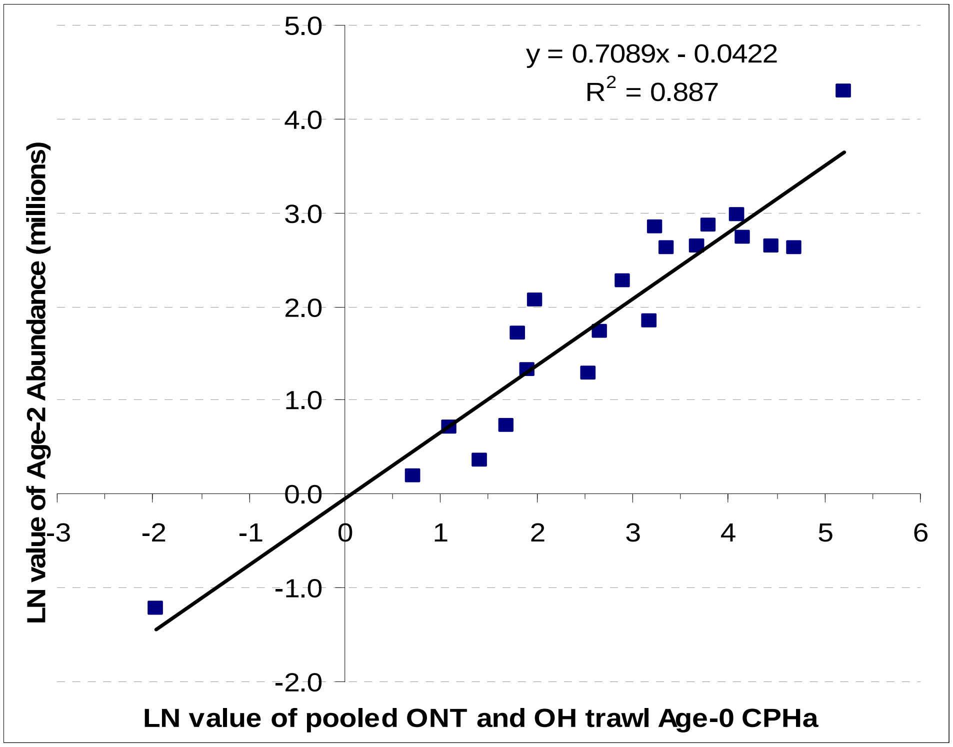


Figure 8. Regression used for estimates of abundance for age-2 Lake Erie walleye using natural logarithm transformed ADMB 2012 model catch-at-age estimates (y) and pooled Ontario and Ohio young-of-the-year trawl indices (x).

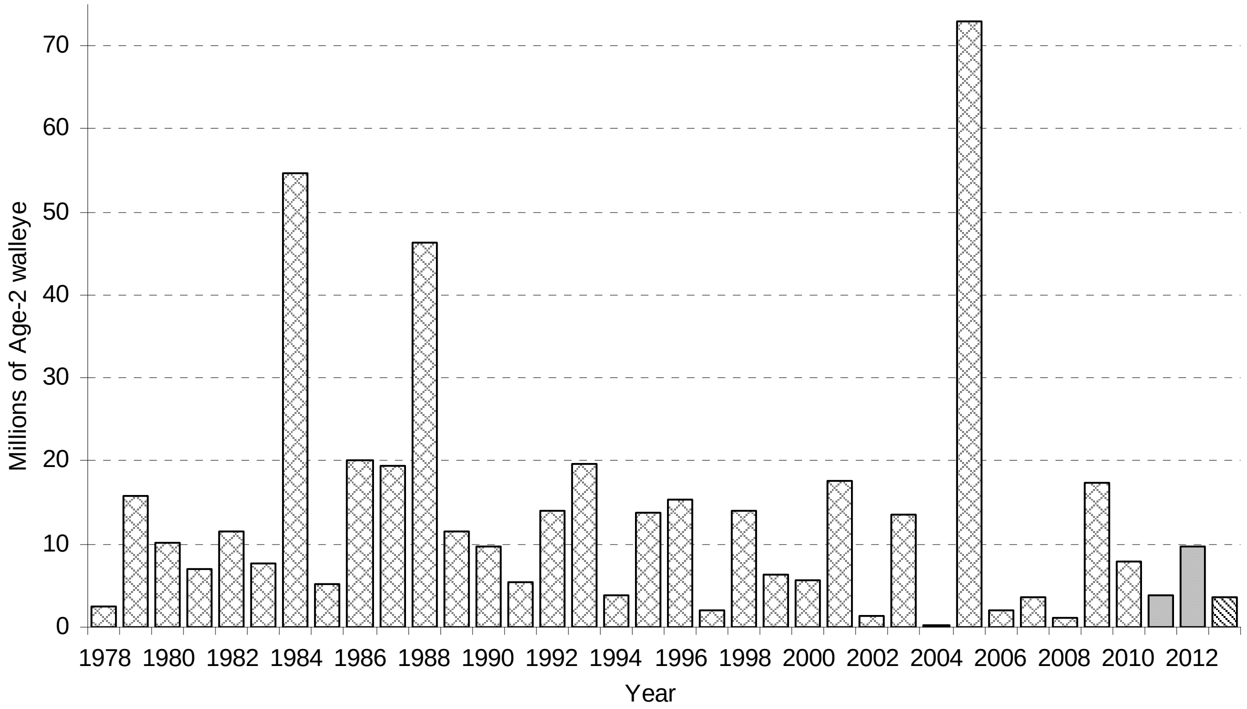


Figure 9. Abundance estimates (from the ADMB WTG 2012 model) of age-2 Lake Erie walleye for 1978 to 2010. Estimates for 2011, 2012 and 2013 are from the regression of YOY catch per hectare and numbers of age-2 from catch-at-age analysis (see Table 9 and Figure 8).

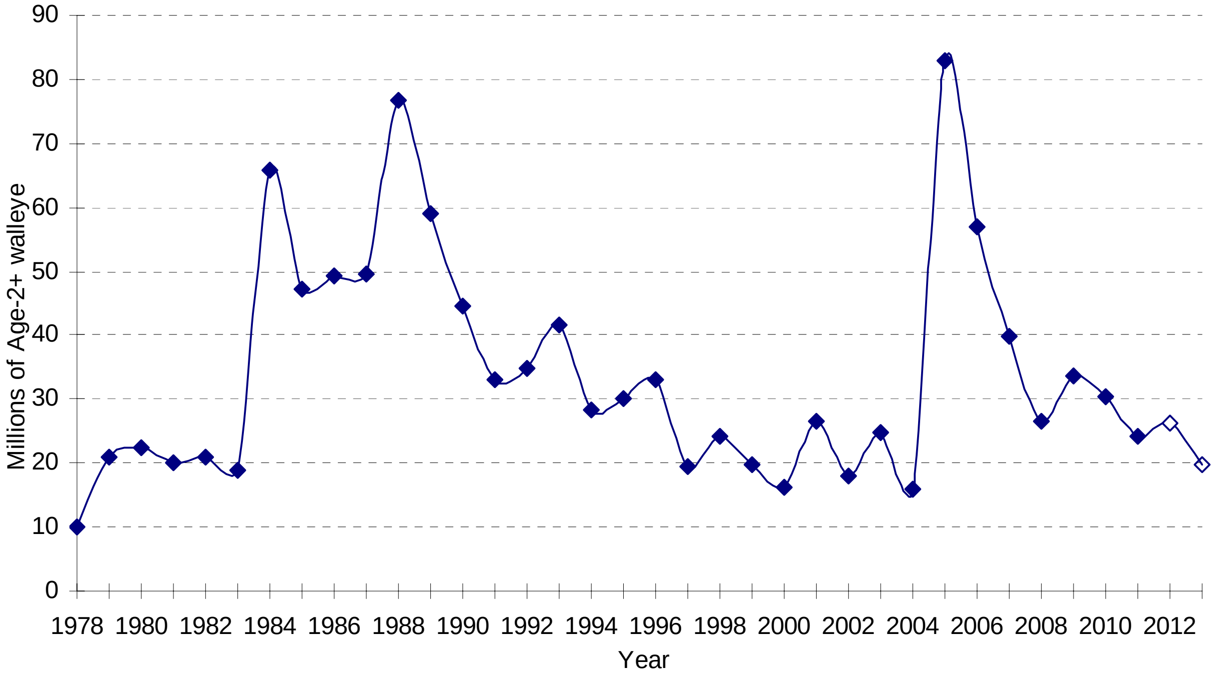


Figure 10. Abundance of Lake Erie walleye (from the ADMB WTG 2012 model) from 1978-2013, forecasting two years of population abundance from regressions (open diamonds).

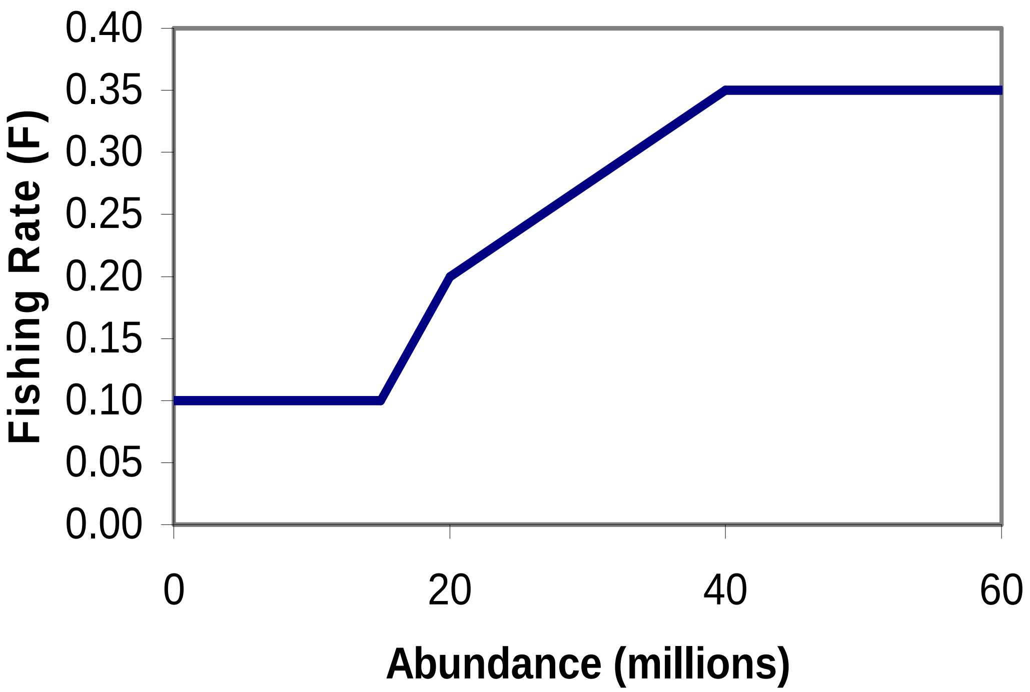


Figure 11. Lake Erie walleye harvest policy for age-2 and older walleye: below 15 million fish, F=0.1; between 15 and 20 million fish, F= 0.02(N)-0.02 (N is abundance in millions of fish); between 20 and 40 million fish, F= 0.0075(N)+0.05; and at 40 million fish and above, F=0.35.

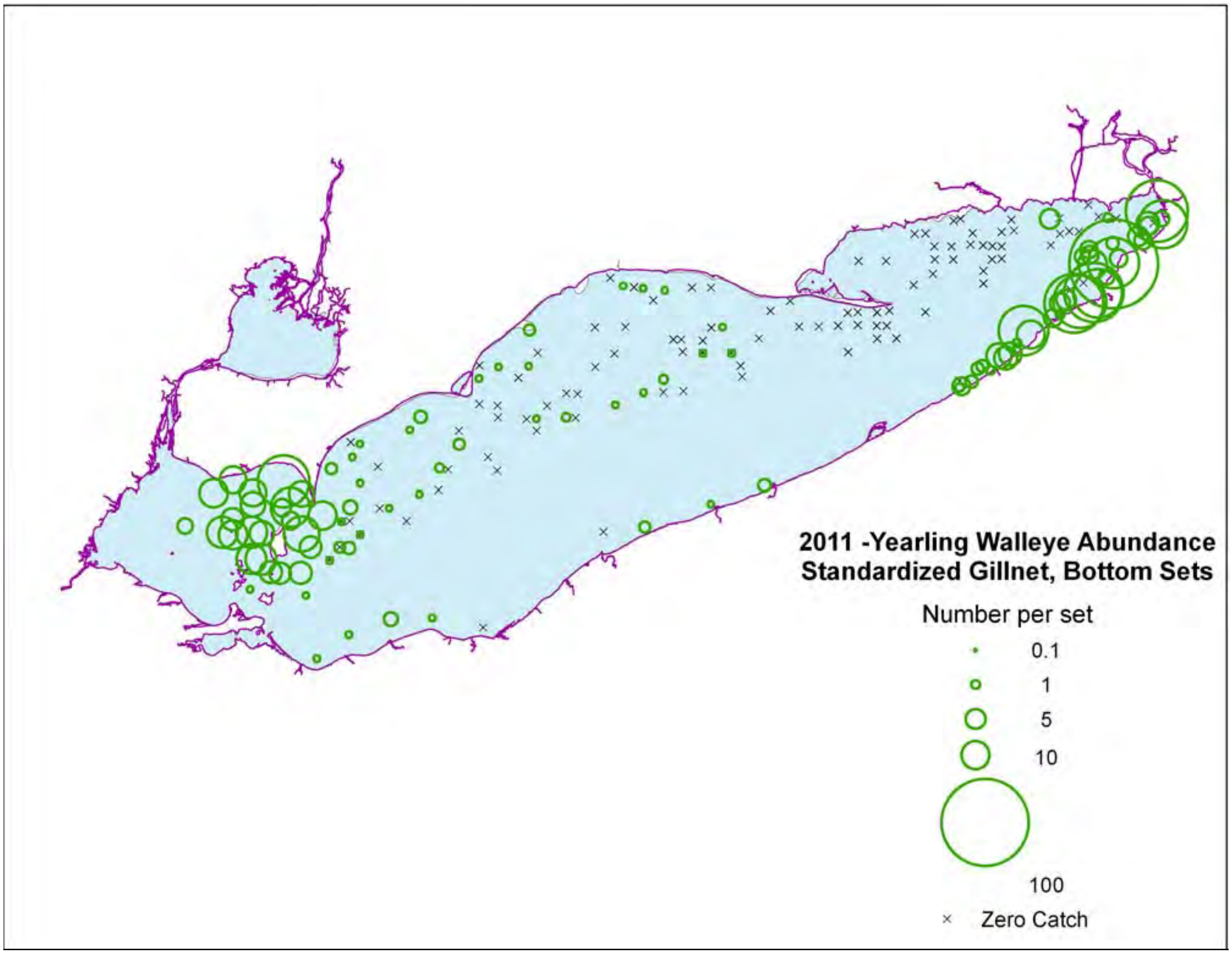
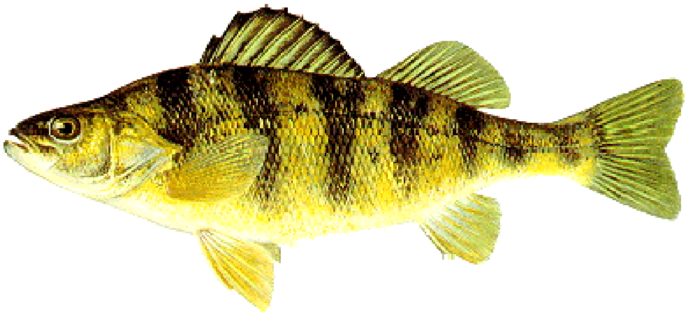


Figure 12. Relative abundance of yearling walleye captured in bottom-set gillnets from Ohio, New York and Ontario waters in 2011. Catches have been adjusted to reflect panel length (standardized to 50ft panels of monofilament) and differences in the presence of large mesh (>5") panels were assumed not to affect catches of yearling sized walleye.

Report of the Lake Erie Yellow Perch Task Group

March 22th, 2012



Members:

Megan Belore (Co-chair)	Ontario Ministry of Natural Resources
Andy Cook	Ontario Ministry of Natural Resources
Don Einhouse	New York Department of Environmental Conservation
Travis Hartman	Ohio Department of Natural Resources
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Mike Thomas (Co-chair)	Michigan Department of Natural Resources
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Presented to:

Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission

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Note: The data and management summaries contained in this report are provisional. Every effort has been made to ensure their correctness. Contact individual agencies for complete state and provincial data. Data reported in pounds for years prior to 1996 have been converted from metric tonnes. Please contact the Yellow Perch Task Group or individual agencies before using or citing data published herein.

Introduction

From April 2011 through March 2012, the Yellow Perch Task Group (YPTG) addressed the following charges:

1. Maintain and update centralized time series of datasets required for population models and assessment including:
    a. Fishery harvest, effort, age composition, biological and stock parameters
    b. Survey indices of young of year, juvenile and adult abundance, size at age and biological parameters
    c. Fishing harvest and effort by grid.

2. Support a sustainable harvest policy by:
    a. Examining exploitation strategies
    b. Recommending an allowable harvest for 2012 for each management unit

3. Assist the STC with the potential development of new exploitation strategies and completion of a Lake Erie Yellow Perch Management Plan.

4. Support QFC modeling efforts for catch-age models and harvest policies.

Charge 1: 2011 Fisheries Review and Population Dynamics

The lakewide total allowable catch (TAC) in 2011 was 12.650 million pounds. This allocation represented a 3.7% decrease from a TAC of 13.137 million pounds in 2010. For yellow perch assessment and allocation, Lake Erie is partitioned into four management units (Units, or MUs; Figure 1.1). The 2011 allocation by management unit was 2.071, 3.537, 6.250, and 0.792 million pounds for Units 1 through 4, respectively. Please note that in 2011, the LEC set the TAC for MU1, MU2 and MU3 higher than the mean RAH values suggested in the March 2011 YPTG report (1.437, 2.526, and 4.996 million pounds respectively, YPTG 2011). Also, in 2011, the LEC set the TAC for MU4 at 0.792 million pounds which was lower than the mean RAH suggested in the YPTG report (0.952 million pounds, YPTG 2011). The lakewide harvest of yellow perch in 2011 was 9.620 million pounds, or 76.0% of the total 2011 TAC. This was a 0.7% decrease from the 2010 harvest of 9.689 million pounds. Harvest by Lake Erie Management Units 1 through 4 was 1.813, 3.065, 4.156, and 0.586 million pounds, respectively (Table 1.1). The portion of TAC harvested was 87.6%, 86.6%, 66.5%, and 74.0%, in MUs 1 through 4, respectively. In 2011, Ontario harvested 6.370 million pounds, followed by Ohio (2.833 million lbs.), Pennsylvania (190 thousand lbs.), Michigan (146 thousand lbs.), and New York (81 thousand lbs.).

Ontario's fraction of allocation harvested was 103.5% in MU1, 103.2% in MU2, 103.0% in MU3, and 102.0% in MU4 (see comments below regarding Ontario's harvest reporting and commercial ice allowance policy). Ohio fishers attained 76.4% of their TAC in the western basin (MU1), 72.7% in the west central basin (MU2), and 31.4% in the east central basin (MU3). Michigan anglers in MU1 attained 77.6% of their TAC. Pennsylvania fisheries harvested 16.0% of their TAC in MU3 and 42.6% of their TAC in MU4. New York fisheries attained 32.9% of their TAC in MU4.

Ontario's portion of the lakewide yellow perch harvest decreased slightly to 66.2% in 2011 from 68.2% in 2010 (Table 1.1). Ohio's proportion of lakewide harvest increased slightly to 29.4% in 2011, from 29.1% in 2010. Harvest in Michigan, Pennsylvania, and New York waters combined represented 4.3% of the lakewide harvest in 2011.

Ontario continued to employ a commercial ice allowance policy implemented in 2002, by which 3.3% is subtracted from commercial landed weight. This step was taken so that ice was not debited towards fishers' quotas. Ontario's landed weights in the YPTG report have not been adjusted to account for ice content. Ontario's reported yellow perch harvest in tables and figures is represented exclusively by the commercial gill net fishery. Reported sport harvests for Michigan, Ohio, Pennsylvania, and New York are based on creel survey estimates. Ohio, Pennsylvania, and New York trap net harvest and effort are based on landed catch reports. Additional fishery documentation is available in annual agency reports.

Harvest, fishing effort, and fishery harvest rates are summarized for the time period 2000 to 2011 by management unit, year, agency, and gear type in Tables 1.2 to 1.5. Trends over a longer time series (1975 to 2011) are depicted graphically for harvest (Figure 1.2), fishing effort (Figure 1.3), and harvest rates (Figure 1.4) by management unit and gear type. The spatial distributions of harvest (all gears) and effort by gear type for 2011 in ten-minute interagency grids are presented in Figures 1.5 through 1.8.

Ontario's yellow perch harvest from large mesh (3 inches or greater) gill nets in 2011 was 9.0%, 20.6%, and 13.4% of the gill net harvest in MUs 1, 2 and 3, respectively, but was negligible in MU4 (0.6%). Harvest, effort, and catch per unit effort from (1) small mesh yellow perch effort (<3 inch stretched mesh) and (2) larger mesh sizes, are distinguished in Tables 1.2 to 1.5. Harvest from targeted small mesh gill nets in 2011 decreased 1.0% in MU1 and 12.2% in MU2, from 2010 harvest. Harvest in MU3 and MU4 in 2011 remained similar to 2010 harvest. Ontario trap net harvest is minimal (103 pounds in 2011) and is included in the total harvest of yellow perch in MU1 (Tables 1.1 and 1.2). Ontario commercial smelt trawlers incidentally catch yellow perch in management units 2, 3 and 4. Trawl catches are included in the total harvest of yellow perch in Table 1.1 and documented by MU at the bottom of Tables 1.2 to 1.5.

Targeted gill net effort in 2011 increased from 2010 by 11.4% in MU2, 6.0% in MU3, and 27.4% in MU4, but decreased 18.4% in MU1. Gill net effort remained lower in 2011 compared to the 1990s and earlier decades (Figure 1.3). Targeted gill net harvest rates in 2011 decreased 16.5% in MU2, 10.4% in MU3 and 21.8% in MU4 from 2010, but increased 19.2% in MU1 (Figure 1.4).

In 2011, sport harvest in U.S. waters increased 1.1% in MU1, 7.6% in MU3, and 96.4% in MU4 from 2010 harvest , but decreased 37.1% in MU2 (Figure 1.2). Angling effort in U.S. waters increased in 2011 from 2010 in MU3 (3.3%) and MU4 (59.5%), but decreased in MU1 (6.7%) and MU2 (21.3%; Figure 1.3). Yellow perch sport harvest from Ontario waters is assessed periodically, but creel surveys were not performed in 2011.

Sport fishing harvest rates are commonly expressed as fish harvested per angler hour for those anglers seeking yellow perch. These harvest rates are presented in Tables 1.2 to 1.5. Compared to 2010 rates, harvest per angler hour in Ohio waters slightly increased in MU1 (2.9%) and MU3 (2.5%), but decreased in MU2 (18.8%). Angler harvest rates increased from 2010 in Michigan waters (47.8% in MU1), in Pennsylvania waters (32.5% in MU3, 31.8% in MU4), and in New York waters (53.4% in MU4).

Angler harvest in kilograms per angler hour is presented graphically in Figure 1.4 for each management unit, by pooling jurisdictions' harvest weights and effort. In 2011, the sport harvest rate (in kg/hr) increased in MU1 (8.3%), MU3 (9.5%), and MU4 (32.8%), and decreased in MU2 (20.0%).

Harvest from Ohio, Pennsylvania, and New York commercial trap nets in 2011 increased 14.5% in MU2, 74.2% in MU3 and 27.8% in MU4, but decreased 20.2% in MU1 from 2010. Compared to 2010, trap net effort (lifts) in 2011 increased in MU1 (23.5%), MU3 (4.1%), and MU4 (33.5%), and decreased in MU2 (14.8%). In 2011, trap net harvest rates decreased from 2010 in MU1 (35.4%), MU4 (4.4%) and increased in MU2 (34.4%) and MU3 (67.6%).

Age Composition and Growth

Lakewide, the yellow perch harvest in 2011 consisted mostly of age-4 fish (2007 year class, 37.0%), with a fair contribution of age-5 fish (2006 year class, 22.1%), the pooled older cohorts (ages 6+, 20.1%), and age-3 fish (2008 year class, 19.3%) (Table 1.6). In MU1, age-4 (2007 year class, 42.7%) and age-3 (2008 year class, 36.5%) fish contributed the most to the fishery. These year classes also contributed to the MU2 fishery (47.1% and 21.2% respectively) and the MU4 fishery (38.7% and 28.3% respectively). In MU3, the fishery consisted of 34% pooled older cohorts (mainly comprised of the 2003 year class), followed by age-5 fish (2006 year class, 33.3%) and age-4 (2007 year class, 25.4%).

Yellow perch growth differs among life stages and between basins as illustrated by trends in total length-at-age (Figure 1.9). For simplicity, Figure 1.9 is comprised of young-of-the-year data from summer and fall interagency trawls, while data for age-1 and successive ages to age-4 are from Ontario Partnership gill net surveys (MUs 1 and 4) and Ohio fall trawls (MUs 2 and 3). As these data are taken from fall surveys, caution must be exercised when evaluating these figures. Seasonal exploitation patterns and density-dependent effects may alter the overall picture of growth trends. In addition, separate surveys in the same MU may show dissimilar trends in size-at-age due to north-south growth differences or fishery influences. However, size-at-age long-term time series results describe relatively stable length-at-age for ages 0 to 4 across the management units. Nevertheless, size-at-age in Ontario Partnership gill net surveys in MU1 decreased for ages 2 and 3, since 2008 and age-4 in 2009. On the other hand, in MU3, size-at-age for age 3 and 4 fish in Ohio fall trawls has increased since 2009. Yellow perch condition in Figure 1.10 is comprised of data from Ontario Partnership gill net surveys (MUs 1 and 4) and Ohio fall trawls (MUs 2 and 3). Trends in condition may be influenced by seasonal differences in sampling. Additional data from Long Point Bay trawl surveys are used to determine condition of age-0 yellow perch in MU4.

The task group continues to update yellow perch growth data in: (1) weight-at-age values recorded annually in the harvest and (2) length- and weight-at-age values taken from interagency trawl and gill net surveys. These values are applied in the calculation of population biomass and the forecasting of harvest in the approaching year. Therefore, changes in weight-at-age factor into the changes in overall population biomass and determination of recommended allowable harvest (RAH). In 2007, the YPTG moved from using a two-year average of weight-at-age to using a three-year average, and this was continued in 2011. This was done to minimize the impacts of weak year classes on determining the mean weight-at-age of yellow perch in the population and in the harvest.

ADMB Catch-at-Age Analysis

Population size for each management unit was estimated by catch-at-age analysis using the Auto Differentiation Model Builder computer program (ADMB), with a standard version that incorporates commercial gill net catchability coefficients based on the seasonal distribution of harvest and relative catch rates. Estimates of population size from 1990 to 2011 and projections for 2012 are presented in Table 1.7. Abundance, biomass, survival, and exploitation rates are presented by management unit graphically for 1975 to 2011 in Figures 1.11 to 1.14. Mean weights-at-age from assessment surveys were applied to abundance estimates to generate population biomass estimates (Table 1.8 and Figure 1.12). Population abundance and biomass estimates are critical to monitoring the status of stocks and determining allowable harvest.

Abundance estimates should be interpreted with several caveats. Inclusion of abundance estimates from 1975 to 2011 implies that the time series are continuous. Lack of data continuity for the entire time series weakens the validity of this assumption. Survey data from multiple agencies are represented only in the latter part of the time series (since the late 1980s); methods of fishery data collection have also varied. Some model parameters are constrained to constants, such as natural mortality, catchability, and selectivity blocks. This technique lessens our ability to directly compare abundance levels over three decades. In addition, commercial gill net selectivity, is estimated independently in the latter part of the time series using gill net selectivity curves derived from index gillnet data by the method of Helser (1998); involving back calculation of length-at-age and weightings based on the monthly distribution of harvest-at-age. With catch-at-age analysis the most recent year's population estimates inherently have the widest error bounds; this is to be expected for cohorts that remain at-large under less than full selectivity in the population.

In the catch-at-age model, population estimates are derived by minimizing an objective function weighted by data sources including fishery effort, fishery catch, and survey catch rates. In 2011-2012, the YPTG group determined data weightings (referred to as lambdas in ADMB) using an expert opinion approach for evaluating potential sources of bias in data sets that could negatively influence model performance. Expert opinions were expressed in a spreadsheet template by evaluating possible sources of bias pertaining to all data sources used in the catch-at-age model. YPTG members supplied background materials for each data source to facilitate completion of the lambda spreadsheet templates. The perceived magnitude of bias in each data set was ranked according to factors associated with spatial, temporal, sampling, modeling assumptions, and fishing methodology. These qualitative selections linked to numeric values were then weighted by the relative importance assigned to each factor. The YPTG worked as a group to complete the lambda spreadsheet templates to determine data weightings for each data set in the model. Data weighting lambdas are presented in Appendix A Table 1.

Recruitment Estimator for Incoming Age-2 Yellow Perch

Age-2 yellow perch recruitment in 2012 was predicted by robust regression of juvenile yellow perch trawl and gill net indices against catch-at-age analysis estimates of two-year-old abundance in each management unit. All values were transformed by natural logarithm, and the regression equations included y-intercepts. Only survey data from within each individual management unit was used to project age-2 abundance from that management unit. Age-2 yellow perch recruitment in 2012 was calculated using the mean of age-2 values predicted from the young-of-year and yearling indices that performed well in the regressions ($r^2 > 0.50$) with age-2 abundance estimates (Appendix A Table 2). Data from trawl and gill net index series for the time period examined are presented in Appendix A Table 3, while a key that summarizes abbreviations used for the trawl and gill net series is presented as a legend in Appendix A Table 4.

Estimates of age-2 yellow perch recruitment for 2012 (the 2010 year class) were below average in MU1 and MU2, and above average in MU3 and MU4 (Table 1.7, Appendix A Table 2). Due to differences in selectivity between management units, the 2010 year class will have a moderate contribution to the fishery in MU1 and MU2, and a small contribution to the fishery in MU3 and MU4 in 2012.

2012 Population Size Projection

Stock size estimates for 2012 yellow perch age-3-and-older were projected from statistical catch-at-age analysis (SCAA) estimates of 2011 population size and age-specific survival rates in 2011 (Table 1.8). Projected age-2 yellow perch recruitment from the 2010 year class (method described above) was added to the 2012 population estimate for older fish in each unit, producing the total standing stock in 2012 (Table 1.8). Standard errors and ranges for estimates are provided for each age in 2011, and following estimated survival from SCAA, for 2012. Descriptions of *min, mean*, and *max* population estimates refer to the age-specific estimates minus or plus one standard deviation (Table 1.8).

Management unit stock size estimates for 2011 from SCAA (Table 1.7) were higher than those projected in the spring of 2011 in MUs 2 and 3, and were similar to predicted values in MU's 1 and 4 (YPTG 2011). Differences in stock size estimates were due to additional data in the model and an updated method for determining data weightings (see ADMB Catch Age Analysis). Current estimates of age-2 fish in 2011 are from the SCAA's first assessment of this cohort and as such have the widest error bounds.

Stock size estimates projected for 2012 were slightly lower than 2011 in MUs 1, and 2, and slightly higher in MUs 3 and 4 (Tables 1.7, 1.8, Appendix A Table 2, and Figure 1.11). Abundance projections for 2012 were 21.8, 50.4, 72.4, and 21.9 million age-2-and-older yellow perch in management units 1 through 4, respectively. Abundance estimates of age-2-and-older yellow perch in 2012 are projected to decrease by 6.0% and 10.5% in MUs 1 and 2 compared to the 2011 abundance estimates, and increase by 2.6% and 9.4% in management units 3 and 4. Age-3-and-older yellow perch abundance in 2012 is projected to be 11.8, 31.2, 44.3, and 12.4 million fish in Units 1 through 4, respectively. Model estimates of abundance for age-3-and-older yellow perch in 2012 are projected to decrease from the 2011 estimates in MU1 (26.2%), MU2 (39.2%), MU3 (36.4%) and MU4 (35.4%).

As a function of population estimates and mean weight-at-age from surveys, total biomass estimates of age-2-and-older yellow perch for 2012 are projected to decline in each MU compared to 2011 (Table 1.8 and Figure 1.12): decreasing 3.2%, 8.4%, 2.4%, and 1.1% in MUs 1-4, respectively. The biomass estimates for 2011 are above the historic long-term (1975 to 2010) mean in MU2 (101.8% of the mean value), MU3 (193.1%) and MU4 (316.1%). The biomass estimate for 2011 is below the historic long-term (1975 to 2010) mean in MU1 (57.9% of the mean value). In 2012, age-4 yellow perch (2008 year class) are expected to represent the largest fraction of biomass in MUs 2, 3 and 4. In MU1, age-2 yellow perch (2010 year class) are expected to represent the largest fraction of total biomass.

Estimates of yellow perch survival for age-3-and-older in 2010 were 48.7%, 54.3%, 60.4%, and 62.8% in MUs 1 to 4, respectively (Figure 1.13). In 2011, estimated survival rates of age-3-and-older were 45.1%, 54.5%, 62.7%, and 61.7% in Units 1 through 4 (Table 1.8 and Figure 1.13). Estimates of yellow perch survival in 2011 for age-2-and-older were 50.7% in MU1, 55.4% in MU2, 62.8% in MU3, and 61.9% in MU4 (Table 1.8 and Figure 1.13). Survival rates in 2011 compared to 2010 decreased in MUs 1 and 4, for age-2-and-older and age-3-and-older yellow perch. In MU2, survival rates of age-2-and-older fish decreased from 2010 to 2011, while survival rates of age-3-and-older fish increased slightly. In MU3, 2011 survival rates of age-2-and-older fish remained the same as 2010, while survival rates of age-3-and-older fish increased slightly.

Estimated exploitation rates in 2010 were 22.8%, 15.7%, 8.2%, and 5.2% in management units 1 to 4, respectively, for age-3-and-older yellow perch. Exploitation rates for yellow perch age-3-and-older in 2011 were estimated at 27.3%, 15.5%, 5.3%, and 6.6%, for

MUs 1 to 4, respectively (Figure 1.14). Estimates of yellow perch exploitation for age-2-and-older in 2011 were 20.2% in MU1, 14.3% in MU2, 5.3% in MU3, and 6.3% in MU4 (Table 1.8 and Figure 1.14).

Charge 2: Harvest Strategy and RAH

Harvest Strategy Methodology

Fishing rates applied in 2012 are presented in Table 2.1, along with associated RAH values for each management unit. These fishing rates are similar to those used in 2009 and 2010. These interim harvest strategies were developed for a draft Yellow Perch Management Plan (YPMP), tested using an updated yellow perch simulation (see YPTG 2010 report).

Harvest Strategies and RAH Determination

Fishing rates for 2012 were based on interim harvest strategies from work on the YPMP and yellow perch simulation results (see Charge 3: Lake Erie Yellow Perch Management Plan). The yellow perch simulation determined that fishing rates that were one-half of F_{msy} could support viable sport and commercial fisheries without inviting excessive biological risk. These fishing rates were used to determine *min*, *mean*, and *max* RAH's for 2012 for each management unit (Tables 2.1 and 2.2).

In 2005, an exercise was completed to update the allocation area shares using geographical information system (GIS) mapping. In late 2008, the YPTG proposed that the line dividing MUs 3 and 4 be moved five minutes to the east in order to be consistent with Ontario's Eastern Basin Management Zone. The Lake Erie Committee (LEC) and Standing Technical Committee (STC) approved the change and new areas and allocation shares by jurisdiction were calculated (Figure 2.1). The change was implemented in 2009. These same allocation shares will be used in 2012. The allocation shares by management unit and jurisdiction are:

Allocation of TAC within Management Unit and Jurisdiction, 2012:

MU1:	MI	9.1%	OH	50.3%	ONT	40.6%
MU2:	OH	54.4%	ONT	45.6%		
MU3:	OH	32.4%	PA	15.3%	ONT	52.3%
MU4:	NY	31.0%	PA	11.0%	ONT	58.0%

Charge 3: Lake Erie Yellow Perch Management Plan

With guidance from the STC, the YPTG was charged with supporting the development of a Lake Erie Yellow Perch Management Plan (YPMP). In February 2009, a draft YPMP was submitted to Michigan State University's Quantitative Fisheries Center (QFC) for a technical review of the background material, exploitation strategies and associated yellow perch simulation. The QFC returned preliminary comments in March 2009; however, they indicated that additional time would be required to carry out a more thorough review of the harvest strategies and thresholds defined in the management plan.

During 2009 the YPTG implemented some of the suggestions put forth by the QFC, including changes to the yellow perch simulation and YPMP exploitation policies. Although the yellow perch simulation was used in 2010, full yellow perch exploitation strategies have not been completed for each management unit. The fishing rates currently applied for RAH in MUs 1, 2 and 3 are ½F_{msy}. They are 0.67, 0.67, and 0.70 for management units 1–3, respectively. In MU4, a more conservative fishing rate of 0.30 was chosen.

The LEC, STC, QFC, and stakeholder groups from all jurisdictions on Lake Erie have formed the Lake Erie Percid Management Advisory Group (LEPMAG), to address stakeholder objectives, modeling concerns and exploitation policies for Lake Erie percids. During 2011, LEPMAG focused on walleye objectives and assessment models. In 2012, LEPMAG will begin discussions on stakeholder objectives and catch-at-age modeling concerns for yellow perch. These discussions are expected to lead to updated exploitation strategies for yellow perch in a Lake Erie yellow perch management plan.

Charge 4: Support QFC Modeling Efforts for Catch-Age Models

The YPTG was tasked with reviewing the methodology of assigning weighting factors to data sources in the catch-at-age models. In 2011-12, the YPTG adopted a new approach to determining data weightings in the yellow perch catch-at-age models. This approach is described in Charge 1 of this report.

The LEPMAG, facilitated by the QFC, will review the yellow perch assessment models during the course of their discussion on yellow perch management over the next two years. The YPTG will continue to support this endeavor.

Acknowledgments

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- Tim Bader, Ann Marie Gorman, and Jeff Tyson of the Ohio Department of Natural Resources, Division of Wildlife;
- Karen Soper and Dr. Yingming Zhao of the Ontario Ministry of Natural Resources;
- Dr. Michael Jones, Dr. James Bence, Aaron Berger, Travis Brenden, and Matthew Catalano of Michigan State University's Quantitative Fishery Center;
- Dr. Carol Stepien and the Lake Erie Center of the University of Toledo;
- Richard Kraus and Patrick Kocovsky of the U.S. Geological Survey, Biological Resources Division, Sandusky.

The YPTG report could not be completed without the contributions of all Lake Erie staff from the Michigan Department of Natural Resources, Ohio Division of Wildlife, Pennsylvania Fish and Boat Commission, New York Department of Environmental Conservation, US Geological Survey – Biological Resources Division, and the Ontario Ministry of Natural Resources. In addition, the YPTG expresses thanks to the Great Lakes Fishery Commission for their continued support.

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Yellow Perch Task Group (YPTG). 2011. Report of the Yellow Perch Task Group, March 2011. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission. Ann Arbor, Michigan, USA.

Table 1.1. Lake Erie yellow perch harvest in pounds by management unit (Unit) and agency, 2000-2011.

		Ontario*		**Ohio**		**Michigan**		**Pennsylvania**		**New York**		**Total**
	Year	Harvest	%	Harvest	%	Harvest	%	Harvest	%	Harvest	%	**Harvest**
Unit 1	2000	980,323	47	1,038,650	50	67,010	3	--	--	--	--	2,085,983
	2001	813,066	45	915,641	51	70,910	4	--	--	--	--	1,799,617
	2002	1,454,105	50	1,316,553	45	147,065	5	--	--	--	--	2,917,723
	2003	1,179,667	44	1,406,385	53	84,878	3	--	--	--	--	2,670,930
	2004	1,698,761	59	1,090,669	38	94,732	3	--	--	--	--	2,884,162
	2005	1,513,890	60	965,231	38	49,485	2	--	--	--	--	2,528,606
	2006	1,325,464	54	1,055,378	43	62,854	3	--	--	--	--	2,443,696
	2007	727,678	41	982,677	55	62,815	4	--	--	--	--	1,773,170
	2008	580,050	56	409,705	39	47,934	5	--	--	--	--	1,037,689
	2009	853,137	61	463,564	33	87,319	6	--	--	--	--	1,404,020
	2010	879,358	47	889,512	48	83,725	5	--	--	--	--	1,852,595
	2011	870,802	48	796,447	44	145,960	8	--	--	--	--	1,813,209
Unit 2	2000	1,484,125	56	1,169,234	44	--	--	--	--	--	--	2,653,359
	2001	1,794,275	51	1,747,069	49	--	--	--	--	--	--	3,541,344
	2002	2,190,621	52	1,986,730	48	--	--	--	--	--	--	4,177,351
	2003	2,107,639	50	2,113,285	50	--	--	--	--	--	--	4,220,924
	2004	2,051,473	48	2,246,264	52	--	--	--	--	--	--	4,297,737
	2005	2,666,231	59	1,843,190	41	--	--	--	--	--	--	4,509,421
	2006	3,102,269	69	1,393,732	31	--	--	--	--	--	--	4,496,001
	2007	1,847,139	45	2,244,656	55	--	--	--	--	--	--	4,091,795
	2008	1,990,237	50	2,005,000	50	--	--	--	--	--	--	3,995,237
	2009	2,495,611	58	1,801,978	42	--	--	--	--	--	--	4,297,589
	2010	1,888,876	56	1,457,823	44	--	--	--	--	--	--	3,346,699
	2011	1,665,258	54	1,399,503	46	--	--	--	--	--	--	3,064,761
Unit 3	2000	771,646	62	443,250	36	--	--	32,613	3	--	--	1,247,509
	2001	999,450	64	464,811	30	--	--	91,211	6	--	--	1,555,472
	2002	1,192,691	60	640,104	32	--	--	140,821	7	--	--	1,973,616
	2003	1,667,133	72	481,558	21	--	--	177,516	8	--	--	2,326,207
	2004	1,453,419	62	659,447	28	--	--	244,063	10	--	--	2,356,929
	2005	1,771,800	75	457,593	19	--	--	142,028	6	--	--	2,371,421
	2006	3,451,499	90	271,144	7	--	--	106,260	3	--	--	3,828,903
	2007	2,997,101	84	391,285	11	--	--	193,065	5	--	--	3,581,451
	2008	2,200,168	74	629,366	21	--	--	155,014	5	--	--	2,984,548
	2009	2,266,727	74	597,214	20	--	--	190,742	6	--	--	3,054,683
	2010	3,370,099	85	476,808	12	--	--	117,640	3	--	--	3,964,547
	2011	3,366,412	81	636,686	15	--	--	153,233	4	--	--	4,156,331
Unit 4	2000	35,686	73	--	--	--	--	10,950	22	2,458	5	49,094
	2001	35,893	60	--	--	--	--	8,337	14	15,319	26	59,549
	2002	87,541	54	--	--	--	--	46,903	29	26,903	17	161,347
	2003	84,772	60	--	--	--	--	39,821	28	16,511	12	141,104
	2004	98,733	49	--	--	--	--	46,344	23	54,862	27	199,939
	2005	195,347	67	--	--	--	--	42,226	15	53,468	18	291,041
	2006	230,226	69	--	--	--	--	57,005	17	48,107	14	335,338
	2007	185,954	78	--	--	--	--	25,859	11	25,935	11	237,748
	2008	240,270	77	--	--	--	--	31,325	10	40,809	13	312,404
	2009	272,579	72	--	--	--	--	37,991	10	70,030	18	380,600
	2010	467,612	89	--	--	--	--	19,989	4	37,730	7	525,331
	2011	468,001	80	--	--	--	--	37,040	6	80,848	14	585,889
Lakewide Totals	2000	3,271,780	54	2,651,134	44	67,010	1	43,563	<1	2,458	<1	6,035,945
	2001	3,642,684	52	3,127,521	45	70,910	1	99,548	1	15,319	<1	6,955,982
	2002	4,924,958	53	3,943,387	43	147,065	2	187,724	2	26,903	<1	9,230,037
	2003	5,039,211	54	4,001,228	43	84,878	1	217,337	2	16,511	<1	9,359,165
	2004	5,302,386	54	3,996,380	41	94,732	1	290,407	3	54,862	<1	9,738,767
	2005	6,147,268	63	3,266,014	34	49,485	<1	184,254	2	53,468	<1	9,700,489
	2006	8,109,458	73	2,720,254	24	62,854	<1	163,265	1	48,107	<1	11,103,938
	2007	5,757,872	59	3,618,618	37	62,815	<1	218,924	2	25,935	<1	9,684,164
	2008	5,010,725	60	3,044,071	37	47,934	<1	186,339	2	40,809	<1	8,329,878
	2009	5,888,054	64	2,862,756	31	87,319	1	228,733	3	70,030	1	9,136,892
	2010	6,605,945	68	2,824,143	29	83,725	1	137,629	1	37,730	<1	9,689,172
	2011	6,370,473	66	2,832,636	29	145,960	2	190,273	2	80,848	1	9,620,190

*processor weight (quota debit weight) to 2001; fisher/observer weight from 2002 to 2011 (negating ice allowance).

Table 1.2. Harvest, effort and harvest per unit effort summaries for Lake Erie yellow perch fisheries in Management Unit 1 (Western Basin) by agency and gear type, 2000-2011.

		Unit 1				
		Michigan	Ohio		Ontario Gill Nets*	
	Year	Sport	Trap Nets	Sport	Small Mesh	Large Mesh**
Harvest (pounds)	2000	67,010	240,541	798,109	980,323	--
	2001	70,910	179,234	736,407	711,745	101,321
	2002	147,065	337,829	978,724	1,359,637	94,468
	2003	84,879	250,456	1,155,929	1,151,358	28,309
	2004	94,732	289,136	801,533	1,637,488	61,273
	2005	49,485	357,182	608,049	1,402,523	111,082
	2006	62,854	235,852	819,526	1,264,370	61,094
	2007	62,815	200,818	781,859	671,536	56,142
	2008	47,934	0	409,705	484,409	49,378
	2009	87,319	0	463,564	728,012	125,024
	2010	83,725	195,674	693,838	815,170	64,188
	2011	145,960	156,138	640,309	792,336	78,363
Harvest (Metric) (tonnes)	2000	30	109	362	445	--
	2001	32	81	334	323	46
	2002	67	153	444	617	43
	2003	38	114	524	522	13
	2004	43	131	364	743	28
	2005	22	162	276	636	50
	2006	29	107	372	573	28
	2007	28	91	355	305	25
	2008	22	0	186	220	22
	2009	40	0	210	330	57
	2010	38	89	315	370	29
	2011	66	71	290	359	36
Effort *(a)*	2000	122,447	4,026	965,628	6,741	--
	2001	97,761	1,518	720,923	2,167	2,142
	2002	190,573	2,715	900,289	4,546	739
	2003	121,638	2,213	1,182,694	3,725	395
	2004	206,902	4,351	833,690	6,052	901
	2005	98,429	3,903	816,959	5,170	1,182
	2006	118,628	3,517	683,994	5,194	787
	2007	181,698	2,951	823,624	2,230	1,125
	2008	95,925	0	519,050	1,653	899
	2009	130,556	0	578,303	3,058	1,680
	2010	132,852	2,607	798,240	3,152	845
	2011	139,344	3,219	729,369	2,571	682
Harvest Rates *(b)*	2000	2.2	27.1	3.0	66.0	--
	2001	2.9	53.5	3.4	149.0	21.5
	2002	2.5	56.4	3.4	135.6	58.0
	2003	2.4	51.3	3.5	140.2	32.5
	2004	1.6	30.1	3.0	122.7	30.8
	2005	1.7	41.5	3.1	123.0	42.6
	2006	1.7	30.4	4.2	110.4	35.2
	2007	1.0	30.9	3.4	136.6	22.6
	2008	1.5	--	2.7	132.9	24.9
	2009	2.7	--	3.1	108.0	33.8
	2010	2.3	34.0	3.4	117.3	34.4
	2011	3.4	22.0	3.5	139.8	52.1

(a) sport effort in angler-hours; gill net effort in km; trap net effort in lifts
(b) harvest rates for sport in fish/hr, gill net in kg/km, trap net in kg/lift
(*) Ontario commercial trap netters harvested 46,263 pounds of yellow perch in MU1 in 2008.
(*) Ontario commercial trap netters harvested 70 pounds of yellow perch in MU1 in 2009.
(*) Ontario commercial trap netters harvested 103 pounds of yellow perch in MU1 in 2011.
(**) Large mesh catch rates are not targeted and therefore of limited value

Table 1.3. Harvest, effort and harvest per unit effort summaries for Lake Erie yellow perch fisheries in Management Unit 2 (western Central Basin) by agency and gear type, 2000-2011.

		Unit 2			
		Ohio		Ontario* Gill Nets	
	Year	Trap Nets	Sport	Small Mesh	Large Mesh**
Harvest	2000	565,009	604,225	1,484,125	--
(pounds)	2001	905,088	841,891	1,593,704	200,571
	2002	1,099,971	886,759	1,892,070	298,551
	2003	1,255,205	858,080	2,019,617	88,022
	2004	1,287,747	958,517	1,893,871	157,602
	2005	1,162,746	680,444	2,446,007	219,723
	2006	744,452	649,280	2,981,793	120,476
	2007	1,701,552	543,104	1,561,287	173,699
	2008	1,376,588	628,412	1,669,682	253,984
	2009	1,338,616	463,362	1,994,208	482,402
	2010	935,616	522,207	1,410,051	470,926
	2011	1,070,817	328,686	1,312,168	339,404
Harvest	2000	256	274	673	--
(Metric)	2001	410	382	723	91
(tonnes)	2002	499	402	858	135
	2003	569	389	916	40
	2004	584	435	859	71
	2005	527	309	1,109	100
	2006	338	294	1,352	55
	2007	772	246	708	79
	2008	624	285	757	115
	2009	607	210	904	219
	2010	424	237	639	214
	2011	486	149	595	154
Effort	2000	5,272	601,712	6,266	--
(a)	2001	4,747	594,741	3,445	4,975
	2002	7,675	658,799	4,786	3,209
	2003	10,214	632,813	5,311	1,555
	2004	12,023	659,454	4,929	2,787
	2005	9,103	784,942	9,716	2,173
	2006	7,544	499,412	11,692	1,925
	2007	9,158	498,843	2,966	2,826
	2008	3,983	450,060	3,124	2,629
	2009	6,317	417,660	5,545	4,241
	2010	6,701	502,507	3,783	3,905
	2011	5,707	395,407	4,214	3,789
Harvest Rates	2000	48.6	2.9	107.4	--
(b)	2001	86.5	3.2	209.9	18.3
	2002	65.0	3.1	179.3	42.1
	2003	55.7	3.3	172.5	25.7
	2004	48.6	3.7	174.3	25.6
	2005	57.9	2.8	114.2	45.9
	2006	44.8	3.7	115.7	28.4
	2007	84.3	2.8	238.7	27.9
	2008	156.7	3.5	242.4	43.8
	2009	96.1	3.0	163.1	51.6
	2010	63.3	3.2	169.0	54.7
	2011	85.1	2.6	141.2	40.6

(a) sport effort in angler-hours; gill net effort in km; trap net effort in lifts
(b) harvest rates for sport in fish/hr, gill net in kg/km, trap net in kg/lift
(*) Ontario commercial trawlers harvested 112,153 pounds of yellow perch in MU2 in 2007.
(*) Ontario commercial trawlers harvested 66,203 pounds of yellow perch in MU2 in 2008.
(*) Ontario commercial trawlers harvested 15,439 pounds of yellow perch in MU2 in 2009.
(*) Ontario commercial trawlers harvested 7,899 pounds of yellow perch in MU2 in 2010.
(*) Ontario commercial trawlers harvested 13,686 pounds of yellow perch in MU2 in 2011.
(**) Large mesh catch rates are not targeted and therefore of limited value

Table 1.4. Harvest, effort and harvest per unit effort summaries for Lake Erie yellow perch fisheries in Management Unit 3 (eastern Central Basin) by agency and gear type, 2000-2011.

		Unit 3					
		Ohio		Ontario* Gill Nets		Pennsylvania	
	Year	Trap Nets	Sport	Small Mesh	Large Mesh**	Trap Nets	Sport
Harvest (pounds)	2000	156,510	286,740	771,646	--	5,930	26,683
	2001	4,472	460,339	948,622	50,828	2,602	96,946
	2002	0	640,104	1,094,894	97,797	2,009	138,812
	2003	0	481,559	1,647,047	20,086	5,050	172,467
	2004	0	659,447	1,443,314	10,105	7,753	236,310
	2005	43,253	414,340	1,657,498	113,969	15,228	126,800
	2006	70,310	200,834	3,332,037	119,461	20,467	85,793
	2007	48,286	342,999	2,941,451	42,570	23,471	169,594
	2008	139,023	490,343	2,160,041	32,673	22,927	132,087
	2009	112,030	485,184	2,180,834	77,858	35,296	155,446
	2010	153,097	323,711	3,065,336	302,410	36,026	104,224
	2011	327,871	308,815	2,911,506	451,628	1,542	151,691
Harvest (Metric) (tonnes)	2000	71	130	350	--	2.7	12
	2001	2.0	209	430	23	1.2	44
	2002	0	290	497	44	0.9	63
	2003	0	218	747	9.1	2.3	78
	2004	0	299	655	4.6	3.5	107
	2005	20	188	752	52	6.9	58
	2006	32	91	1,511	54	9.3	39
	2007	22	156	1,334	19	10.6	77
	2008	63	222	980	15	10.4	60
	2009	51	220	989	35	16.0	70
	2010	69	147	1,390	137	16.3	47
	2011	149	140	1,320	205	0.7	69
Effort *(a)*	2000	1,640	214,825	2,342	--	231	48,561
	2001	32	269,062	2,451	1,047	175	90,214
	2002	0	416,543	2,490	1,055	95	123,287
	2003	0	256,890	4,617	316	87	138,720
	2004	0	368,537	3,750	268	70	175,596
	2005	947	305,885	5,098	743	129	127,462
	2006	881	139,536	11,130	1,030	124	60,612
	2007	713	218,683	6,115	614	88	135,611
	2008	1,288	234,179	3,336	417	78	110,403
	2009	482	289,602	4,050	728	121	139,438
	2010	972	182,485	5,747	1,125	128	85,294
	2011	1,108	182,630	6,093	1,481	37	94,025
Harvest Rates *(b)*	2000	43.3	3.0	149.4	--	11.6	1.9
	2001	63.4	2.9	175.4	22.0	6.7	2.6
	2002	--	2.7	199.6	41.7	9.6	3.6
	2003	--	3.1	161.8	28.8	26.3	5.3
	2004	--	4.3	174.6	17.1	50.2	3.9
	2005	20.7	3.1	147.4	69.6	53.5	2.9
	2006	36.2	3.3	135.8	52.6	74.9	3.7
	2007	30.7	3.4	218.2	31.4	121.0	3.8
	2008	49.0	4.6	293.6	35.5	133.3	4.5
	2009	105.4	3.5	244.2	48.5	132.3	4.8
	2010	71.4	4.0	241.9	121.9	127.6	4.0
	2011	134.2	4.1	216.7	138.3	18.9	5.3

(a) sport effort in angler-hours; gill net effort in km; trap net effort in lifts

(b) harvest rates for sport in fish/hr, gill net in kg/km, trap net in kg/lift

(*) Ontario commercial trawlers harvested 13,080 pounds of yellow perch in MU3 in 2007.

(*) Ontario commercial trawlers harvested 7,454 pounds of yellow perch in MU3 in 2008.

(*) Ontario commercial trawlers harvested 8,035 pounds of yellow perch in MU3 in 2009.

(*) Ontario commercial trawlers harvested 2,353 pounds of yellow perch in MU3 in 2010.

(*) Ontario commercial trawlers harvested 3,278 pounds of yellow perch in MU3 in 2011.

(**) Large mesh catch rates are not targeted and therefore of limited value

Table 1.5. Harvest, effort and harvest per unit effort summaries for Lake Erie yellow perch fisheries in Management Unit 4 (Eastern Basin) by agency and gear type, 2000-2011.

		Unit 4					
		New York		Ontario* Gill Nets		Pennsylvania	
	Year	Trap Nets	Sport	Small Mesh	Large Mesh**	Trap Nets	Sport
Harvest	2000	625	1,833	35,686	--	0	10,950
(pounds)	2001	27	15,292	34,284	1,608	0	8,337
	2002	1,951	24,952	85,935	1,606	29	46,874
	2003	1,048	15,464	84,648	124	0	39,822
	2004	3,907	50,955	98,716	17	0	90,514
	2005	7,726	45,742	195,258	52	0	42,226
	2006	9,423	38,684	229,063	1,163	0	57,005
	2007	9,511	16,424	179,595	3,076	0	25,859
	2008	11,136	29,673	234,366	2,689	0	31,325
	2009	13,476	56,554	266,425	4,738	0	37,991
	2010	11,772	25,958	465,775	1,517	0	26,263
	2011	15,045	65,803	464,331	2,761	0	37,040
Harvest	2000	0.3	0.8	16.2	--	0	5.0
(Metric)	2001	0.01	6.9	15.5	0.73	0	3.8
(tonnes)	2002	0.9	11.3	39.0	0.70	0.01	21.3
	2003	0.5	7.0	38.4	0.06	0	18.1
	2004	1.8	23.1	44.8	0.01	0	41.0
	2005	3.5	20.7	88.6	0.02	0	19.2
	2006	4.3	17.5	103.9	0.53	0	25.9
	2007	4.3	7.4	81.4	1.40	0	11.7
	2008	5.1	13.5	106.3	1.22	0	14.2
	2009	6.1	25.6	120.8	2.15	0	17.2
	2010	5.3	11.8	211.2	0.69	0	11.9
	2011	6.8	29.8	210.6	1.25	0	16.8
Effort	2000	44	2,606	314	--	0	21,146
(a)	2001	39	22,950	128	28.0	0	12,451
	2002	89	44,270	224	28.0	9	61,734
	2003	91	33,162	373	21.0	0	32,525
	2004	44	73,056	355	3.2	0	62,639
	2005	179	58,667	782	7.8	0	70,921
	2006	208	46,174	1,007	31.8	0	47,274
	2007	144	29,999	550	62.1	0	31,545
	2008	137	34,511	569	69.2	0	27,041
	2009	215	58,829	718	50.9	0	58,475
	2010	287	35,526	1,227	21.7	0	26,544
	2011	383	50,479	1,564	28.6	0	48,537
Harvest Rates	2000	6.4	0.20	51.5	--	--	1.7
(b)	2001	0.3	1.65	121.5	26.0	--	1.5
	2002	9.9	1.13	174.0	25.0	1.5	2.4
	2003	5.2	0.76	102.9	2.9	--	1.9
	2004	40.3	1.14	126.1	2.4	--	1.7
	2005	19.6	1.23	113.2	3.0	--	1.8
	2006	20.5	1.36	103.2	16.6	--	2.9
	2007	30.0	0.97	148.1	22.5	--	1.5
	2008	36.9	1.68	186.8	17.6	--	6.4
	2009	28.4	1.77	168.3	42.2	--	3.2
	2010	18.6	1.31	172.1	31.7	--	2.2
	2011	17.8	2.01	134.6	43.8	--	2.9

(a) sport effort in angler-hours; gill net effort in km; trap net effort in lifts
(b) harvest rates for sport in fish/hr, gill net in kg/km, trap net in kg/lift
(*) Ontario commercial trawlers harvested 3,283 pounds of yellow perch in MU4 in 2007.
(*) Ontario commercial trawlers harvested 3,215 pounds of yellow perch in MU4 in 2008.
(*) Ontario commercial trawlers harvested 1,416 pounds of yellow perch in MU4 in 2009.
(*) Ontario commercial trawlers harvested 320 pounds of yellow perch in MU4 in 2010.
(*) Ontario commercial trawlers harvested 909 pounds of yellow perch in MU4 in 2011.
(**) Large mesh catch rates are not targeted and therefore of limited value

Table 1.6. Estimated 2011 Lake Erie yellow perch harvest by age and numbers of fish by gear and management unit (Unit).

		Unit 1		**Unit 2**		**Unit 3**		**Unit 4**		**Lakewide**	
Gear	Age	Number	%	Number	%	Number	%	Number	%	Number	%
Gill Nets	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	2	24,918	0.8	16,819	0.3	0	0.0	1,650	0.1	43,386	0.2
	3	1,108,500	37.2	1,208,762	23.4	327,378	3.6	337,721	29.6	2,982,360	16.2
	4	1,289,358	43.3	2,391,354	46.4	2,021,496	22.0	469,363	41.1	6,171,572	33.4
	5	402,245	13.5	916,540	17.8	3,367,828	36.6	198,124	17.3	4,884,737	26.5
	6+	151,624	5.1	621,609	12.1	3,473,286	37.8	135,258	11.8	4,381,777	23.7
	Total	2,976,645	*45.9*	5,155,083	*56.0*	9,189,987	*81.6*	1,142,117	*81.6*	18,463,832	*65.1*
Trap Nets	1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	2	986	0.2	5,358	0.2	0	0.0	0	0.0	6,344	0.1
	3	67,330	13.6	410,725	13.6	114,033	13.5	2,233	6.0	594,321	13.5
	4	251,446	50.8	1,539,751	50.8	389,668	46.3	10,423	28.0	2,191,288	49.8
	5	86,312	17.4	528,321	17.4	172,125	20.4	8,438	22.7	795,196	18.1
	6+	88,645	17.9	546,719	18.0	165,902	19.7	16,131	43.3	817,397	18.6
	Total	494,719	*7.6*	3,030,874	*32.9*	841,728	*7.5*	37,225	*2.7*	4,404,546	*15.5*
Sport	1	11,518	0.4	0	0.0	3,048	0.2	744	0.3	15,310	0.3
	2	311,336	10.3	6,743	0.7	17,613	1.4	3,618	1.6	339,310	6.2
	3	1,191,127	39.6	335,833	32.9	309,581	25.0	56,902	25.7	1,893,443	34.5
	4	1,228,372	40.8	401,353	39.3	448,337	36.2	62,008	28.0	2,140,070	39.0
	5	169,212	5.6	164,608	16.1	209,862	17.0	49,128	22.2	592,810	10.8
	6+	97,882	3.3	113,628	11.1	248,682	20.1	48,740	22.0	508,932	9.3
	Total	3,009,447	*46.4*	1,022,165	*11.1*	1,237,123	*11.0*	221,140	*15.8*	5,489,875	*19.4*
All Gear	1	11,518	0.2	0	0.0	3,048	0.0	744	0.1	15,310	0.1
	2	337,240	5.2	28,920	0.3	17,613	0.2	5,268	0.4	389,040	1.4
	3	2,366,957	36.5	1,955,320	21.2	750,992	6.7	396,857	28.3	5,470,125	19.3
	4	2,769,176	42.7	4,332,458	47.1	2,859,501	25.4	541,795	38.7	10,502,930	37.0
	5	657,769	10.1	1,609,469	17.5	3,749,815	33.3	255,690	18.3	6,272,742	22.1
	6+	338,151	5.2	1,281,956	13.9	3,887,870	34.5	200,129	14.3	5,708,106	20.1
	Total	6,480,811	22.9	9,208,122	32.5	11,268,838	39.7	1,400,482	4.9	28,358,253	100.0

Note: Values in italics delineate harvest percentage by gear in each Unit, while the values in the 'All Gear' boxes are for lakewide harvest percentage by Unit.

Table 1.7. Yellow perch stock size (millions of fish) in each Lake Erie management unit. Abundance in the years 1990 to 2011 are estimated by ADMB catch-age analysis. The 2012 population estimates use age-2 yellow perch estimates derived from regressions of ADMB age-2 abundance values against YOY and yearling trawl index values

	Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Unit 1	2	3.967	10.310	15.465	3.806	9.305	23.214	29.065	22.518	43.775	10.390	33.995	33.457	7.747	40.635	3.209	52.716	1.559	8.997	9.733	22.513	9.815	7.249	10.051
	3	1.404	2.085	5.431	8.592	1.521	5.606	14.159	17.269	13.934	26.880	6.623	21.612	21.560	4.957	25.534	2.040	32.668	1.000	5.400	5.984	14.168	6.218	4.576
	4	5.248	0.525	0.636	1.906	2.183	0.640	2.488	6.064	7.946	6.909	14.613	3.618	12.729	11.097	2.709	11.803	1.003	12.912	0.536	2.791	3.027	7.165	3.134
	5	2.115	1.533	0.126	0.148	0.312	0.505	0.180	0.680	1.914	2.972	3.159	7.331	1.971	5.241	4.967	1.009	4.282	0.407	5.143	0.289	1.335	1.365	3.047
	6+	1.696	0.708	0.334	0.077	0.028	0.075	0.174	0.093	0.167	0.486	1.305	2.001	4.862	2.423	3.144	2.362	0.994	1.606	0.766	2.898	1.478	1.213	1.014
	2 and Older	14.431	15.162	21.993	14.529	13.348	30.039	46.064	46.623	67.737	47.638	59.696	68.020	48.869	64.353	39.562	69.929	40.506	24.922	21.579	34.475	29.823	23.210	21.823
	3 and Older	10.464	4.852	6.528	10.723	4.044	6.826	17.000	24.105	23.962	37.248	25.700	34.563	41.122	23.718	36.353	17.214	38.947	15.925	11.846	11.961	20.009	15.961	11.772
Unit 2	2	5.750	16.025	22.086	6.310	12.707	13.183	26.995	14.312	61.816	15.356	54.712	48.189	11.202	88.014	4.975	192.472	5.128	22.580	24.894	46.006	35.053	4.966	19.186
	3	1.348	2.424	6.723	10.580	3.004	7.272	7.339	13.119	7.445	32.826	9.489	32.943	28.540	7.050	53.104	3.238	123.773	3.375	14.685	16.405	29.699	22.632	3.243
	4	8.204	0.506	0.830	2.391	4.050	1.059	2.664	2.894	4.258	3.190	18.218	5.213	18.615	15.246	3.947	28.067	1.869	69.963	2.002	8.863	9.569	17.266	13.482
	5	2.719	2.237	0.114	0.220	0.676	0.817	0.208	0.575	0.511	0.900	1.557	8.701	2.531	8.411	6.428	1.885	12.368	1.099	33.078	1.046	4.206	4.852	8.826
	6+	2.319	1.140	0.585	0.188	0.103	0.156	0.193	0.087	0.076	0.089	0.405	0.905	4.664	3.237	4.961	5.190	3.143	7.236	3.893	19.434	9.444	6.626	5.688
	2 and Older	20.339	22.332	30.338	19.690	20.540	22.488	37.398	30.987	74.107	52.360	84.381	95.952	65.553	121.958	73.415	230.851	146.280	104.253	78.552	91.754	87.971	56.343	50.426
	3 and Older	14.589	6.307	8.252	13.380	7.832	9.304	10.403	16.675	12.290	37.005	29.670	47.763	54.350	33.944	68.440	38.379	141.152	81.672	53.658	45.748	52.918	51.377	31.240
Unit 3	2	4.202	8.386	5.106	2.946	6.298	7.111	13.411	10.520	43.064	12.145	46.069	26.794	6.717	37.743	4.489	151.179	6.023	30.670	44.897	35.163	45.871	0.937	28.110
	3	1.765	2.531	3.614	2.293	1.469	3.622	4.399	8.532	6.648	27.929	7.889	29.809	17.173	4.315	24.477	2.944	100.405	3.992	19.275	29.857	23.491	30.365	0.626
	4	3.874	0.808	0.828	1.299	0.980	0.775	2.129	2.589	4.717	4.021	17.914	5.002	18.938	10.733	2.676	15.118	1.821	56.113	2.448	12.173	19.525	14.957	19.773
	5	1.230	1.283	0.295	0.244	0.432	0.314	0.390	1.075	1.314	2.641	2.520	10.858	3.096	11.295	6.266	1.566	8.685	0.997	31.945	1.471	7.581	11.584	9.209
	6+	4.731	1.697	0.689	0.306	0.187	0.220	0.274	0.331	0.659	1.019	2.237	2.849	8.413	6.892	10.622	9.833	6.599	6.818	4.391	21.842	14.469	12.737	14.695
	2 and Older	15.802	14.705	10.533	7.089	9.366	12.042	20.602	23.047	56.401	47.754	76.630	75.312	54.337	70.977	48.530	180.640	123.532	98.590	102.955	100.505	110.937	70.580	72.412
	3 and Older	11.600	6.318	5.427	4.143	3.069	4.931	7.191	12.527	13.338	35.609	30.561	48.518	47.620	33.234	44.041	29.461	117.509	67.920	58.059	65.343	65.066	69.643	44.302
Unit 4	2	0.604	0.396	0.086	0.263	0.159	1.422	0.864	0.394	4.595	1.834	14.788	3.573	2.425	8.221	1.523	11.751	1.009	9.596	10.655	9.391	13.860	0.832	9.479
	3	0.674	0.391	0.253	0.058	0.168	0.103	0.938	0.570	0.260	3.078	1.218	9.876	2.395	1.625	5.496	1.011	7.796	0.673	6.369	7.095	6.292	9.227	0.553
	4	0.958	0.342	0.178	0.163	0.027	0.084	0.061	0.556	0.337	0.172	1.973	0.805	6.597	1.587	1.066	3.569	0.641	4.723	0.439	4.155	4.684	4.045	5.802
	5	0.400	0.368	0.104	0.100	0.051	0.010	0.043	0.032	0.293	0.215	0.108	1.286	0.536	4.291	1.017	0.676	2.208	0.377	3.038	0.283	2.689	2.919	2.498
	6+	0.958	0.519	0.266	0.208	0.095	0.052	0.031	0.037	0.036	0.201	0.256	0.235	1.009	0.981	3.324	2.694	2.042	2.401	1.787	3.065	2.132	2.960	3.519
	2 and Older	3.594	2.017	0.888	0.791	0.499	1.671	1.936	1.589	5.522	5.499	18.342	15.775	12.962	16.705	12.426	19.700	13.696	17.770	22.288	23.990	29.657	19.982	21.850
	3 and Older	2.990	1.621	0.801	0.529	0.340	0.249	1.073	1.195	0.926	3.666	3.554	12.202	10.537	8.484	10.903	7.950	12.687	8.175	11.633	14.598	15.797	19.150	12.372

Table 1.8. Projection of the 2012 Lake Erie yellow perch population. Stock size estimates are derived from survival from ADMB 2011 abundance, and age 2 estimates for 2012 are derived from regressions of ADMB age-2 abundance against YOY and yearling survey indices (see Appendix A). Standard errors are produced from ADMB catch-age and regression analyses.

		2011 Parameters				Rate Functions					2012 Parameters				Stock Biomass			
		Stock Size (numbers)				Mortality Rates				Survival Rate		Stock Size (numbers)			3-yr Mean Weight in	millions kg		millions lbs.
	Age	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**(F)**	**(Z)**	**(A)**	**(u)**	**(S)**	**Age**	**Mean**	**Min.**	**Max.**	Pop'n. (kg)	**2011**	**2012**	**2012**
Unit 1	2	7.249	4.251	2.998	11.499	0.060	0.460	0.369	0.048	0.631	2	10.051	4.084	24.512	0.066	0.464	0.663	1.463
	3	6.218	2.633	3.585	8.851	0.285	0.685	0.496	0.206	0.504	3	4.576	1.893	7.259	0.111	0.616	0.508	1.120
	4	7.165	2.718	4.448	9.883	0.455	0.855	0.575	0.306	0.425	4	3.134	1.807	4.461	0.162	0.989	0.508	1.120
	5	1.365	0.529	0.836	1.894	0.474	0.874	0.583	0.316	0.417	5	3.047	1.892	4.203	0.198	0.202	0.603	1.330
	6+	1.213	0.466	0.747	1.679	0.604	1.004	0.634	0.381	0.366	6+	1.014	0.622	1.405	0.252	0.352	0.256	0.563
	Total	23.210		12.614	33.805	0.279	0.679	0.493	0.202	0.507	Total	21.823	10.298	41.842	0.116	2.622	2.538	5.596
	(3+)	15.961		9.616	22.306	0.397	0.797	0.549	0.273	0.451	(3+)	11.772	6.214	17.329	0.159	2.158	1.875	4.133
Unit 2	2	4.966	2.700	2.266	7.666	0.026	0.426	0.347	0.021	0.653	2	19.186	8.723	42.629	0.071	0.323	1.362	3.004
	3	22.632	8.983	13.649	31.615	0.118	0.518	0.404	0.092	0.596	3	3.243	1.480	5.007	0.121	2.467	0.392	0.865
	4	17.266	5.886	11.380	23.153	0.271	0.671	0.489	0.197	0.511	4	13.482	8.131	18.833	0.164	2.521	2.211	4.875
	5	4.852	1.586	3.267	6.438	0.268	0.668	0.487	0.195	0.513	5	8.826	5.817	11.836	0.202	0.806	1.783	3.931
	6+	6.626	2.258	4.368	8.884	0.328	0.728	0.517	0.233	0.483	6+	5.688	3.784	7.591	0.264	1.796	1.502	3.311
	Total	56.343		34.930	77.756	0.190	0.590	0.446	0.143	0.554	Total	50.426	27.936	85.895	0.144	7.912	7.250	15.987
	(3+)	51.377		32.664	70.090	0.207	0.607	0.455	0.155	0.545	(3+)	31.240	19.213	43.267	0.188	7.589	5.888	12.983
Unit 3	2	0.937	0.585	0.352	1.522	0.004	0.404	0.332	0.003	0.668	2	28.110	11.466	67.539	0.053	0.037	1.490	3.285
	3	30.365	14.072	16.293	44.437	0.029	0.429	0.349	0.024	0.651	3	0.626	0.235	1.016	0.102	3.006	0.064	0.141
	4	14.957	5.963	8.994	20.919	0.085	0.485	0.384	0.067	0.616	4	19.773	10.610	28.936	0.154	2.079	3.045	6.714
	5	11.584	4.302	7.283	15.886	0.096	0.496	0.391	0.076	0.609	5	9.209	5.538	12.880	0.200	1.946	1.842	4.061
	6+	12.737	4.272	8.464	17.009	0.111	0.511	0.400	0.087	0.600	6+	14.695	9.513	19.878	0.269	3.579	3.953	8.716
	Total	70.580		41.387	99.774	0.066	0.466	0.372	0.053	0.628	Total	72.412	37.361	130.249	0.144	10.647	10.393	22.917
	(3+)	69.643		41.034	98.251	0.067	0.467	0.373	0.053	0.627	(3+)	44.302	25.895	62.710	0.201	10.610	8.904	19.632
Unit 4	2	0.832	0.584	0.248	1.416	0.008	0.408	0.335	0.007	0.665	2	9.479	3.904	21.426	0.096	0.096	0.910	2.006
	3	9.227	5.210	4.018	14.437	0.064	0.464	0.371	0.051	0.629	3	0.553	0.165	0.941	0.165	1.523	0.091	0.201
	4	4.045	2.097	1.947	6.142	0.082	0.482	0.382	0.065	0.618	4	5.802	2.526	9.077	0.248	0.938	1.439	3.173
	5	2.919	1.468	1.451	4.387	0.111	0.511	0.400	0.087	0.600	5	2.498	1.203	3.793	0.288	0.797	0.719	1.586
	6+	2.960	1.455	1.505	4.415	0.115	0.515	0.402	0.090	0.598	6+	3.519	1.769	5.269	0.328	1.009	1.154	2.545
	Total	19.982		9.168	30.795	0.079	0.479	0.381	0.063	0.619	Total	21.850	9.567	40.507	0.197	4.363	4.314	9.512
	(3+)	19.150		8.920	29.380	0.083	0.483	0.383	0.066	0.617	(3+)	12.372	5.663	19.081	0.275	4.267	3.404	7.505

Table 2.1. Estimated harvest of Lake Erie yellow perch for 2012 using the proposed fishing policy and selectivity-at-age from combined fishing gears.

		2012							2012			3-yr Mean	2012 Harvest Range					
		Stock Size (numbers)			Exploitation Rate				Catch (millions of fish)			Weight in	Catch (millions of kg)			Catch (millions of lbs)		
	Age	**Mean**	**Min.**	**Max.**	**F**	**s(age)**	**F(age)**	**(u)**	**Mean**	**Min.**	**Max.**	Harvest (kg)	**Mean**	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**
Unit 1	2	10.051	4.084	24.512	0.670	0.140	0.094	0.074	0.744	0.302	1.815	0.098	0.073	0.030	0.178	0.161	0.065	0.392
	3	4.576	1.893	7.259	0.670	0.610	0.409	0.280	1.282	0.530	2.035	0.122	0.156	0.065	0.248	0.345	0.143	0.547
	4	3.134	1.807	4.461	0.670	0.782	0.524	0.342	1.072	0.618	1.526	0.144	0.154	0.089	0.220	0.340	0.196	0.484
	5	3.047	1.892	4.203	0.670	0.802	0.537	0.349	1.063	0.660	1.466	0.158	0.168	0.104	0.232	0.370	0.230	0.511
	6+	1.014	0.622	1.405	0.670	0.866	0.580	0.370	0.375	0.230	0.520	0.179	0.067	0.041	0.093	0.148	0.091	0.205
	Total	21.823	10.298	41.842				0.208	4.536	2.341	7.360	0.136	0.619	0.329	0.970	1.364	0.725	2.140
	(3+)	11.772	6.214	17.329				0.322	3.792	2.038	5.546	0.144	0.546	0.299	0.793	1.204	0.660	1.748
Unit 2	2	19.186	8.723	42.629	0.670	0.109	0.073	0.058	1.116	0.508	2.480	0.122	0.136	0.062	0.303	0.300	0.137	0.667
	3	3.243	1.480	5.007	0.670	0.395	0.265	0.193	0.627	0.286	0.968	0.141	0.088	0.040	0.136	0.195	0.089	0.301
	4	13.482	8.131	18.833	0.670	0.742	0.497	0.328	4.425	2.669	6.181	0.152	0.673	0.406	0.940	1.483	0.894	2.072
	5	8.826	5.817	11.836	0.670	0.791	0.530	0.345	3.045	2.007	4.084	0.162	0.493	0.325	0.662	1.088	0.717	1.459
	6+	5.688	3.784	7.591	0.670	0.838	0.561	0.361	2.052	1.365	2.738	0.190	0.390	0.259	0.520	0.859	0.572	1.147
	Total	50.426	27.936	85.895				0.223	11.265	6.834	16.451	0.158	1.780	1.092	2.560	3.926	2.409	5.646
	(3+)	31.240	19.213	43.267				0.325	10.149	6.327	13.971	0.162	1.644	1.030	2.258	3.625	2.272	4.978
Unit 3	2	28.110	11.466	67.539	0.700	0.037	0.026	0.021	0.593	0.242	1.424	0.106	0.063	0.026	0.151	0.139	0.057	0.333
	3	0.626	0.235	1.016	0.700	0.241	0.169	0.129	0.081	0.030	0.131	0.136	0.011	0.004	0.018	0.024	0.009	0.039
	4	19.773	10.610	28.936	0.700	0.693	0.485	0.322	6.365	3.415	9.314	0.155	0.987	0.529	1.444	2.175	1.167	3.183
	5	9.209	5.538	12.880	0.700	0.755	0.529	0.344	3.170	1.907	4.434	0.168	0.533	0.320	0.745	1.174	0.706	1.643
	6+	14.695	9.513	19.878	0.700	0.786	0.550	0.355	5.219	3.378	7.059	0.191	0.997	0.645	1.348	2.198	1.423	2.973
	Total	72.412	37.361	130.249				0.213	15.427	8.972	22.363	0.168	2.590	1.525	3.706	5.710	3.362	8.171
	(3+)	44.302	25.895	62.710				0.335	14.835	8.730	20.939	0.170	2.527	1.499	3.555	5.572	3.305	7.838
Unit 4	2	9.479	3.904	21.426	0.300	0.032	0.010	0.008	0.075	0.031	0.169	0.119	0.009	0.004	0.020	0.020	0.008	0.044
	3	0.553	0.165	0.941	0.300	0.327	0.098	0.077	0.043	0.013	0.073	0.161	0.007	0.002	0.012	0.015	0.005	0.026
	4	5.802	2.526	9.077	0.300	0.535	0.161	0.123	0.713	0.310	1.115	0.185	0.132	0.057	0.206	0.291	0.127	0.455
	5	2.498	1.203	3.793	0.300	0.774	0.232	0.172	0.430	0.207	0.653	0.208	0.089	0.043	0.136	0.197	0.095	0.299
	6+	3.519	1.769	5.269	0.300	0.782	0.235	0.174	0.611	0.307	0.915	0.233	0.142	0.072	0.213	0.314	0.158	0.470
	Total	21.850	9.567	40.507				0.086	1.871	0.868	2.925	0.203	0.379	0.178	0.587	0.837	0.392	1.295
	(3+)	12.372	5.663	19.081				0.145	1.797	0.837	2.756	0.206	0.371	0.174	0.567	0.817	0.384	1.250

Table 2.2. Lake Erie yellow perch fishing rates and the Recommended Allowable Harvest (RAH; in millions of lbs) for 2012 by Management Unit (Unit).

		Recommended Allowable Harvest (millions lbs.)		
Unit	**Fishing Rate**	**MIN**	**MEAN**	**MAX**
1	0.670	0.725	1.364	2.140
2	0.670	2.409	3.926	5.646
3	0.700	3.362	5.710	8.171
4	0.300	0.392	0.837	1.295
Total		6.888	11.837	17.251

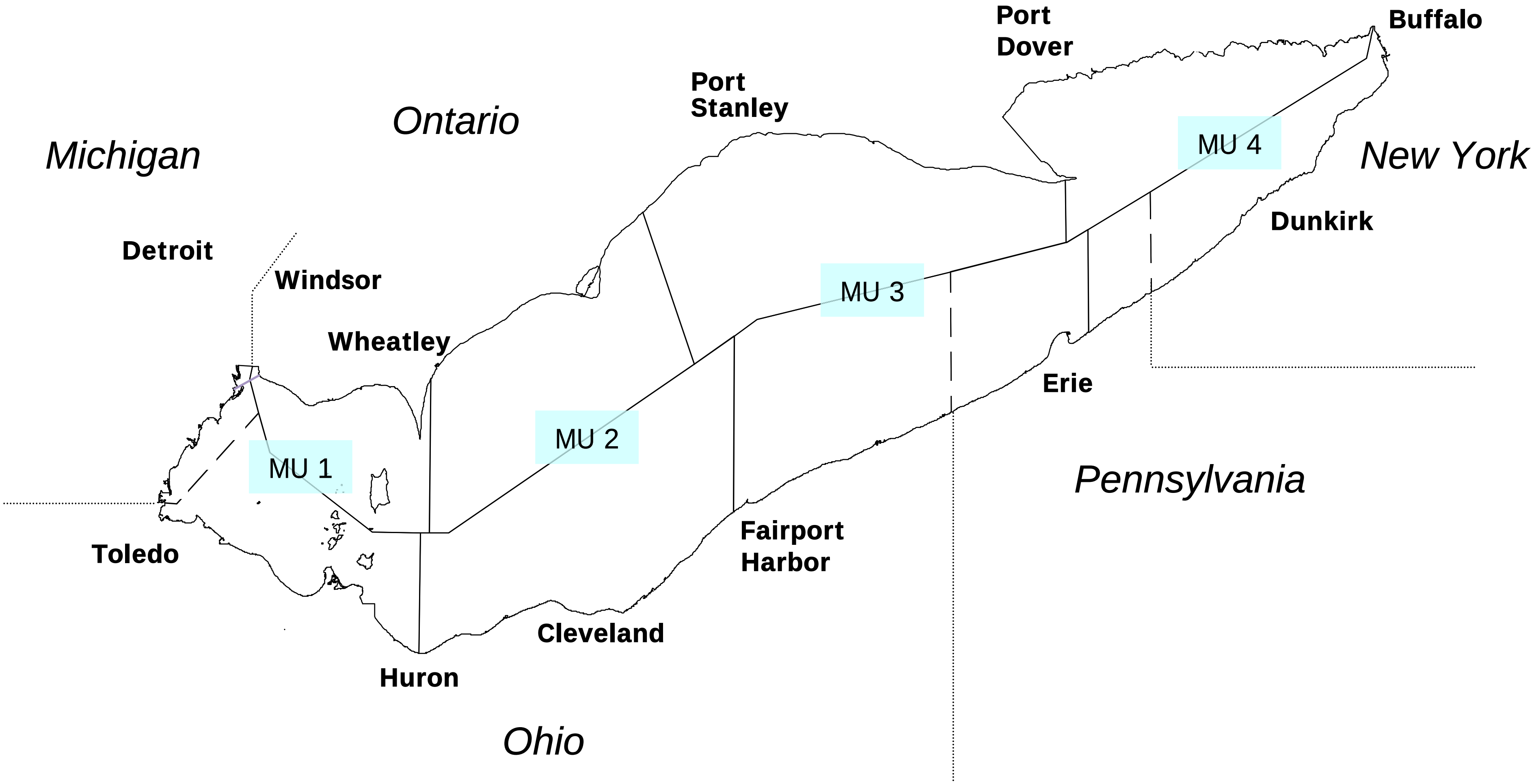


Figure 1.1. Yellow Perch Management Units (MUs) of Lake Erie. For illustrative purposes only, this map should not be used for quota determination or border delineation.

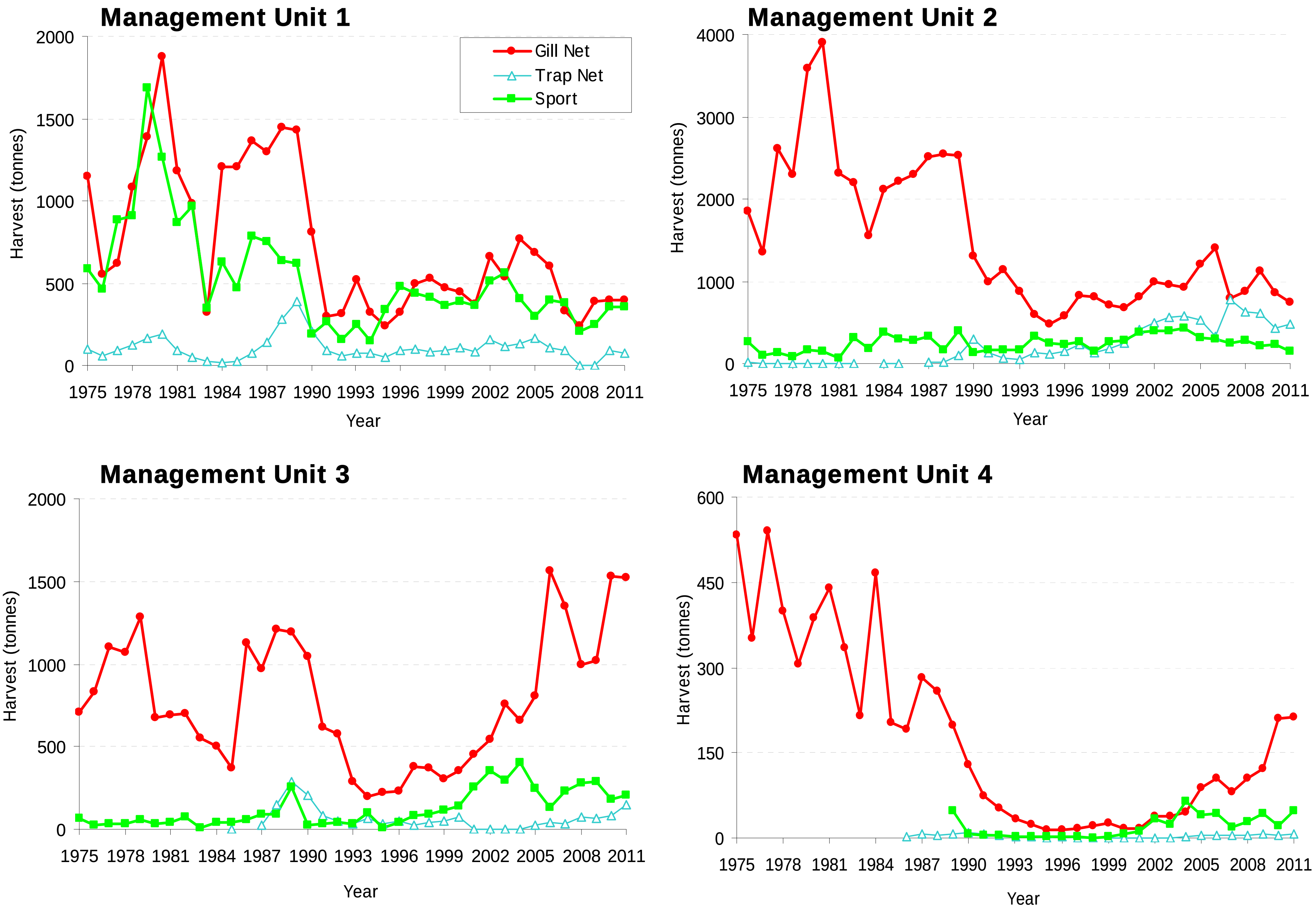


Figure 1.2. Lake Erie yellow perch harvest (metric tonnes) by management unit and gear type.

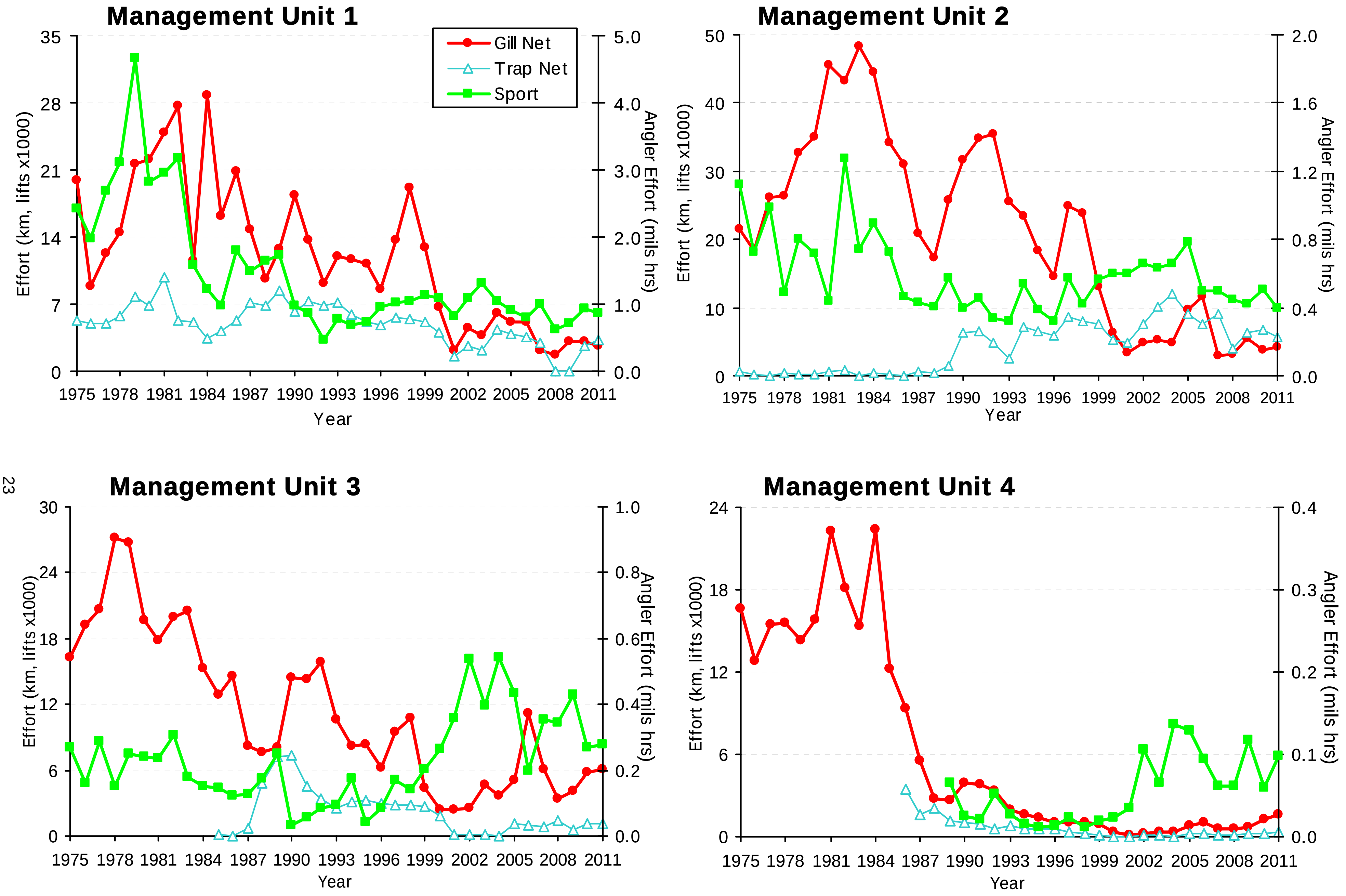


Figure 1.3. Lake Erie yellow perch effort by management unit and gear type. Note: gill net effort presented is targeted effort with small mesh (< 3”) only.

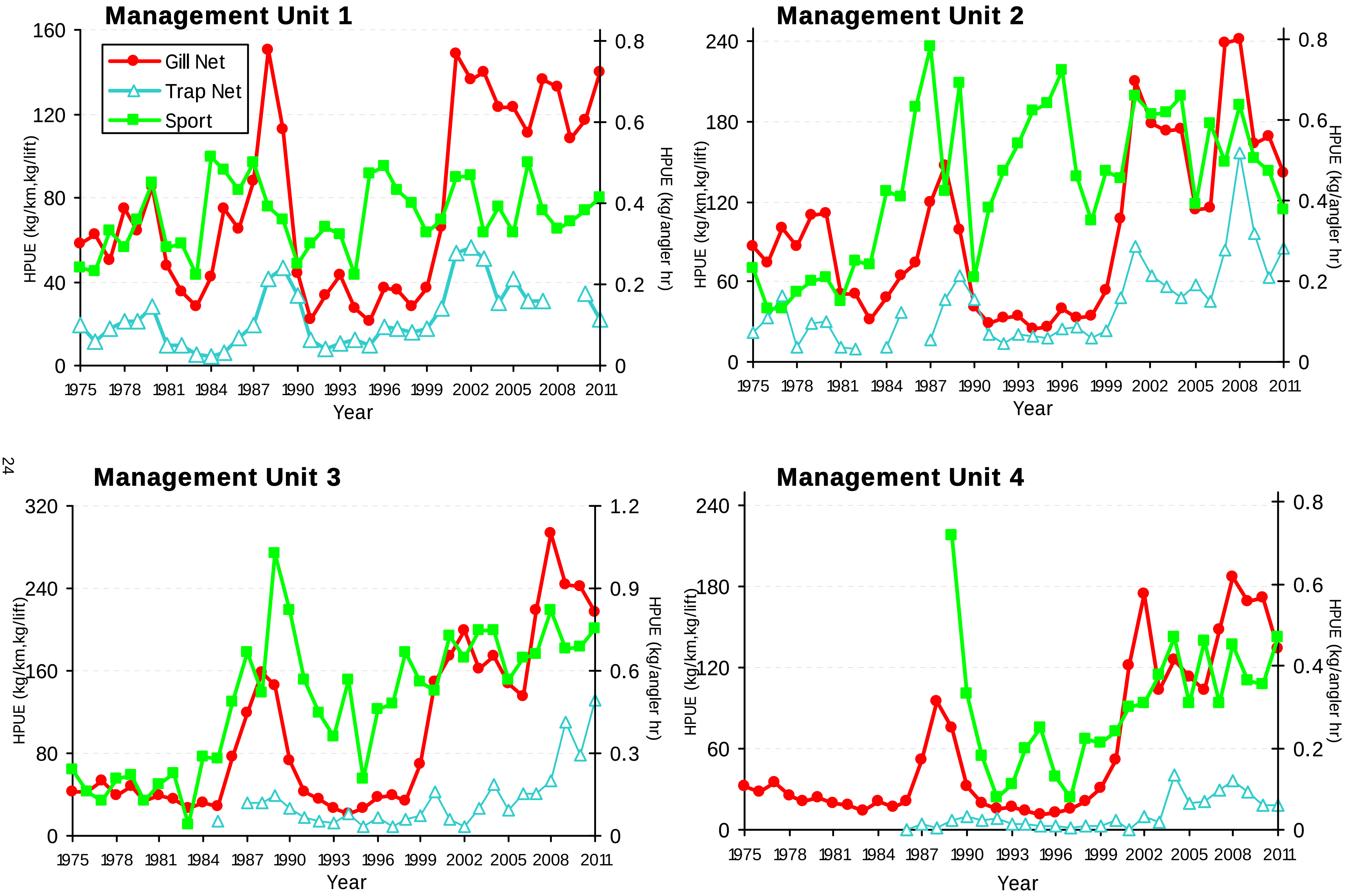


Figure 1.4. Lake Erie yellow perch harvest per unit effort (HPUE) by management unit and gear type. Note: 2001 to 2011 gill net CPUE is for small mesh (< 3") only.

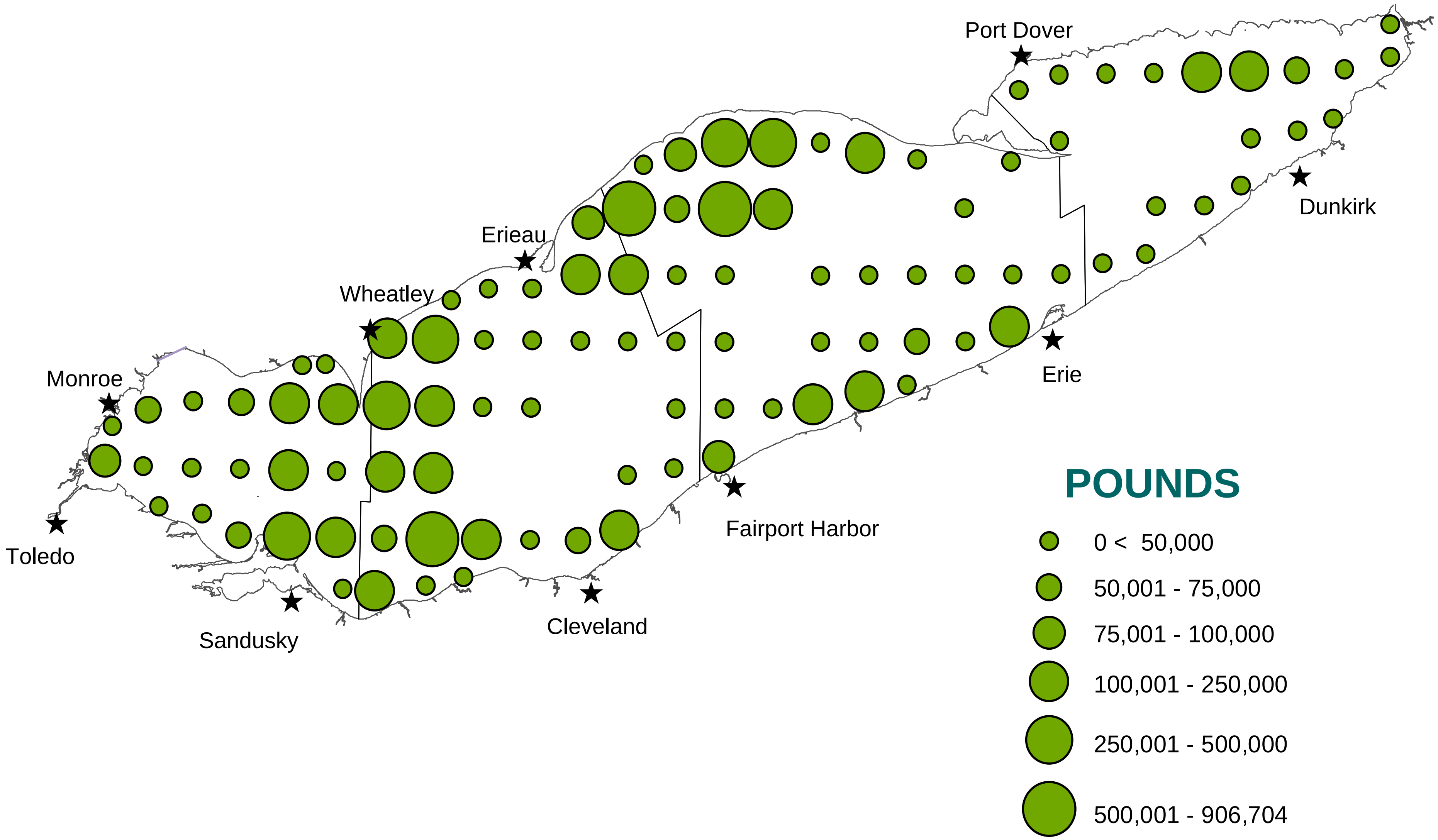


Figure 1.5. Spatial distribution of yellow perch total harvest (lbs.) in 2011 by 10-minute grid.

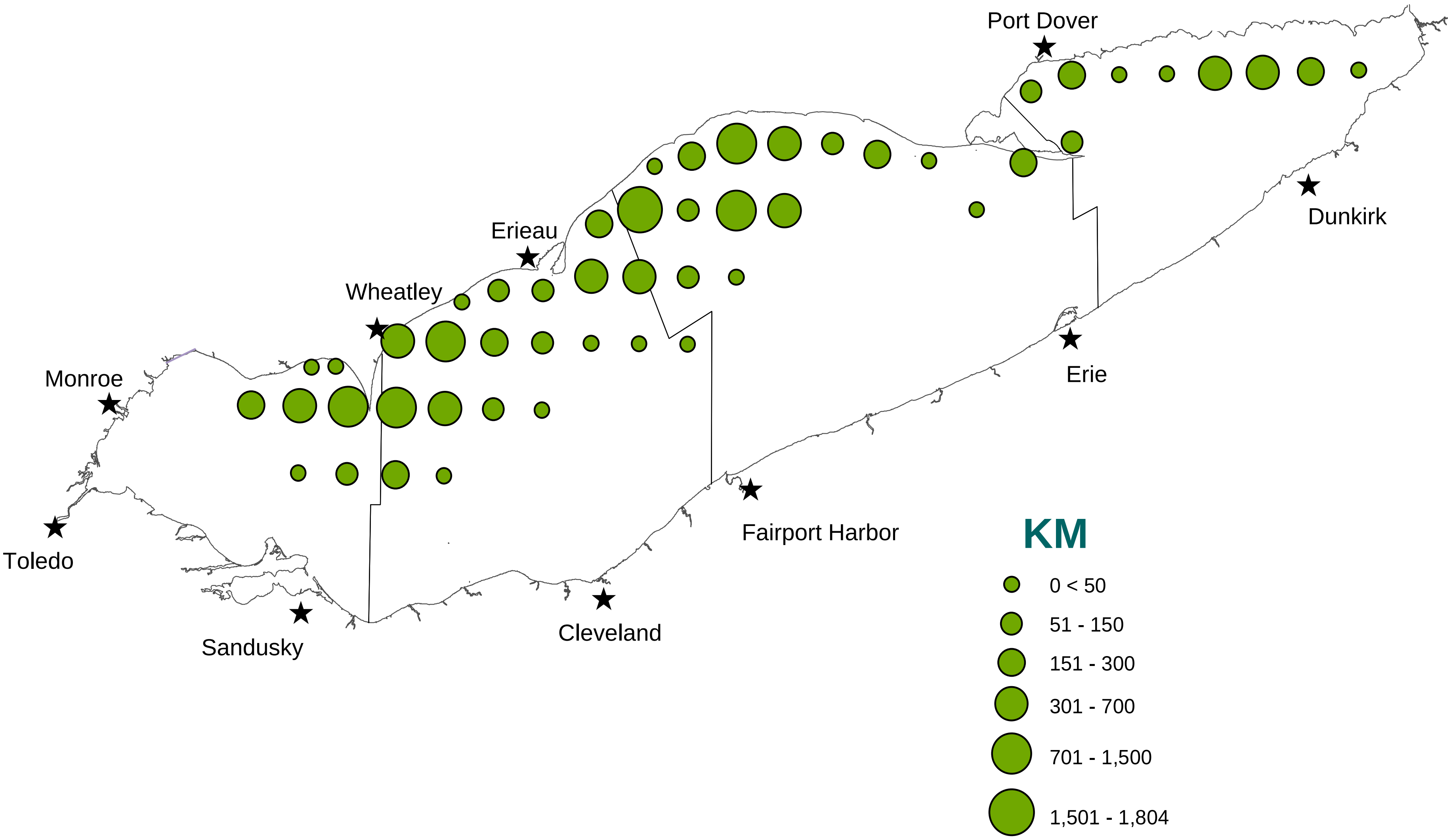


Figure 1.6. Spatial distribution of yellow perch gill net effort (km) in 2011 by 10-minute grid.

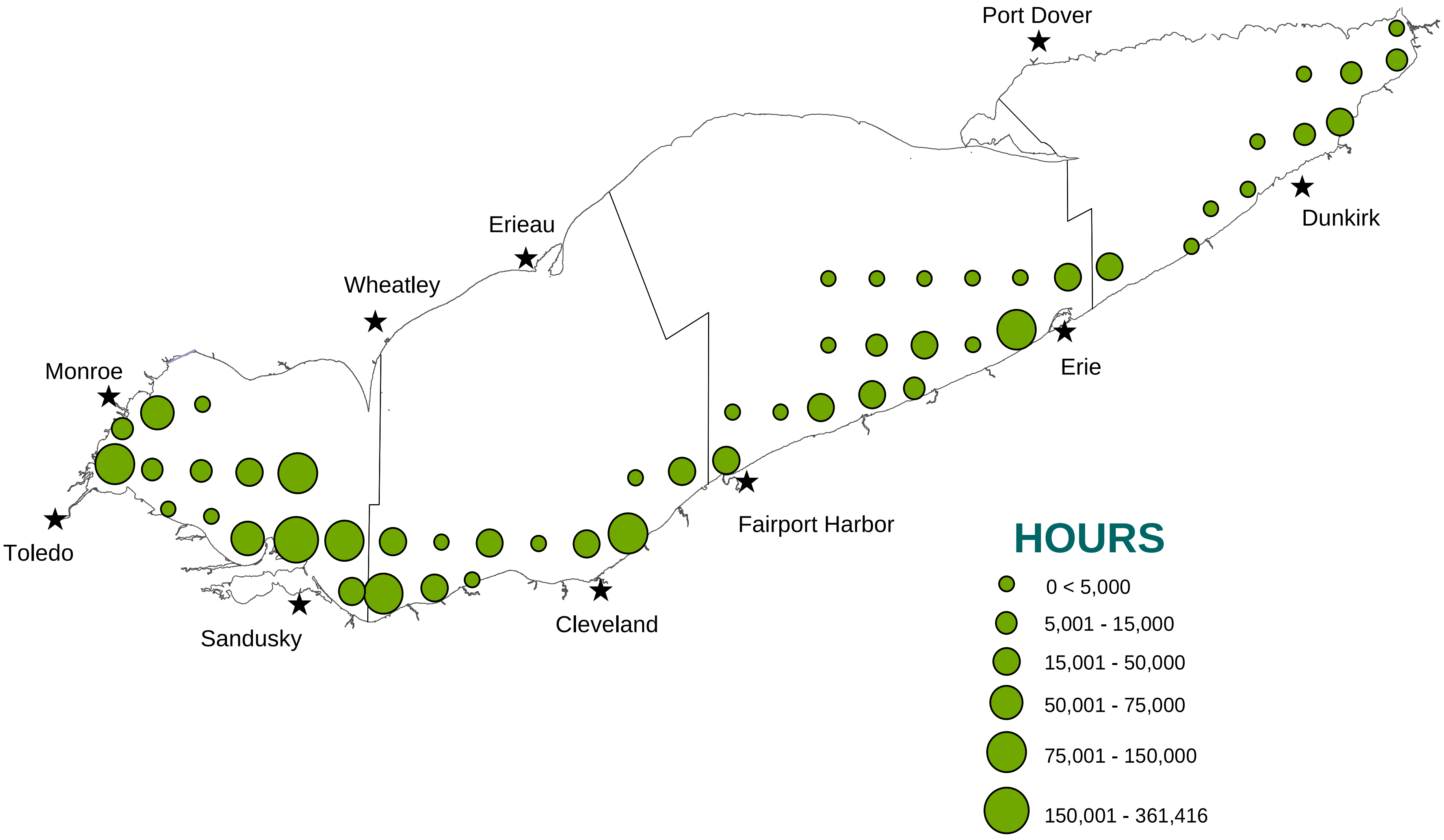


Figure 1.7. Spatial distribution of yellow perch sport angling effort (angler hours) in 2011 by 10-minute grid.

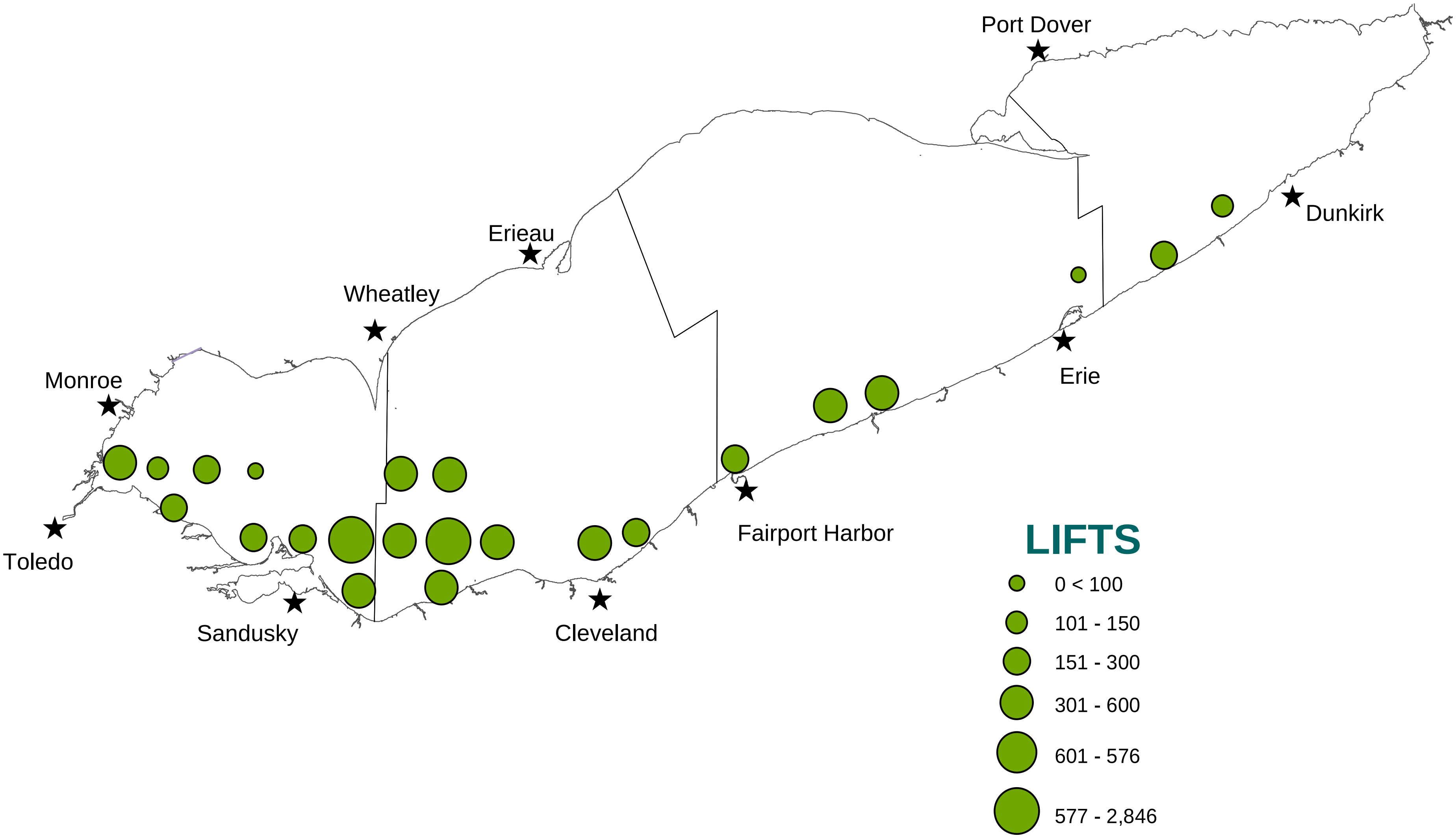


Figure 1.8. Spatial distribution of yellow perch trap net effort (lifts) in 2011 by 10-minute grid.

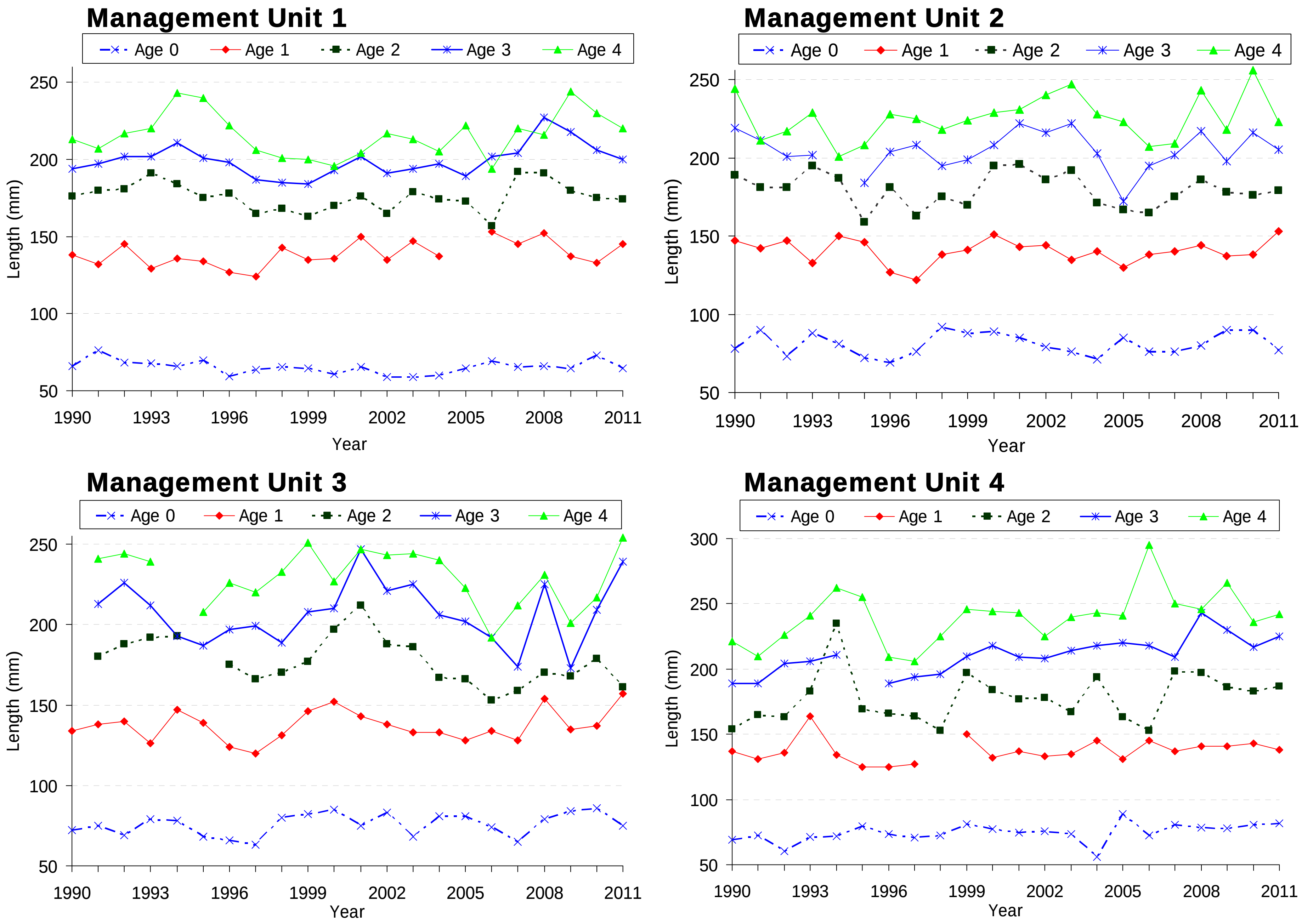


Figure 1.9. Yellow perch total length-at-age from 1990-2011 fall interagency experimental samples for ages 0-4 by management unit (MU).

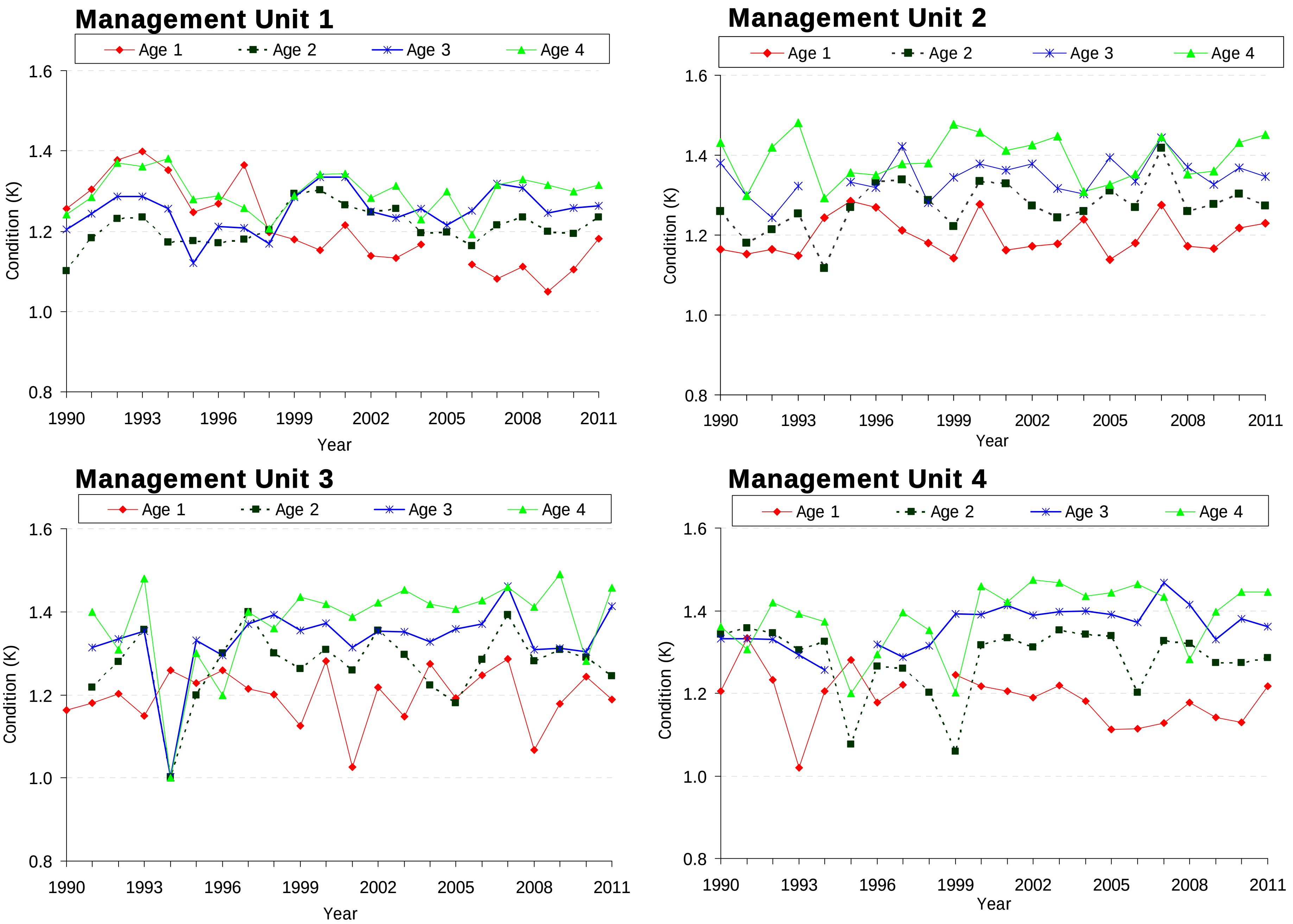


Figure 1.10. Yellow perch condition (K) at age from 1990-2011 fall interagency experimental samples for ages 1-4 by management unit (MU).

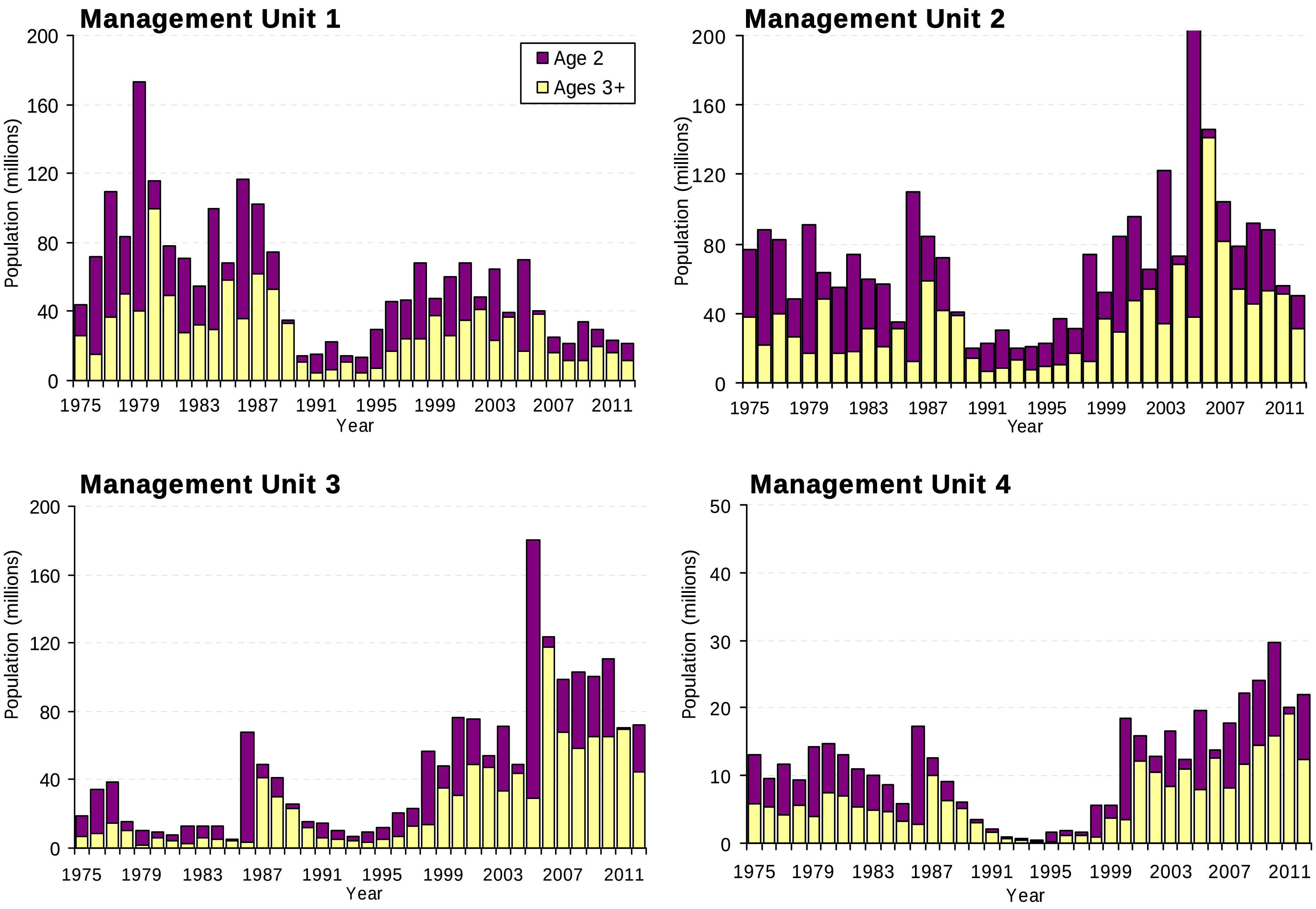


Figure 1.11. Lake Erie yellow perch population estimates by management unit for age 2 (dark bars) and ages 3+ (light bars). Estimates for 2012 are from ADMB and regressions for age 2 from survey gears.

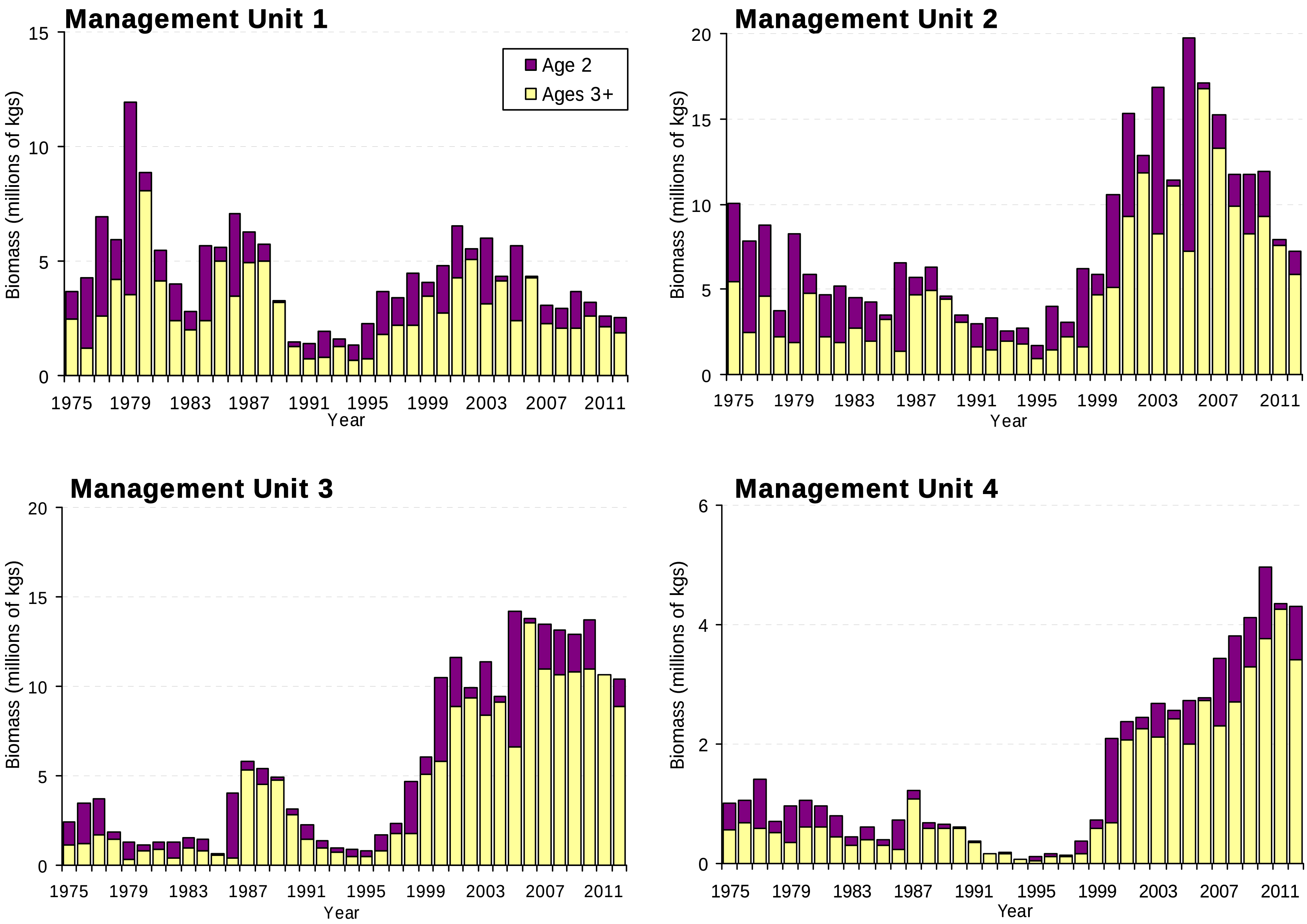


Figure 1.12. Lake Erie yellow perch biomass estimates by management unit for age 2 (dark bars) and ages 3+ (light bars). Estimates for 2012 are from ADMB and regressions for age 2 from survey gears.

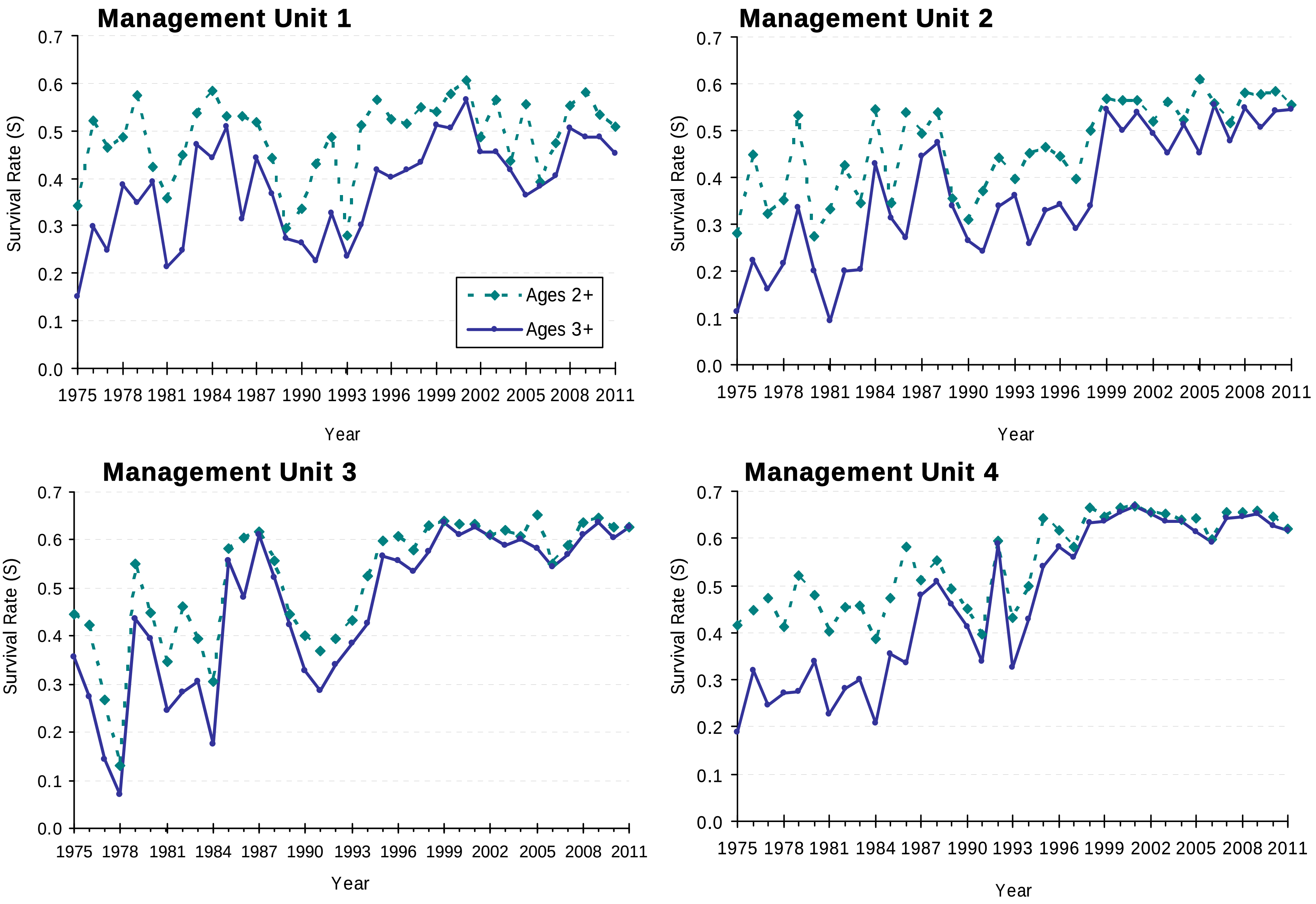


Figure 1.13. Lake Erie yellow perch survival rates by management unit for ages 2+ (dashed line) and ages 3+ (solid line). Estimates are derived from ADMB.

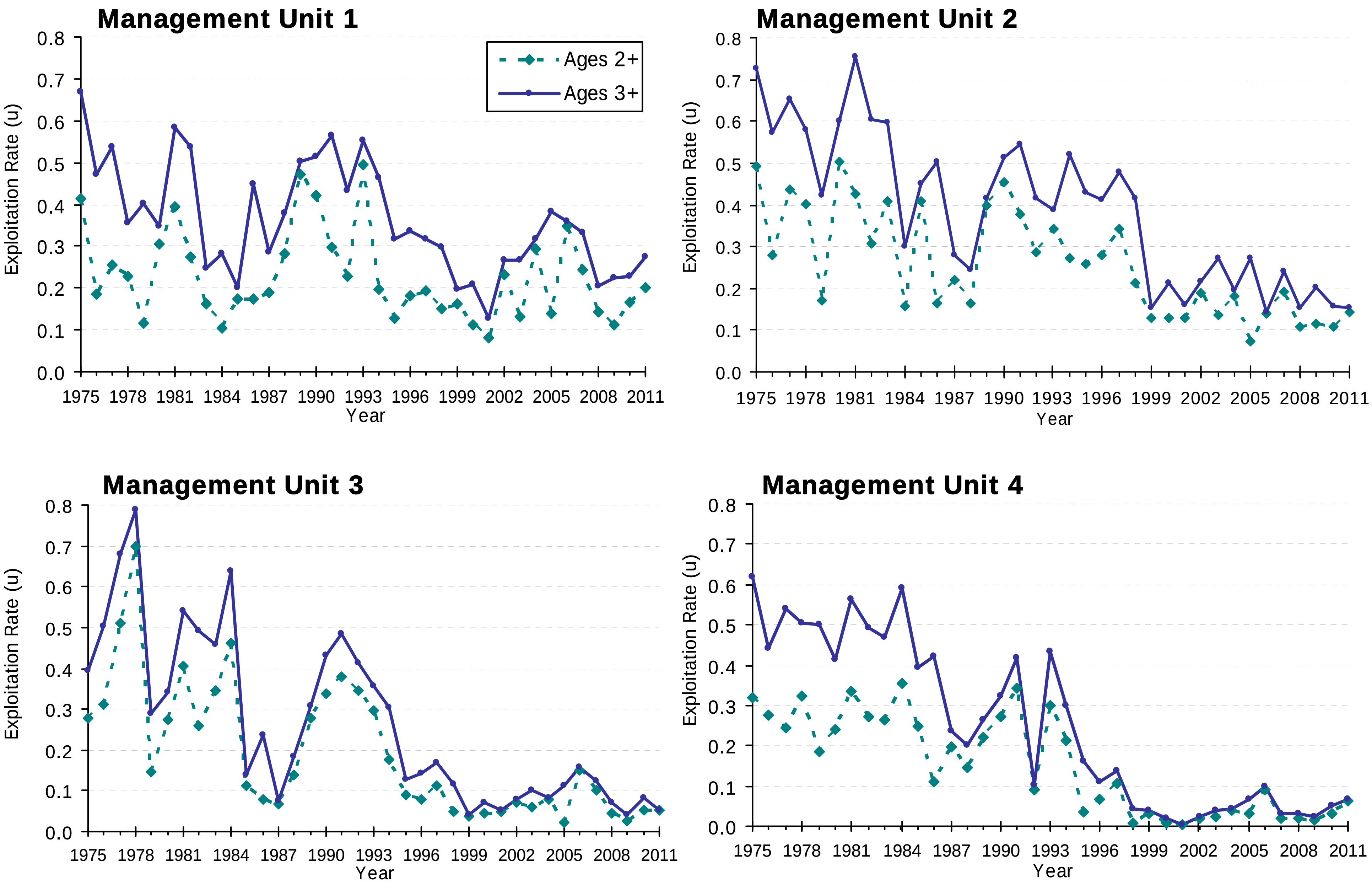
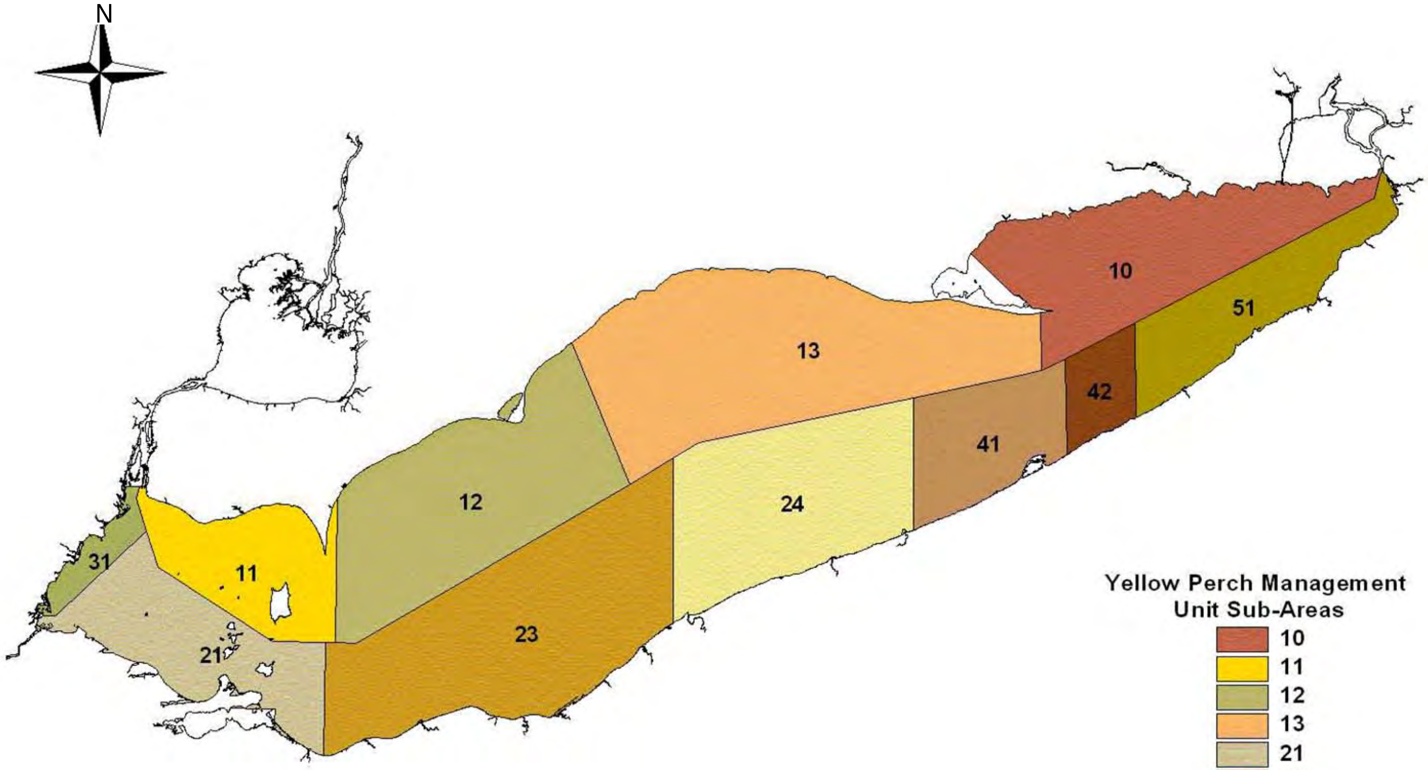


Figure 1.14. Lake Erie yellow perch exploitation rates by management unit for ages 2+ (dashed line) and ages 3+ (solid line). Estimates are derived from ADMB.



Management Unit	Sub-Area	Jurisdiction	Area Estimate (km2)	New Relative Surface Area
MU1	11	Ontario	1537.1	**40.6%**
	31	Michigan	344.8	**9.1%**
	21	Ohio	1905.6	**50.3%**
		MU1 Total	**3787.5**	
MU2	12	Ontario	3497.4	**45.6%**
	23	Ohio	4175.3	**54.4%**
		MU2 Total	**7672.7**	
MU3	13	Ontario	4749.9	**52.3%**
	24	Ohio	2943.7	**32.4%**
	41	Pennsylvania	1385.8	**15.3%**
		MU3 Total	**9079.4**	
MU4	10	Ontario	2818.7	**58.0%**
	42	Pennsylvania	535.6	**11.0%**
	51	New York	1507.2	**31.0%**
		MU4 Total	**4861.4**	

Figure 2.1 Calculations for subunit areas in the Yellow Perch Task Group Management Units.

Appendix A Table 1. Expert Opinion (EO) Lambda (λ) values and relative number of terms associated with catch-at-age analysis data sources by management unit (Unit).

Unit	Data Source	λ	Relative Number of Terms
1	Commercial Gill Net Effort	0.8	1
	Sport Effort	0.7	1
	Commercial Trap Net Effort	0.5	1
	Commercial Gill Net Harvest	1.0	5
	Sport Harvest	0.9	5
	Commercial Trap Net Harvest	0.7	5
	Trawl Survey Catch Rates	1.0	3
	Partnership Gill Net Index Catch Rates	1.0	5
2	Commercial Gill Net Effort	0.8	1
	Sport Effort	0.8	1
	Commercial Trap Net Effort	0.6	1
	Commercial Gill Net Harvest	1.0	5
	Sport Harvest	0.9	5
	Commercial Trap Net Harvest	0.7	5
	Trawl Survey Catch Rates	0.9	4
	Partnership Gill Net Index Catch Rates	1.0	5
3	Commercial Gill Net Effort	0.8	1
	Sport Effort	0.8	1
	Commercial Trap Net Effort	0.6	1
	Commercial Gill Net Harvest	1.0	5
	Sport Harvest	0.8	5
	Commercial Trap Net Harvest	0.6	5
	Trawl Survey Catch Rates	1.0	4
	Partnership Gill Net Index Catch Rates	1.0	5
4	Commercial Gill Net Effort	0.8	1
	Sport Effort	0.7	1
	Commercial Trap Net Effort	0.6	1
	Commercial Gill Net Harvest	1.0	5
	Sport Harvest	0.7	5
	Commercial Trap Net Harvest	0.6	5
	NY Gill Net Survey Catch Rates	1.0	5
	Partnership Gill Net Index Catch Rates	0.9	5

Appendix A Table 2. Robust regression results from survey indices used for projecting estimates of age-2 yellow perch recruiting in 2012 by Management Unit.

Management Unit 1

Index	Value	R-Square	Intercept	Lower Int SE	Upper Int SE	Slope	Lower Slope SE	Upper Slope SE	Lower Age-2 Est	Age-2 estimate	Upper Age-2 Est
OHF10	26.9	0.784	-0.3606	-0.7756	0.0544	0.6381	0.5544	0.7218	1.915	4.832	10.670
OOS11	25.9	0.777	-0.0568	-0.3929	0.2793	0.7281	0.6276	0.8286	4.329	9.383	19.230
OPSF11	158.7	0.761	0.9507	0.3728	1.5286	0.4009	0.2970	0.5048	5.551	18.778	58.716
OOS10	96.9	0.720	-0.6714	-1.0347	-0.3081	0.6096	0.5133	0.7059	2.737	7.356	17.685
OHF11	10.0	0.515	1.3716	1.0680	1.6752	0.4244	0.3595	0.4893	5.890	9.905	16.262
								mean	**4.084**	**10.051**	**24.512**

Management Unit 2

Index	Value	R-Square	Intercept	Lower Int SE	Upper Int SE	Slope	Lower Slope SE	Upper Slope SE	Lower Age-2 Est	Age-2 estimate	Upper Age-2 Est
OPSF21	101.8	0.806	1.0410	0.6981	1.3839	0.5188	0.4223	0.6153	13.218	30.327	68.024
OHF20B	8.7	0.718	1.0316	0.5721	1.4911	0.6333	0.4978	0.7688	4.491	10.829	24.480
OHJ21B	73.0	0.622	0.9417	0.4009	1.4825	0.5048	0.3857	0.6239	6.854	21.520	63.574
OHS20	.	0.609	1.8932	1.6026	2.1838	0.3511	0.2799	0.4223	.	.	.
OHF21B	5.5	0.563	1.0039	0.6360	1.3718	0.6570	0.5581	0.7559	4.369	8.334	15.227
OHS21	34.5	0.516	1.6712	1.3965	1.9459	0.4437	0.3799	0.5075	14.683	24.920	41.839
								mean	**8.723**	**19.186**	**42.629**

Management Unit 3

Index	Value	R-Square	Intercept	Lower Int SE	Upper Int SE	Slope	Lower Slope SE	Upper Slope SE	Lower Age-2 Est	Age-2 estimate	Upper Age-2 Est
OHS30	.	0.824	1.2574	1.0279	1.4869	0.4049	0.3537	0.4561	.	.	.
OPSF31	218.6	0.811	0.8579	0.5313	1.1845	0.5438	0.4605	0.6271	19.373	43.255	95.130
OHJ31B	41.7	0.732	1.1485	0.7018	1.5952	0.5481	0.4129	0.6833	8.506	23.685	63.100
OHF31	55.5	0.675	1.2312	0.8514	1.6110	0.6140	0.4866	0.7414	15.684	39.781	98.682
OHF30	15.1	0.649	1.1781	0.8152	1.5410	0.5781	0.4614	0.6948	7.145	15.192	31.192
OHS31B	41.3	0.552	1.6214	1.1581	2.0847	0.3621	0.2331	0.4911	6.622	18.636	49.591
								mean	**11.466**	**28.110**	**67.539**

Management Unit 4

Index	Value	R-Square	Intercept	Lower Int SE	Upper Int SE	Slope	Lower Slope SE	Upper Slope SE	Lower Age-2 Est	Age-2 estimate	Upper Age-2 Est
NYF41	138.2	0.786	-0.0126	-0.2819	0.2567	0.6253	0.5218	0.7288	8.911	20.624	46.181
NYF40	192.7	0.743	0.0986	-0.2043	0.4015	0.3554	0.2829	0.4279	2.617	6.172	13.224
OPSF41	95.4	0.622	0.3250	0.0165	0.6335	0.3988	0.2929	0.5047	2.875	7.558	17.901
LPC40	51.8	0.507	0.4410	0.0953	0.7867	0.2713	0.1761	0.3665	1.212	3.559	8.397
								mean	**3.904**	**9.479**	**21.426**

Appendix A Table 3. Interagency trawl surveys indices. All series are reported in arithmetic mean catch per hectare.

Year	OHS10	OHF10	OHS11	OHF11	OOS10	OOS11	OHS20	OHF20	OHS21	OHF21	OHS30	OHF30	OHF20B	OHF21B	OHF30B	OHF31B	OHS20B	OHS21B	OHS30B	OHS31B	OHJ21B	OHJ31B	OHJ21	OHJ31
1984	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1985	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1986	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1987	16.3	.	74.9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1988	188.6	.	11.2	.	212.6	13.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1989	106.1	.	11.8	.	265.4	12.5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1990	144.4	310.1	20.7	82.0	259.2	35.2	1.7	43.6	67.4	24.0	0.9	21.1	52.2	23.0	20.5	14.3	1.7	67.4	0.6	7.2	.	.	.	.
1991	146.9	58.1	27.6	0.4	113.3	42.1	5.4	10.8	43.5	51.6	4.5	1.3	9.3	50.0	1.2	18.5	5.4	43.5	6.4	103.4	216.5	19.7	216.5	19.7
1992	60.7	90.9	9.5	0.7	94.2	16.5	7.2	40.2	8.0	15.6	19.6	27.5	35.8	14.3	31.8	3.4	7.2	8.0	24.3	2.7	18.5	0.8	18.5	0.8
1993	1164.2	256.4	14.4	3.7	862.5	39.5	41.7	10.3	29.1	39.6	39.7	16.0	10.6	49.0	27.3	12.1	41.7	29.1	39.7	16.0	9.7	5.8	9.7	5.8
1994	508.5	287.1	57.7	73.1	469.7	62.9	73.3	77.1	5.0	11.1	77.2	14.7	71.9	12.0	16.1	3.4	73.3	5.0	77.2	16.7	23.3	10.2	23.3	10.2
1995	348.9	82.4	128.8	0.1	478.8	113.5	3.2	2.9	102.2	67.7	25.3	10.0	2.5	82.3	12.4	27.3	2.2	151.1	30.5	18.7	.	.	.	.
1996	3290.8	579.3	79.9	82.3	2544.9	122.8	998.1	128.7	11.6	13.0	1912.1	122.0	119.1	11.2	128.4	3.9	843.3	15.7	1785.8	2.7	11.1	0.8	7.9	0.9
1997	52.2	33.7	121.8	104.9	55.2	93.8	29.0	9.3	677.7	148.0	.	2.9	12.3	110.2	2.6	34.0	29.0	677.7	.	.	539.0	66.9	506.2	63.8
1998	174.5	250.9	4.8	16.0	170.6	8.2	235.1	74.4	3.5	6.4	275.5	38.9	69.8	6.3	38.1	3.7	223.8	2.9	298.9	3.5	21.1	11.9	22.5	16.2
1999	270.1	155.3	68.5	47.1	330.0	75.0	31.4	63.1	19.4	41.7	44.8	22.0	73.6	40.7	21.0	40.0	26.8	19.4	44.8	63.5	470.0	85.3	399.2	85.3
2000	186.4	41.5	85.3	38.0	102.5	113.6	0.6	18.0	86.6	57.1	0.0	1.0	21.9	61.6	1.3	19.3	0.6	86.6	.	84.8	58.1	9.3	50.6	10.3
2001	322.1	246.3	12.8	10.3	398.4	11.3	313.2	118.0	7.7	5.2	1283.7	13.2	114.6	5.7	13.6	0.4	341.9	6.4	1283.7	10.2	351.7	3.5	299.0	4.3
2002	33.1	30.4	77.1	86.5	26.4	59.5	0.3	3.8	191.0	45.9	1.7	3.1	6.0	51.7	2.5	38.3	0.3	191.0	1.7	749.6	223.9	40.2	247.1	39.0
2003	1509.9	1111.6	3.0	7.1	1620.8	12.3	1174.9	126.7	3.8	2.5	1170.2	56.5	149.0	3.2	47.5	1.2	1077.5	4.2	844.6	1.5	11.3	2.5	10.4	2.6
2004	40.9	9.3	210.7	127.7	45.2	240.7	35.1	8.2	313.0	206.1	3.6	2.0	8.7	216.5	1.9	45.2	39.7	323.7	3.6	61.9	459.4	42.7	422.0	42.7
2005	124.2	62.3	5.2	2.0	114.8	5.2	108.8	43.9	23.1	19.2	278.2	126.8	37.8	18.3	156.2	132.3	118.8	25.0	278.2	82.3	42.6	19.3	44.9	19.3
2006	180.2	121.9	6.4	12.5	222.9	12.4	4.9	11.3	2.2	4.3	60.7	19.7	10.0	4.2	18.9	12.5	4.9	2.2	60.7	10.8	30.2	113.6	29.7	113.6
2007	592.9	631.5	14.5	23.6	444.6	18.8	237.0	150.6	22.6	20.2	237.0	166.5	167.0	19.8	177.8	37.0	244.5	25.1	237.0	40.9	171.3	281.8	192.7	281.8
2008	267.0	74.7	23.5	15.3	387.2	142.1	219.5	32.1	63.1	55.0	558.3	52.8	37.3	56.6	52.8	26.4	287.2	66.6	558.3	150.2	297.1	97.2	303.5	97.2
2009	186.0	69.36	85.3	57.0	136.6	88.4	16.0	1.6	58.3	20.2	0.1	0.5	1.3	20.7	0.5	139.4	12.2	63.1	0.1	104.3	129.9	48.2	125.9	48.2
2010	58.2	26.9	22.2	17.8	96.9	26.4	.	41.1	.	11.9	.	96.3	41.1	11.9	96.3	12.4	.	.	.	.	31.2	12.1	28.8	12.1
2011	29.9	12.0	15.5	10.0	178.0	25.9	7.1	10.5	34.5	6.4	14.1	15.1	8.7	5.5	14.1	50.5	9.9	31.3	14.1	41.3	73.0	41.7	70.8	40.8

Year	OHS31	OHF31	OLPN40	OLPN41	ILP40	ILP41	NYF40	NYF41	LPS41	LPC40	LPC41	OLPO40	OLPO41	OPSF11	OPSF21	OPSF31	OPSF41
1984	.	.	283.9	9.7	761.7	44.5	.	.	.	119.1	5.9	7.3	0.0	.	.	.	.
1985	.	.	2.4	32.6	20.8	125.5	.	.	.	3.8	30.5	1.6	17.1	.	.	.	.
1986	.	.	102.0	0.2	1859.5	61.7	.	.	7.6	212.7	6.9	0.0	0.3	.	.	.	.
1987	.	.	3.4	284.1	3.8	39.7	.	.	5.5	0.8	36.7	0.0	2.1	.	.	.	.
1988	.	.	667.7	0.8	305.0	2.9	.	.	1.1	105.8	0.4	0.4	0.0	.	.	.	.
1989	.	.	296.9	53.2	457.7	84.6	.	.	6.3	82.1	16.4	0.4	1.9	.	.	6.8	76.6
1990	9.2	13.4	43.3	12.0	202.6	21.0	.	.	0.0	26.7	5.6	0.0	2.6	41.3	68.9	29.7	0.6
1991	66.6	19.6	15.5	1.0	144.0	24.5	.	.	1.7	17.8	3.2	0.7	0.6	63.3	56.6	3.8	1.6
1992	4.4	3.1	54.3	9.0	594.0	32.8	10.4	2.3	5.6	70.3	4.6	0.0	0.1	47.5	8.0	5.7	6.3
1993	16.0	12.0	21.6	4.5	239.8	17.9	110.1	3.0	7.9	30.6	2.6	2.9	0.2	146.9	112.0	93.2	0.1
1994	16.7	4.0	159.8	15.3	84.0	29.8	47.7	8.4	2.7	34.7	6.2	10.6	1.7	317.8	22.5	39.7	7.4
1995	22.4	32.7	6.0	33.7	5.3	54.3	5.7	14.2	15.2	4.3	10.9	4.0	1.7	362.5	81.3	55.2	9.6
1996	3.2	3.7	199.1	2.6	53.6	6.1	106.3	0.3	0.4	33.6	1.1	7.9	0.1	198.4	70.8	.	.
1997	.	47.5	18.9	59.8	21.5	5.4	0.2	5.5	4.4	4.4	7.1	0.0	0.1	139.3	350.5	177.9	.
1998	3.7	4.0	114.9	1.2	1005.9	14.9	1.5	0.2	8.4	127.8	1.7	8.1	0.0	17.5	6.7	6.2	0.0
1999	63.5	40.6	2.5	69.5	34.0	155.7	36.1	33.5	23.0	16.1	110.0	15.5	109.3	440.6	107.6	67.9	119.9
2000	84.8	19.9	10.2	2.1	1.2	4.8	23.1	6.6	0.7	3.6	11.3	3.0	13.4	106.1	162.4	55.5	36.9
2001	10.2	0.4	76.7	2.0	463.8	2.7	97.9	11.5	4.8	69.4	2.0	13.8	1.9	12.9	9.6	1.9	9.5
2002	749.6	49.5	0.6	13.9	8.3	42.6	9.3	15.5	6.8	1.0	6.6	0.0	0.7	198.7	245.2	186.6	19.7
2003	2.3	1.1	93.3	0.8	224.0	1.5	472.5	1.9	1.3	222.8	2.3	240.6	2.6	2.7	2.6	7.2	3.2
2004	61.7	44.4	0.5	4.3	0.1	21.4	1.5	28.7	6.5	0.1	12.4	0.1	12.2	976.5	1188.5	332.5	7.7
2005	82.3	131.6	10.3	0.1	8.8	0.2	57.8	5.4	0.4	124.4	0.1	156.2	0.0	0.0	2.2	2.5	0.2
2006	10.8	13.6	2.8	1.4	0.3	4.8	283.2	39.9	19.5	30.1	12.1	38.0	14.6	15.7	28.5	94.8	129.7
2007	40.9	34.5	6.3	0.9	73.9	3.0	401.3	41.2	9.1	63.5	7.9	70.0	9.6	184.4	203.9	202.5	43.4
2008	150.2	26.4	4.9	6.6	0.3	4.1	1088.3	44.3	5.7	279.4	20.8	356.0	25.1	333.1	310.6	150.6	87.0
2009	104.3	137.2	1.5	4.2	0.0	0.0	11.6	62.5	0.7	0.4	10.7	0.3	13.1	265.2	121.4	190.0	30.6
2010	.	12.4	13.2	0.6	5.7	0.6	192.7	4.0	1.7	51.8	0.2	63.5	0.0	49.5	18.1	36.2	15.7
2011	41.3	55.5	3.9	1.9	3.9	12.8	87.2	138.2	5.0	176.7	2.6	224.6	1.3	158.7	101.8	218.6	95.4

Appendix A Table 4. Legend. Lakewide trawl index codes and series names used in Appendix A Tables 2 and 3. All series are reported in arithmetic mean catch per hectare, except LPS41 and OPSF11-41, gill net indices which are reported in mean catch per lift. Abbreviations in Appendix T3 ending with a 'B' represent survey indices blocked by depth strata.

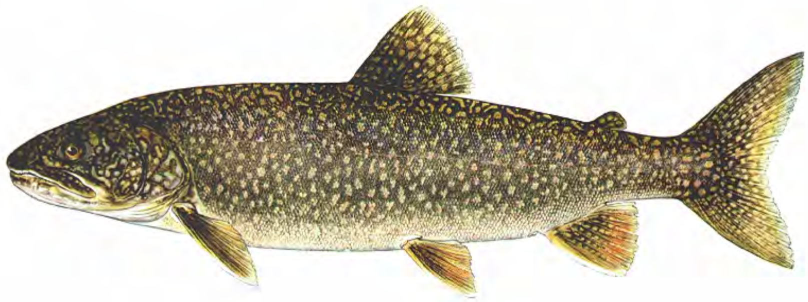
Abbreviation	Series
OHS10	Ohio Management Unit 1 summer age 0
OHS11	Ohio Management Unit 1 summer age 1
OHF10	Ohio Management Unit 1 fall age 0
OHF11	Ohio Management Unit 1 fall age 1
OOS10	Ontario/Ohio Management Unit 1 summer age 0
OOS11	Ontario/Ohio Management Unit 1 summer age 1
OHS20	Ohio Management Unit 2 summer age 0
OHF20	Ohio Management Unit 2 fall age 0
OHS21	Ohio Management Unit 2 summer age 1
OHF21	Ohio Management Unit 2 fall age 1
OHS30	Ohio Management Unit 3 summer age 0
OHF30	Ohio Management Unit 3 fall age 0
OHS31	Ohio Management Unit 3 summer age 1
OHF31	Ohio Management Unit 3 fall age 1
OHJ21	Ohio Management Unit 2 June age 1
OHJ31	Ohio Management Unit 3 June age 1
OLPN40	Outer Long Point Bay Nearshore Management Unit 4 age 0
OLPN41	Outer Long Point Bay Nearshore Management Unit 4 age 1
OLPO40	Outer Long Point Bay Offshore Management Unit 4 age 0
OLPO41	Outer Long Point Bay Offshore Management Unit 4 age 1
ILPF40	Inner Long Point Bay Management Unit 4 age 0
ILPF41	Inner Long Point Bay Management Unit 4 age 1
LPC40	Long Point Composite Management Unit 4 age 0
LPC41	Long Point Composite Unit 4 age 1
LPS41	Long Point Bay Management Unit 4 summer Gill Net age 1
NYF40	New York Management Unit 4 fall age 0
NYF41	New York Management Unit 4 fall age 1
OPSF11	Ontario Partnership Gill Net Management Unit 1 fall age 1
OPSF21	Ontario Partnership Gill Net Management Unit 2 fall age 1
OPSF31	Ontario Partnership Gill Net Management Unit 3 fall age 1
OPSF41	Ontario Partnership Gill Net Management Unit 4 fall age 1

REPORT OF THE
LAKE ERIE
COLDWATER TASK GROUP

23 March 2012

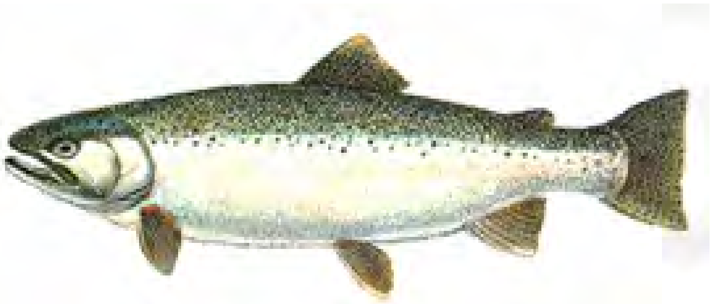
Members:

Kevin Kayle	Ohio Division of Wildlife (Co-Chair)
Larry Witzel	Ontario Ministry of Natural Resources (Co-Chair)
Jeff Braunscheidel	Michigan Department of Natural Resources
Andy Cook	Ontario Ministry of Natural Resources
John Fitzsimons	Department of Fisheries and Oceans, Canada
Richard Kraus	United States Geological Survey
Tom MacDougall	Ontario Ministry of Natural Resources
James Markham	New York Department of Environmental Conservation
Chuck Murray	Pennsylvania Fish and Boat Commission
Fraser Neave	Department of Fisheries and Oceans, Canada
Tim Sullivan	United States Fish and Wildlife Service
Elizabeth Trometer	United States Fish and Wildlife Service



Presented to:

Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission



Protocol for Use of Coldwater Task Group Data and Reports

The Lake Erie Coldwater Task Group (CWTG) uses standardized methods, equipment, and protocols as much as possible; however, data sampling and reporting methods do vary across agencies. The data are based upon surveys that have limitations due to gear, depth, time, and weather constraints that are variable from year to year. Any results or conclusions must be treated with respect to these limitations. Caution should be exercised by outside researchers not familiar with each agency's collection and analysis methods to avoid misinterpretation.

The CWTG strongly encourages outside researchers to contact and involve the CWTG members in the use of any specific data contained in this report. Coordination with the CWTG can only enhance the final output or publication and benefit all parties involved. Any CWTG data or findings intended for outside publication must be reviewed and approved by the CWTG members. Agencies may require written permission for external use of data, please contact the agencies responsible for the data collection.

Citation:

Coldwater Task Group. 2012. Report of the Lake Erie Coldwater Task Group, March 2012. Presented to the Standing Technical Committee, Lake Erie Committee of the Great Lakes Fishery Commission. Ann Arbor, Michigan, USA.

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Raver, Duane. 1999. Duane Raver Art. U.S. Fish and Wildlife Service. Shepherdstown, West Virginia, USA.

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Reporting of 2011 – 2012 Coldwater Task Group Charges

Background

The Coldwater Task Group (CWTG) is one of several technical groups under the Lake Erie Committee (LEC) that addresses specific charges related to the fish community. The group was originally formed in 1980 as the Lake Trout Task Group with its main functions of coordinating, collating, analyzing, and reporting of annual lake trout assessments among Lake Erie's five member agencies, and assessing the results toward rehabilitation status. Restoration of lake trout into its native eastern basin Lake Erie habitat began in 1978, when 236,000 surplus yearlings were obtained from a scheduled stocking in Lake Ontario. Similar numbers of yearlings were also available for Lake Erie in 1979. In 1982, the U.S. Fish and Wildlife Service (USFWS), in cooperation with the Pennsylvania Fish and Boat Commission (PFBC) and the New York State Department of Environmental Conservation (NYSDEC), committed to annually produce and stock at least 160,000 yearlings in Lake Erie and monitor lake trout restoration in the eastern basin.

A formal lake trout rehabilitation plan was developed by the newly-formed Lake Trout Task Group in 1985 (Lake Trout Task Group 1985) that defined goals and specific quantitative objectives for restoration. A draft revision of the plan (Pare 1993) was presented to the LEC in 1993, but the revision was never adopted by the LEC because of a lack of consensus regarding the position of lake trout in the Lake Erie fish community goals and objectives (FCGOs; Cornelius et al. 1995). A revision of the Lake Erie FCGOs was completed in 2003 (Ryan et al. 2003) and identified lake trout as the dominant predator in the profundal waters of the eastern basin. A subsequent revision of the Lake Trout Rehabilitation Plan was completed by the task group in 2008 (Markham et al. 2008).

The Lake Trout Task Group evolved into the CWTG in 1992 as interest in the expanding burbot and lake whitefish populations, as well as predator/prey relationships involving salmonid and rainbow smelt interactions, prompted additional charges to the group from the LEC. Rainbow/steelhead trout dynamics have recently entered into the task group's list of charges and a new charge concerning cisco rehabilitation was added in 1999. Continued assessments of coldwater species' fisheries and biological characteristics has added new depth to the understanding of how these species function in the shallowest and warmest lake of the Great Lakes.

This report is specifically designed to address activities undertaken by the task group toward each charge in this past year and is presented orally to the LEC at the annual meeting, held this year on 22-23 March 2012 in Windsor, Ontario. Data have been supplied by each member agency, when available, and combined for this report, if the data conform to standard protocols. Individual agencies may still choose to report their own assessment activities under separate agency reporting processes.

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COLDWATER TASK GROUP
EXECUTIVE SUMMARY REPORT
MARCH 2012

Lake Erie Committee

REPRESENTING THE FISHERY MANAGEMENT AGENCIES OF LAKE ERIE AND LAKE ST. CLAIR

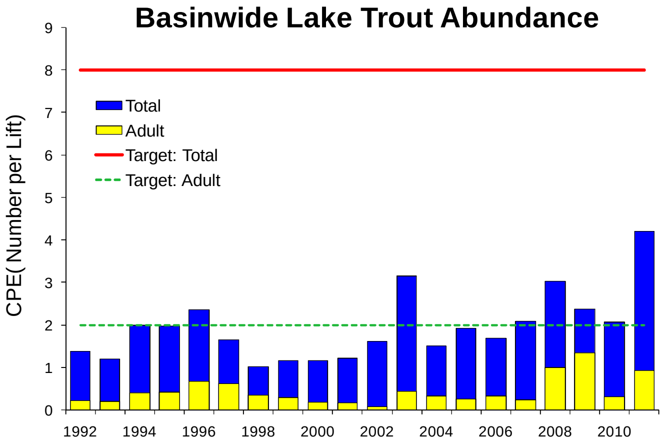
Introduction

This year's Lake Erie Committee (LEC) Coldwater Task Group (CWTG) has produced an Executive Summary Report encapsulating information from the CWTG annual report. The complete report is available from the GLFC's Lake Erie Committee Coldwater Task Group website at http://www.glfc.org/lakecom/lec/CWTG.htm, or upon request from an LEC, Standing Technical Committee (STC), or CWTG representative.

Seven charges were addressed by the CWTG during 2011-2012: (1) Lake trout assessment in the eastern basin; (2) Lake whitefish fishery assessment and population biology; (3) Burbot fishery assessment and population biology; (4) Participation in sea lamprey assessment and control in the Lake Erie watershed; (5) Electronic database maintenance of Lake Erie salmonid stocking information; (6) Steelhead fishery assessment and population biology, and (7) Development of a cisco management plan.

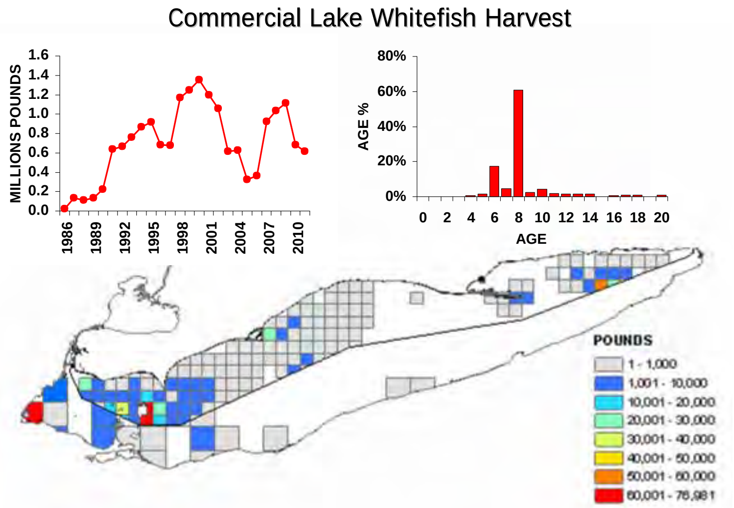
Lake Trout

A total of 717 lake trout were collected in 89 lifts across the eastern basin of Lake Erie in 2011. Record lake trout catches were recorded in New York surveys and near-record in Ontario surveys. Young cohorts (ages 1-5) dominated catches with lake trout ages 10 and older only sporadically caught. Basin-wide lake trout abundance (weighted by area) increased to its highest value in the time series but remains below the rehabilitation target of 8.0 fish/lift. Adult (age 5+) abundance also increased in 2011 and remains below target. Recent estimates indicate very low rates of adult survival. Klondike and Finger Lakes strain lake trout comprise the majority of the population. Successful natural reproduction has yet to be documented in Lake Erie despite more than 30 years of restoration efforts.



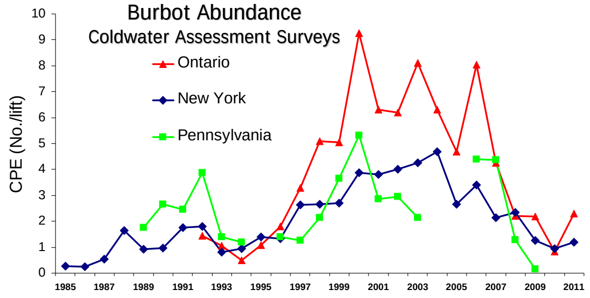
Whitefish

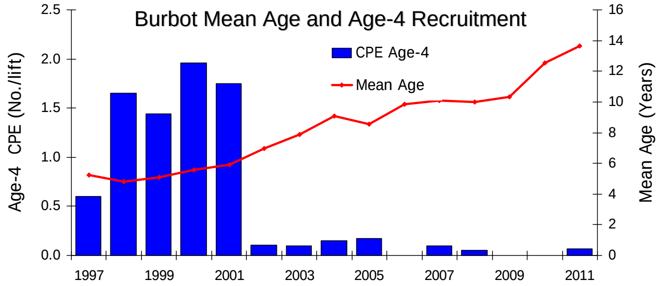
Lake whitefish harvest in 2011 was 616,973 pounds, distributed among Ontario (86%), Ohio (13%), and Michigan (1%) commercial fisheries. The 2003 year class (age 8) dominated the population age structure in the observed harvest and assessment surveys in 2011. Ages present in the 2011 population ranged from 1 to 20, with no evidence of young-of-the-year in assessment surveys lake-wide. With recruitment sparse or absent, population abundance continues to decline. No significant recruitment is expected in 2011, although older lake whitefish persist in the population. Fisheries in 2011 will continue to rely on the 2003 year class followed by the 2005 cohort with some contribution from other adjacent year classes. In 2011, mean condition factor of mature female and male whitefish was above the historic average. Chironomids and isopods represented the largest fraction of prey observed in whitefish diets during 2011.



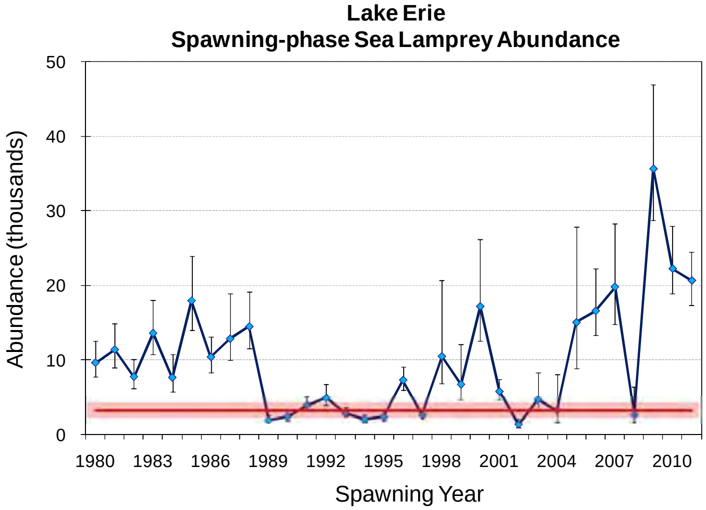
Burbot

Total commercial harvest of burbot in Lake Erie during 2011 was 2,894 pounds, a 40% decrease from 2010. Burbot abundance and biomass indices from annual coldwater gillnet assessments increased slightly in 2011 reversing a downward trend observed across east basin areas following time-series maxima during the early- to mid-2000s. Agency catch rates during 2011 averaged 1.2 (New York) to 2.3 (Ontario) burbot per lift which are about 3.5 to 3.1 times lower than mean catch rates observed from 2000 to 2004. Despite an



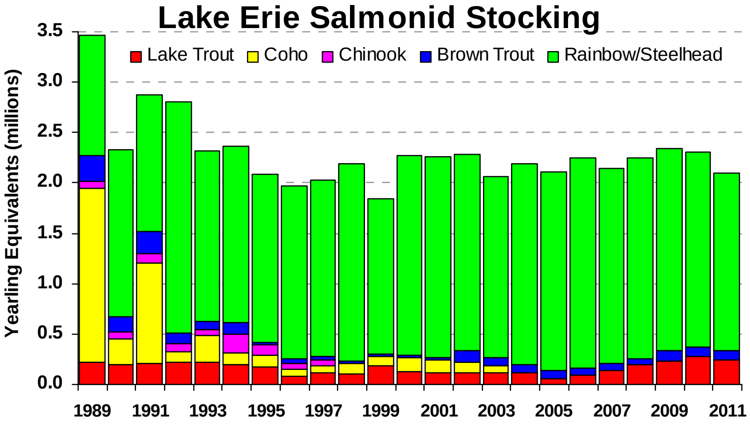


improvement in age-4 recruitment during 2011, ongoing low catch rates of burbot in assessment surveys, combined with increasing mean age of adults and persistent low recruitment, signal continuing troubles for this population. Round gobies and rainbow smelt continue to be the dominant prey items in burbot diets in eastern Lake Erie.



Sea Lamprey

The A1-A3 wounding rate on lake trout over 532 mm was 8.2 wounds per 100 fish in 2011. This was a 36% decline from the 2010 wounding rate of 12.8 wounds per 100 fish and a 58% decrease over the past two years. Despite the decline, likely attributable to a 2008-2010 accelerated lampricide treatment program, the current wounding rate still exceeds the target rate of five wounds per 100 fish. Wounding rates have been above target for 16 of the past 17 years. Large lake trout over 736 mm continue to be the preferred targets for sea lampreys. A4 wounding rates slightly decreased in 2011 to 53.9 wounds/100 fish, the third highest A4 wounding rate in the 27-year time series. A4 wounding rates on lake trout over 736 mm remain very high (163 wounds/100 fish). The estimated number of spawning-phase sea lampreys decreased from 22,179 in 2010 to 20,638 in 2011. However, this is the third highest population estimate in the time-series. Comprehensive stream evaluations in 2011 concluded that intensive streams treatments conducted in 2008-2010 were very effective, suggesting that the continued high abundance of the adult spawning population in Lake Erie is from an unknown and untreated source.



Lake Erie Salmonid Stocking

A total of 2,101,719 salmonids were stocked in Lake Erie in 2011. This was a 9% decrease in the number of yearling salmonids stocked compared to 2010 and the long-term average from 1989-2009. Declines were primarily due to temporary reductions in steelhead/rainbow trout stockings in 2011. By species, there were 240,133 yearling lake trout stocked in New York and Ontario; 100,370 brown trout stocked in New York and Pennsylvania waters, and a 1,761,217 steelhead/rainbow trout stocked in all five jurisdictional waters.

Steelhead

All agencies stocked yearling steelhead/rainbow trout in 2011. A summary of rainbow trout/steelhead stocking in Lake Erie by jurisdictional waters for 2011 is as follows: Pennsylvania (1,091,793; 62%), New York (305,780; 17%), Ohio (265,469; 15%), Michigan (61,445; 3%) and Ontario (36,730; 2%). Overall steelhead stocking numbers (1.761 million in 2011) represented a 4% decrease below the long-term average and a 9% decrease from 2010. Annual stocking numbers have been consistently in the 1.7-2.0 million range since 1993. The summer open lake fishery for steelhead was again evaluated by Ohio, Pennsylvania and New York. Open lake harvest was estimated at 4,480 fish, summed for all reporting agencies; Ohio (2,996), Pennsylvania (1,389), New York (92) and Michigan (3). Overall, this was a 51% decrease from the 2010 harvest and 81% below the average harvest between 1999 and 2010. Open lake steelhead harvest decreased in all jurisdictions from 2010, and was greatest in Pennsylvania (-73%), followed by Ohio (-23%) and New York (-16%). The steelhead harvest is negligible in Michigan and not reported in Ontario waters of Lake Erie. Catch rates in the open water fishery were mixed as well in 2011 and were slightly above the long-term average. Based upon creel surveys, the majority (>90%) of the fishery effort targeting steelhead occurs in the tributaries from fall through spring. Catch rates by tributary anglers in the New York cooperative diary program dropped to 0.52 fish/hour in 2010, declining 33% since 2008, but remained near the long-term average of 0.47 fish/hour.

Cisco

Cisco, considered extirpated in Lake Erie, have been reported in small numbers (1-6) in 10 of the past 15 years by commercial fishers; four were observed in 2011. Preliminary genetic testing of some of these fish found them to be most related to an historic Lake Erie stock, suggesting that a remnant Lake Erie stock may still exist. In 2010-11 observations of larval cisco and juvenile coregonids in the Huron-Erie Corridor provide an alternate source of at least some of the Lake Erie observations. Actions undertaken by the CWTG in 2011 were directed at resolving issues which currently prevent the completion of a cisco management plan (first undertaken in 2007). Consultation with cisco experts from other lakes was used to identify deficiencies (in timing and location) of current fisheries programs for accurately targeting and assessing cisco in Lake Erie. This resulted in preliminary gillnet sampling (USGS) at historic western basin spawning locations in the fall of 2011, which did not catch any cisco. A genetic research strategy to address issues of remnant, historic and related stocks was developed which will utilize recent cisco tissue samples and alternate historic DNA (scales). The task group will seek partnerships and funding to further both of these approaches in 2012.

Charge 1: Coordinate annual standardized lake trout assessments among all eastern basin agencies and update the status of lake trout rehabilitation

James Markham, NYSDEC and Larry Witzel, OMNR

Methods

A stratified, random design, deep-water gill net assessment protocol for lake trout has been in place since 1986. The sampling design divides the eastern basin of Lake Erie into eight sampling areas (A1-A8) defined by North/South-oriented 58000- series Loran C Lines of Position (LOP). The entire survey area is bound between the 58435 LOP on the west and the 58955 LOP on the east (Figure 1.1). New York is responsible for sampling areas A1 and A2, Pennsylvania A3 and A4, and USGS/ OMNR A5 through A8.

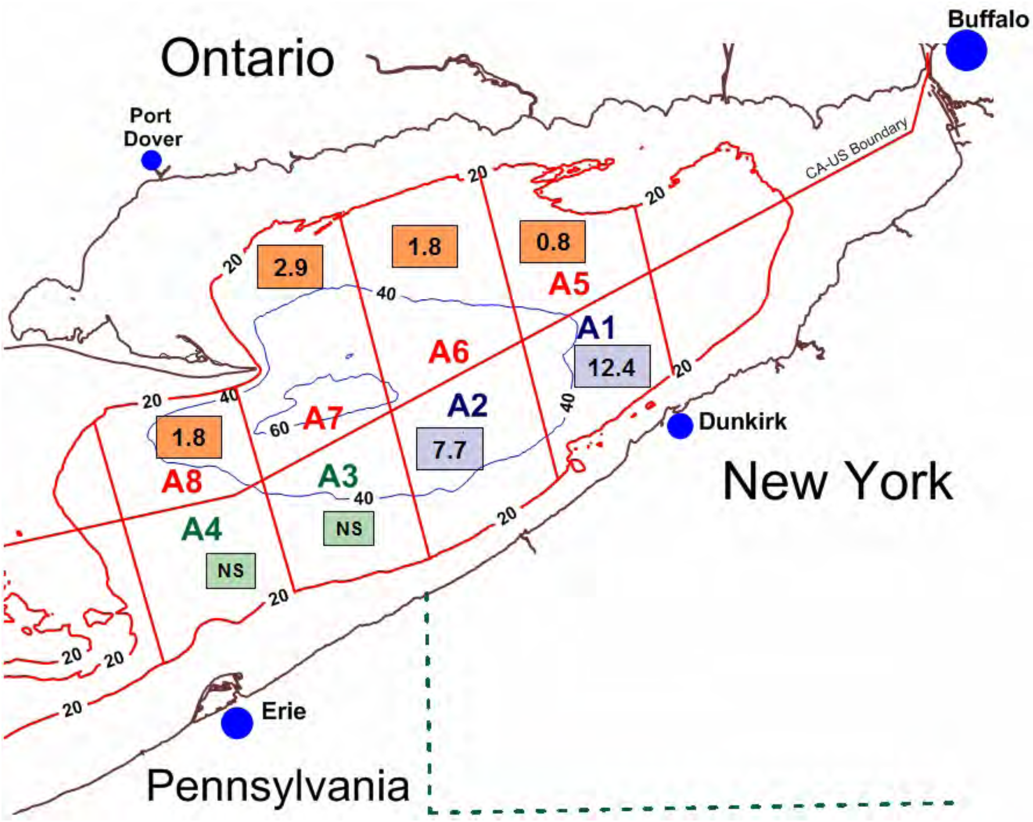


FIGURE 1.1. Standard sampling areas (A1-A8) used for assessment of lake trout in the eastern basin of Lake Erie, 2011, and catch per effort (No. per lift) of lake trout in each area. Areas A3 and A4 were not sampled in 2011.

Each area contains 13 equidistant north/south-oriented LOPs that serve as transects. Six transects are randomly selected for sampling in each area. A full complement of eastern basin effort should be 60 standard gill net lifts each for New York and Pennsylvania waters (two areas each) and 120 lifts from Ontario waters (four areas total). To date, this amount of effort has never been achieved. A1 and A2 have been the most consistently sampled areas across survey years while effort has varied in all other areas (Figure 1.2). Area A4 has only been sampled once due to the lack of enough cold water to set gill nets according to the sampling protocol.

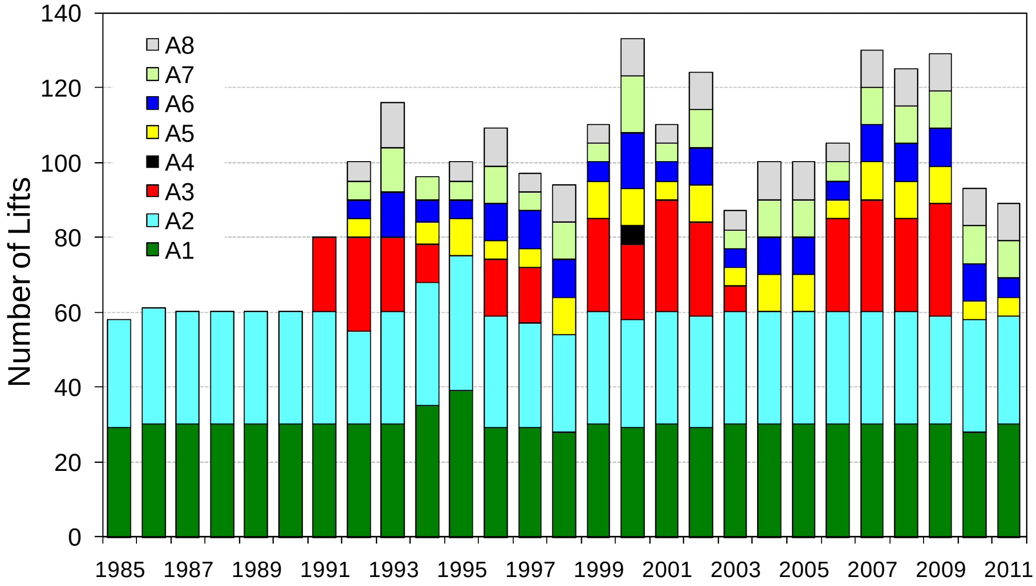


FIGURE 1.2. Number of unbiased coldwater assessment gill net lifts by area in the eastern basin of Lake Erie, 1985-2011.

Ten gill net panels, each 15.2 m (50 ft) long, are tied together to form 152.4-m (500-ft) gangs. Each panel is constructed of diamond-shaped mesh in one of 10 size categories ranging from 38-152 mm on a side in 12.7-mm increments stretched measure (1.5-6 inches; in 0.5 inch increments). Panels are arranged randomly in each gang. A series of five gangs per transect are set overnight, on bottom, along the contour and perpendicular to a randomly selected north/south-oriented transect during the month of August or possibly into early September, prior to fall turnover. New York State Department of Environmental Conservation (NYSDEC) personnel modified the protocol in 1996 using nets made of monofilament mesh instead of the standard multifilament nylon mesh. This modification was made following two years of comparative data collection and analysis that detected no significant difference in the total catch between the two net types (Culligan et al. 1996). In 1998 and 1999, all Coldwater Task Group (CWTG) agencies except the Pennsylvania Fish and Boat Commission (PFBC) switched to standard monofilament assessment nets to sample eastern basin lake trout. Personnel from the PFBC switched to monofilament mesh in 2006.

Sampling protocol requires the first gang in each five net series to be set along the contour where the 8° to 10°C isotherm intersects with the bottom. The top of the gang must be within this isotherm. The next three gangs are set in progressively deeper/ colder water at increments of either 1.5 m depth (5 feet) or a 0.8 km (0.5 miles) distance from the previous (shallower) gang, whichever occurs first along the transect. The fifth and deepest gang is set 15 m (50 feet) deeper than the shallowest net (number 1) or at a maximum distance of 1.6 km (1.0 miles) from net number 4, whichever occurs first. NYSDEC and PFBC have been responsible for completing standard assessments in their jurisdictional waters since 1986 and 1991, respectively. The Sandusky office of the U.S. Geological Survey (USGS) assumed responsibility for standard assessments in Canadian waters in 1992. The Ontario Ministry of Natural Resources (OMNR) began coordinating with USGS in 1998 to complete standard assessments in Canadian waters. Total effort for 2011 by the combined agencies was 89 unbiased standard lake trout assessment lifts in the eastern basin of Lake Erie (Figure 1.2). This included 59 lifts by the NYSDEC and 30 by USGS/ OMNR; no sets were made in Pennsylvania waters in 2011 due to budget and personnel issues. This was the second lowest total effort since combined agency assessments began in 1992.

All lake trout are routinely examined for total length, weight, sex, maturity, fin clips, and wounds by sea lampreys. Snouts from each lake trout are retained and coded-wire tags (CWT) are extracted in the laboratory to accurately determine age and genetic strain. Otoliths are also retained when the fish is not adipose fin-clipped. Stomach content data are usually collected as on-site enumeration or from preserved samples.

Klondike strain lake trout (KL) are an offshore form from Lake Superior and are thought to behave differently than traditional Lean lake trout strains (i.e. Finger Lakes (FL), Superior (SUP), Lewis Lake (LL) strains). They were first stocked in Lake Erie in 2004. In some analysis, Klondikes are reported as a separate strain for comparison with Lean strain lake trout.

Results and Discussion

Abundance

Sampling was conducted in six of the eight standard areas in 2011 (Figure 1.1), collecting a total of 717 lake trout in 89 unbiased lifts. Areas A1 and A2 again produced the highest catch per unit effort (CPE) values (Figure 1.1), coinciding with stocking areas of yearling lake trout. Comparatively, lake trout catches were much lower in Ontario waters (A5-A8), where stocking did not commence until 2006. The large disparity in lake trout catches among survey areas in the east basin indicates a lack of movement away from the stocking area.

Seventeen age-classes of lake trout, ranging from ages 1 to 21, were represented in the 2011 catch of known-aged fish (Table 1.1). Similar to the past ten years, young cohorts (ages 1-5) were the most abundant, representing 90% of the total catch in standard assessment nets (Figure 1.3). Cohort abundance continues to decline rapidly after age-5, and lake trout older than age-10 were only sporadically caught. Lake trout age-10 and older comprised only 2% of the overall catch in 2011.

TABLE 1.1. Number, sex, mean length (mm), mean weight (g), and percent maturity, by age class, of Lean strain (A) and Klondike strain (B) lake trout collected in assessment gill nets from the eastern basin of Lake Erie, August 2011.

A) Lean Strain

AGE	SEX	NUMBER	MEAN LENGTH (mm TL)	MEAN WEIGHT (g)	PERCENT MATURE
1	Combined	7	248	163	0
2	Male	30	410	787	13
	Female	23	410	768	0
3	Male	62	533	1867	87
	Female	31	521	1586	3
4	Male	77	627	2885	99
	Female	38	626	2904	50
5	Male	35	681	3785	100
	Female	49	686	3979	98
6	Male	5	699	4063	100
	Female	1	717	4110	100
8	Male	11	767	5629	100
	Female	12	754	5538	100
9	Male	13	773	5789	100
	Female	12	764	5786	100
10	Male	5	791	5965	100
	Female	4	795	6336	---
11	Male	1	825	6825	100
	Female	0	-----	-----	-----
12	Male	2	788	5855	100
	Female	0	-----	-----	-----
13	Male	1	787	6245	100
	Female	0	-----	-----	-----
15	Male	1	797	4680	100
	Female	0	-----	-----	-----
16	Male	0	-----	-----	-----
	Female	1	796	6505	100
19	Male	0	-----	-----	-----
	Female	1	880	7500	100
21	Male	1	888	8165	100
	Female	0	-----	-----	-----

B) Klondike Strain

AGE	SEX	NUMBER	MEAN LENGTH (mm TL)	MEAN WEIGHT (grams)	PERCENT MATURE
3	Male	81	503	1469	86
	Female	17	485	1288	12
4	Male	40	559	1972	95
	Female	12	576	2269	75
5	Male	12	597	2445	100
	Female	17	628	2995	94
7	Male	6	648	3353	100
	Female	3	623	3117	100
8	Male	2	625	2710	100
	Female	0	-----	-----	100

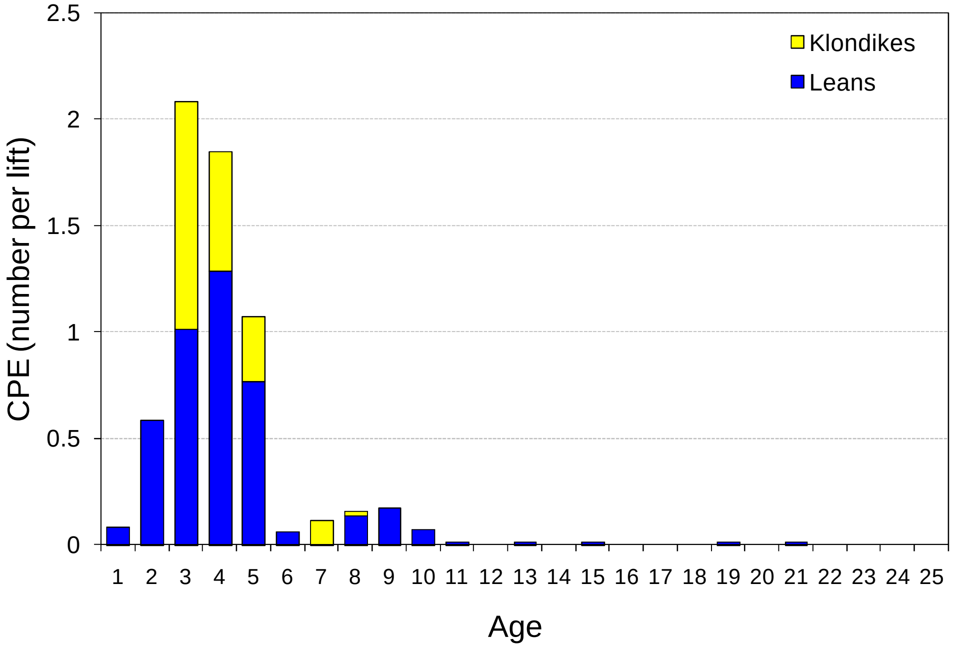


FIGURE 1.3. Relative abundance (number per lift) at age of Lean strain and Klondike strain lake trout sampled in standard assessment gill nets in the eastern basin of Lake Erie 2011.

The overall trend in area-weighted mean CPE of lake trout caught in standard nets in the eastern basin increased in 2011 to 4.3 fish per lift (Figure 1.4). This was the highest value in the time-series and follows two consecutive years of decline in basin-wide abundance. Increases were observed in both NY and ON waters in 2011, and abundance estimates were the highest on record in NY waters. Despite the increases, basin-wide abundance remains below the rehabilitation target of 8.0 fish/lift (Markham et al. 2008).

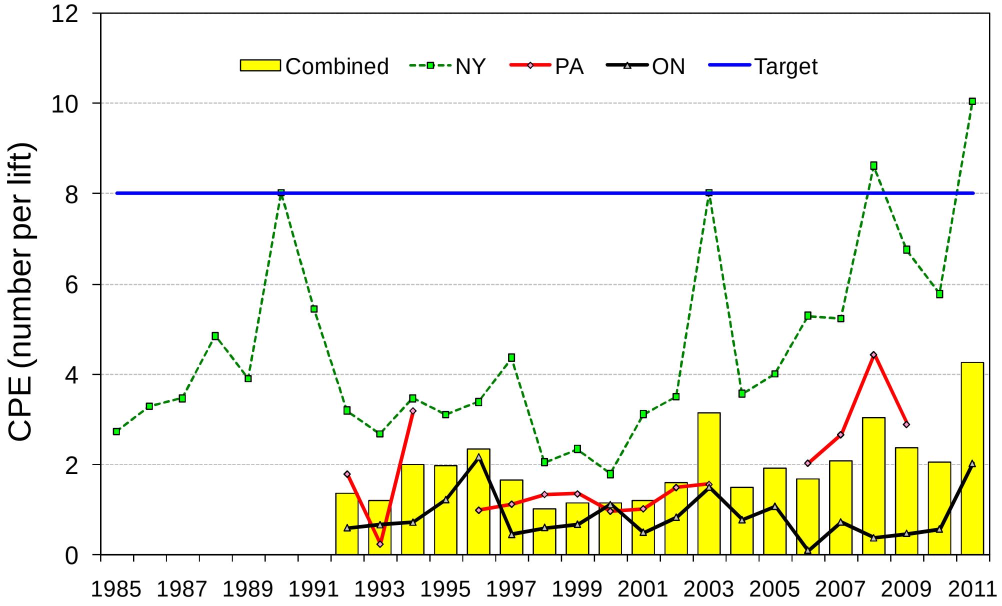


FIGURE 1.4. Mean CPE (number per lift) by jurisdiction and combined (weighted by area) for lake trout sampled in standard assessment gill nets in the eastern basin of Lake Erie, 1985-2011.

The abundance of lake trout in the OMNR Partnership Index Fishing Program in 2011 increased for the third consecutive year in the Pennsylvania Ridge area but remained steady in the East (Figure 1.5). Overall, abundance estimates remained at high levels in the East basin and above average in the Pennsylvania Ridge. The increase in the East basin is most likely due to increased stocking by OMNR over the past five years. Catches remain low in East-Central basin. Variability of abundance estimates in this survey is high due to low sample sizes, especially in the Pennsylvania Ridge, and to a broad spatial sampling that may have extended outside the preferred habitat of lake trout.

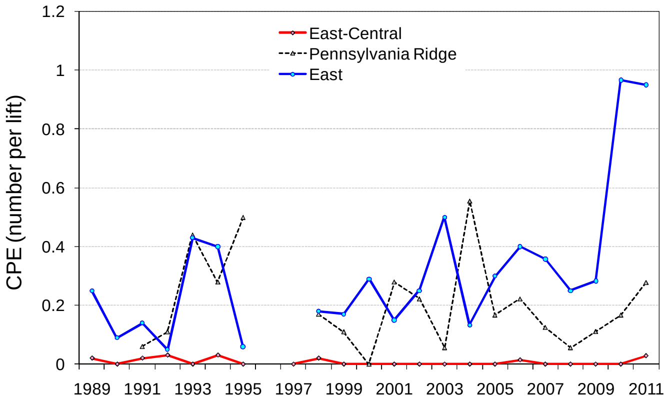


FIGURE 1.5. Lake trout CPE (number per lift) by basin from the OMNR Partnership Index Fishing Program, 1989-2011. Includes canned (suspended) and bottom gill net sets, excluding thermocline sets.

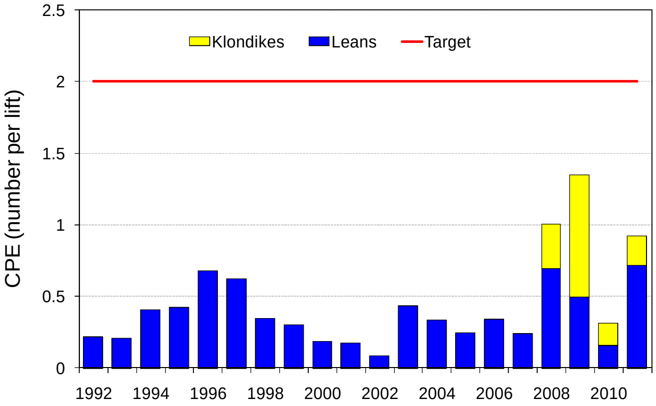


FIGURE 1.6. Relative abundance (number per lift) weighted by area of age 5 and older Lean strain and Klondike strain lake trout sampled in standard assessment gill nets in the eastern basin of Lake Erie, 1992-2011.

The relative abundance of adult (age-5 and older) lake trout caught in standard assessment gill nets (weighted by area) serves as an indicator of the size of the lake trout spawning stock in Lake Erie. Adult abundance increased in 2011 to 0.92 fish per lift following a sharp decline in 2010 (Figure 1.6). Adult abundance estimates in 2011 were comparable to estimates from 2008 and 2009. The index remains well below the basin-wide rehabilitation target of 2.0 fish/lift (Markham et al. 2008).

The relative abundance of mature females over 4500 g, an index of repeat-spawning females ages 6 and older, also increased in 2011 to 0.15 fish per lift (Figure 1.7). This index value remains well below the rehabilitation plan basin-wide target 0.50 fish/lift for adult female abundance (Markham et al. 2008). An overall pattern of low and variable abundance of the adult lake trout spawning stock may be a key contributing factor to the continued absence of any documented evidence of natural reproduction in Lake Erie.

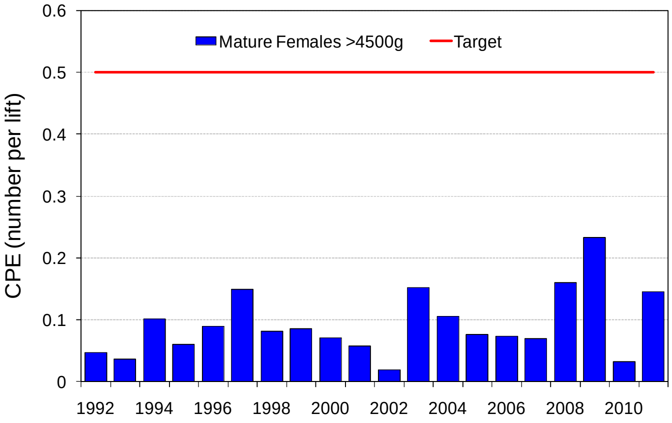


FIGURE 1.7. Relative abundance (number per lift) weighted by area of mature female lake trout (all strains) greater than 4500g in standard assessment gill nets in the eastern basin of Lake Erie, 1992-2011.

Stocking Performance

The proportion of stocked lake trout surviving to age 2 provides an index of stocking success. The stocking performance (SP) index is calculated by dividing age-2 CPE from standardized gill net catches by the number of fish in that year-class stocked. The quotient is multiplied by 10^5 to rescale the index to the number of age-2 lake trout caught per lift per 100,000 yearling lake trout stocked. Because the index is scaled to a standard, it can be used to compare survival of stocked fish to age-2 between years with any confounding effects from stocking amounts.

The SP index shows declining survival of stocked lake trout from 1992 through 1998 with very few of the yearlings stocked from 1994 through 1997 surviving to age-2 in 1995 through 1998 (Figure 1.8). The index increased beginning in 1999, likely due to a combination of different stocking methods, increased lake trout size at stocking, stocking strains, and a decreased adult lake trout population. Of interest was the 2006 spike in survival index to 1.11, which was the highest value in the time-series and can be attributed entirely to returns from Klondike-strain lake trout stocked in 2005. The 2011 SP index was 0.22, which was slightly above average for the time series and identical to the 2010 index. Stocking success has been near average for the past four years. However, actual age-2 abundances have been high the last two years relative to the time series due to

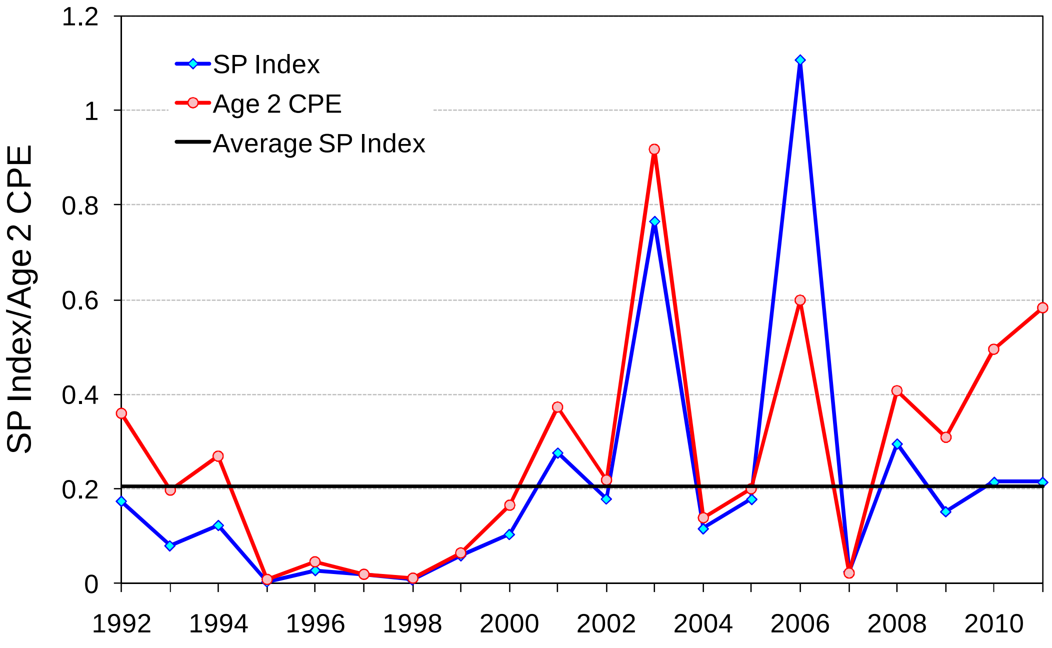


FIGURE 1.8. Stocking Performance (SP) index and age-2 CPE (number per lift) for lake trout sampled in standard assessment gill nets in the eastern basin of Lake Erie, 1992-2011. The SP index is equal to the number of age-2 fish caught per lift for every 100,000 yearling lake trout stocked.

Strains

Ten different lake trout strains were found in the 615 fish caught with either hatchery-implanted coded-wire tags (CWTs) or fin-clips in 2011 (Table 1.2). Finger Lakes (FL; 48%) and Klondike (KL; 31%) strain lake trout remain the most prevalent strains in the Lake Erie lake trout population. Finger Lakes have been the most prevalent strain stocked in Lake Erie while Klondikes have only been stocked in five of the past eight years. Lake Champlain (LC; 9%), Slate Island (SI; 5%), Traverse Island (TI; 3%) and Apostle Island (AI; 2%)) were the only other strains caught in significant numbers. Superior (SUP) strain lake trout, stocked extensively in Lake Erie in the 1980s and again from 1997-2002, disappeared in assessment netting in 2010 and only one individual was sampled in 2011. The FL strain continues to show the most consistent returns at older ages; all but two of lake trout age-9 and older were FL or FL-hybrid (LE, LO, LC) strain fish.

TABLE 1.2. Number of lake trout per stocking strain by age collected in gill nets from the eastern basin of Lake Erie, August 2011. Stocking strain codes are: FL = Finger Lakes, SUP = Superior, LL = Lewis Lake, KL = Klondike, LE = Lake Erie, SI = Slate Island, TI = Traverse Island, AI = Apostle Island, LC = Lake Champlain, MIC = Michipicoten. Shaded cells indicate cohorts with a stocking history.

AGE	FL	SUP	LL	KL	LE	SI	TI	AI	LC	MIC
1									7	
2						20			32	1
3	46		6	99		12		14	15	
4	115			52						
5	66			29			18			
6	6									
7				10						
8	23			2						
9	25									
10	9									
11	1									
12	2									
13		1								
14										
15	1									
16					1					
17										
18										
19			1							
20										
21	1									
TOTAL	**295**	**1**	**7**	**192**	**1**	**32**	**18**	**14**	**54**	**1**

TABLE 1.3. Cohort analysis estimates of annual survival (S) by strain and year class for lake trout caught in standard assessment nets in the New York waters of Lake Erie, 1985–2011. Three-year running averages of CPE from ages 4–11 were used due to year-to-year variability in catches. Shaded cells indicate survival estimates that fall below the 0.60 target rate. Asterisk (*) indicates years where straight CPE's were used for ages 4-10 (SUP 2001, FL 2001), 5-9 (FL 2002), 5-8 (FL 2003, KL 2003), or 4-7 (KL 2004).

	STRAIN					
Year Class	**LE**	**LO**	**LL**	**SUP**	**FL**	**KL**
1983				0.687		
1984				0.619	0.502	
1985				0.543	0.594	
1986				0.678		
1987				0.712	0.928	
1988		0.784		0.726	0.818	
1989		0.852		0.914	0.945	
1990		0.840		0.789	0.634	
1991		0.763	0.616			
1992	0.719		0.568			
1993	0.857				0.850	
1994						
1995						
1996					0.780	
1997				0.404	0.850	
1998				0.414		
1999				0.323	0.760	
2000				0.438	0.769	
2001*				0.296	0.753	
2002*					0.692	
2003*					0.596	0.321
2004*						0.308
MEAN	**0.788**	**0.81**	**0.592**	**0.580**	**0.748**	**0.315**

Survival

Cohort analysis estimates of annual survival (S) were calculated by strain and year class using a 3-year running average of CPE with ages 4 through 11. A running average was used due to the high year-to-year variability in catches. Mean overall adult survival estimates varied by strain and year. The Finger Lakes (FL) strain, the most consistently stocked lake trout strain in Lake Erie, had an overall mean survival estimate of 0.748. Survival estimates prior to 1986 are low due to the effects of a large sea lamprey population. Survival of the 1987 –1991 year classes were comparably higher as the sea lamprey population declined and the number of adult lake trout increased, decreasing the affect of host density. Survival estimates during this period (1987-91) were highest for the FL strain (0.83) and lowest for the SUP strain (0.79). The LO strain, a cross between SUP and FL strains, was intermediate at 0.81. Survival estimates declined beginning with the 1992 year class as the lamprey population increased.

More recent estimates indicate that survival has declined well below target levels, presumably due to increased levels of sea lamprey predation. Survival estimates of the 1997-2001 year classes of SUP strain lake trout range from 0.296-0.438 (Table 1.3). Survival estimates from the 1996, 1997, and 1999-2001 FL strain are much higher, but are based on very low returns. More recent estimates from the 2002 and 2003 year classes of FL strain indicate lower survival rates. All of these survival estimates are below the ranges that were observed for these strains during the period of high-lamprey control. Preliminary estimates of the 2003 and 2004 year classes of Klondike strain fish indicate very low survival rates (0.308 – 0.321) at adult ages. These rates are comparable to survival rates of Superior strain lake trout from the 1997-2001 year classes. Mean overall survival estimates were above the target goal of 60% or higher (Lake Trout Task Group 1985; Markham et al. 2008) for LE, LO, and FL strains but below target for the LL, SUP, and KL strains.

Growth and Condition

Mean length-at-age and mean weight-at-age of eastern basin Lean strain lake trout remain consistent with averages from the previous ten years (2001-2010) through age 11 (Figures 1.9 and 1.10). Deviations at older ages were due to low sample sizes. Klondike strain lake trout show lower growth trajectories than Lean strain lake trout through age-7. Mean length and weight of Klondike strain lake trout was significantly less than FL strain fish by age-3 (two sample t-test; P<.01).

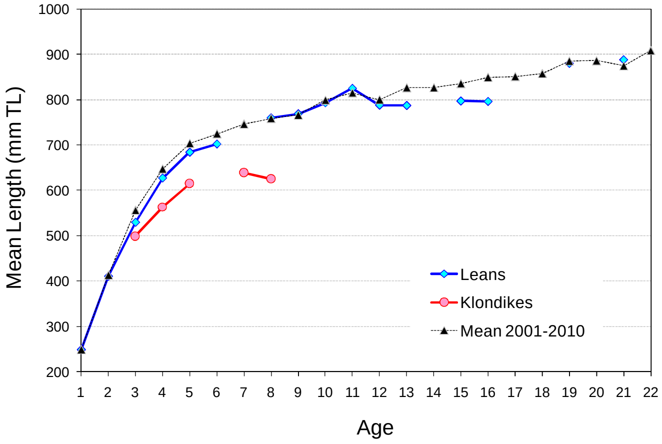


FIGURE 1.9. Mean length-at-age of Lean strain and Klondike strain lake trout sampled in assessment gill nets in the eastern basin of Lake Erie, August 2011. The previous 10-year average (2001-2010) from New York waters is shown for current growth rate comparison.

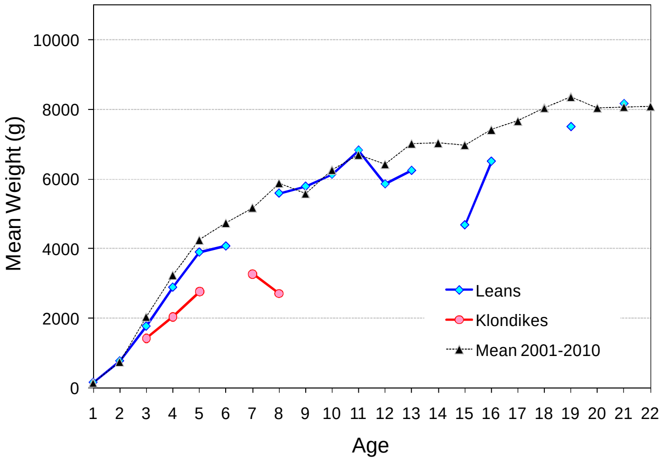


FIGURE 1.10. Mean weight-at-age of Lean strain and Klondike strain lake trout sampled in assessment gill nets in the eastern basin of Lake Erie, August 2011. The previous 10-year average (2001-2010) from New York waters is shown for current growth rate comparison.

Mean coefficients of condition (Everhart and Youngs 1981) were calculated for age-5 lake trout by sex to determine time-series changes in body condition. Overall condition coefficients for age-5 lake trout remain well above 1.0, indicating that Lake Erie lake trout are, on average, heavy for their length (Figure 1.11). Condition coefficients for age-5 male and female lake trout show an increasing trend from 1993-2000. Female condition began to decline in 2004 and male condition in 2001, but both increased again in 2007 and 2008. Condition of male and female age-5 fish was lower for Klondike than for Lean strain lake trout in 2008; condition of Klondike's in both sexes decreased in 2009. In 2011, condition coefficients increased slightly for females of both Lean and Klondike strains compared to their last value, but decreased slightly for both Lean strain and Klondike strain males.

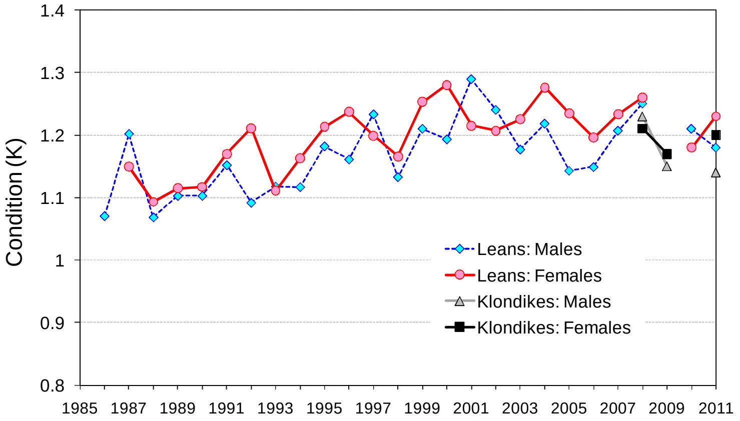


FIGURE 1.11. Mean coefficients of condition for age-5 Lean strain and Klondike strain lake trout, by sex, collected in NYSDEC assessment gill nets in Lake Erie, August 1985-2011.

Maturity

Maturity rates of Lean strain lake trout remain consistent with past years where males are nearly 100% mature by age 4 and females by age 5 (Table 1.1A). Klondike strain lake trout appear to have similar maturity rates to Lean strain lake trout in Lake Erie (Table 1.1B).

Harvest

Angler harvest of lake trout in Lake Erie remains very low. Approximately 247 lake trout were harvested in New York waters out of an estimated catch of 637 in 2011 (Figure 1.12). In Pennsylvania waters, a total 117 lake trout were harvested out of an estimated total catch of 1,338 fish. This was the first harvest of lake trout in Pennsylvania waters since 2005.

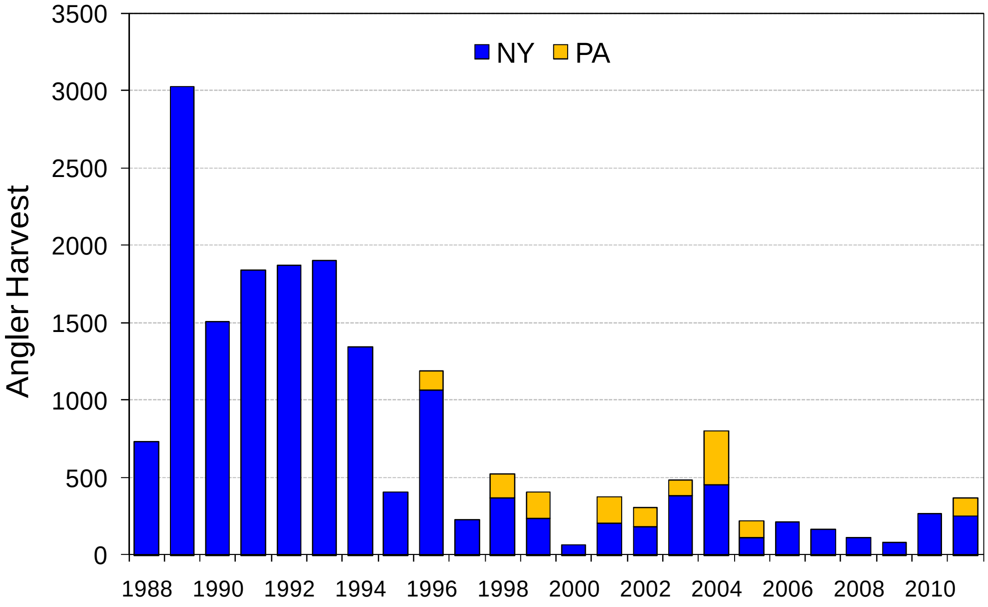


FIGURE 1.12. Estimated lake trout harvest by recreational anglers in the New York and Pennsylvania waters of Lake Erie, 1988-2011.

Natural Reproduction

Despite more than 30 years of lake trout stocking in Lake Erie, no naturally reproduced lake trout have been documented. Five potentially wild fish (no fin clips; no CWT's) were caught in eastern basin coldwater gill net surveys in 2011, making a total of 54 potentially wild lake trout recorded over the past eleven years. Otoliths are collected from lake trout found without CWTs or fin-clips and will be used in future stock discrimination studies.

A GIS project was conducted by the USGS (Sandusky) and Ohio Division of Wildlife to determine potential lake trout spawning sites within Lake Erie (Habitat Task Group 2006). The goal of this exercise was to identify areas with suitable physical habitat for lake trout spawning within Lake Erie so that future stocking efforts may be directed at those sites. Side-scan sonar work was also accomplished during 2007, 2008 and 2009 on several of the identified sites in the eastern basin of Lake Erie near Port Maitland, Ontario, and at Brocton Shoal near Dunkirk, New York (Habitat Task Group 2011). Several funding proposals (Canada-Ontario Agreement; USFWS Restoration Funds) were accepted in 2007 and 2008 to further examine the sites identified in the GIS-phase of this exercise using side-scan sonar and underwater video imaging. Results of the data analysis of the side-scan mosaics and underwater video indicate potential spawning habitat on Brocton Shoal, Presque Isle Bay, Nanticoke

Shoal, Hoover Point, and Tecumseh Reef. However, underwater video indicates that the quality of the habitat has undergone considerable deterioration, especially at Brocton Shoal, mainly due to dreissenid colonization and extensive sedimentation. There are nearshore areas in Presque Isle Bay and Nanticoke Shoal that do not exhibit extensive dreissenid colonization, and appear to hold more favorable spawning substrate.

For the fourth consecutive year, a gill net survey was conducted by the NYSDEC during November to determine if lake trout were using any local spawning areas. Underwater bottom video work conducted during the summer months revealed a large area of rocks off the mouth of 18 Mile Creek near Hamburg, NY. Rock formations at this site appeared to be favorable for spawning lake trout – cobble sized rocks in piles with open interstitial spaces (Figure 1.13). Furthermore, the rocks did not appear to be as heavily encrusted with dreissenids as areas on Brocton Shoal. Despite being far from lake trout stocking locations (25 miles), the quality and quantity of suitable habitat in this area made it a candidate for lake trout spawning assessment.

FIGURE 1.13. Underwater photo of bottom habitat off 18 Mile Creek Shoal in Lake Erie, July 2011.

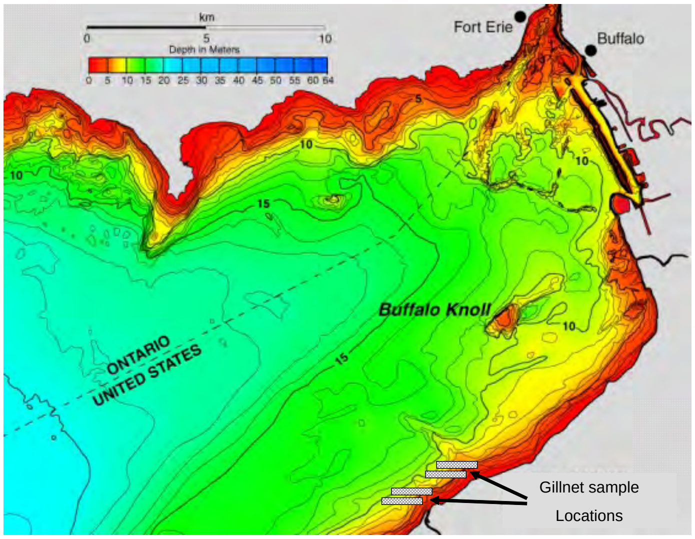


FIGURE 1.14. Gill net survey locations sampled for spawning lake trout in the New York waters of Lake Erie, November 2011.

A total of four gangs (1200 gill net feet) were fished overnight on 7 November 2011 at 18 Mile Creek (Figure 1.14). Two sets were made at the east end of rocky area in 11-17 feet of water, and two at the west end in 12-18 feet of water. Bottom water temperature during all sampling was 50F. Poor weather conditions prevented further sampling later in the fall.

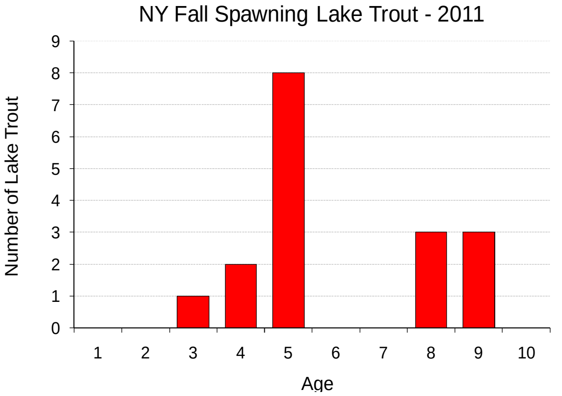


FIGURE 1.15. Age distribution of lake trout sampled in the New York waters of Lake Erie, November 2011.

A total of 18 lake trout were caught in the four nets. The fish were generally scattered over the site with 10 fish caught in the two western nets and 8 fish in the two eastern nets. Twelve of the lake trout were males and six females, and all the females were pre-spawn, mature fish. All the lake trout were Finger Lakes (FL) strain with the exception of a single 3-year old Lake Champlain (LC) strain fish. Ages ranged from 3-9 years old with the majority of the fish being 5 years old (2006 year class; Figure 1.15). Fifteen of the lake trout caught were stocked offshore of Dunkirk and the remaining three were stocked offshore at Barcelona.

Lake Trout Population Model

The CWTG has assisted the Forage Task Group (FTG) in the past by providing a lake trout population model to estimate the lake trout population in Lake Erie. The model is a spreadsheet-type accounting model, initially created in the late 1980's, and uses stocked numbers of lake trout and annual mortality to generate an estimated adult (age 5+) population. The Lake Erie CWTG has been updating and revising the model since 2005, incorporating new information on strain performance, survival, sea lamprey mortality, longevity, and stocking. The most recent working version of the model separates each lake trout strain to accommodate strain-specific mortality, sea lamprey mortality, and stocking. The individual strains are then combined to provide an overall estimate of the adult (ages 5+) lake trout population. Unlike previous versions, the current model's output now follows the general trends of the survey data and computes mortality estimates that are near levels measured from survey data. While the absolute numbers generated from model simulations are probably not comparable to the actual Lake Erie lake trout population, the model does provide a good tool for predicting trends into the future under various management and population scenarios.

The 2011 lake trout model estimated the Lake Erie population at 307,817 fish and the age-5 and older population at 35,817 fish, less than half of what it was a decade ago when the lake trout population was at its peak (Figure 1.16). The Strategic Plan for Lake Trout Restoration (Lake Trout Task Group 1985) suggested that successful Lake Erie rehabilitation required an adult population of 75,000 lake trout. Model projections using low and moderate rates of sea lamprey mortality and proposed stocking rates show that the adult lake trout population is suppressed by one-third over the next decade with moderate mortality compared to low mortality. Model simulations indicate that both stocking and sea lamprey control are major influences on the Lake Erie lake trout population.

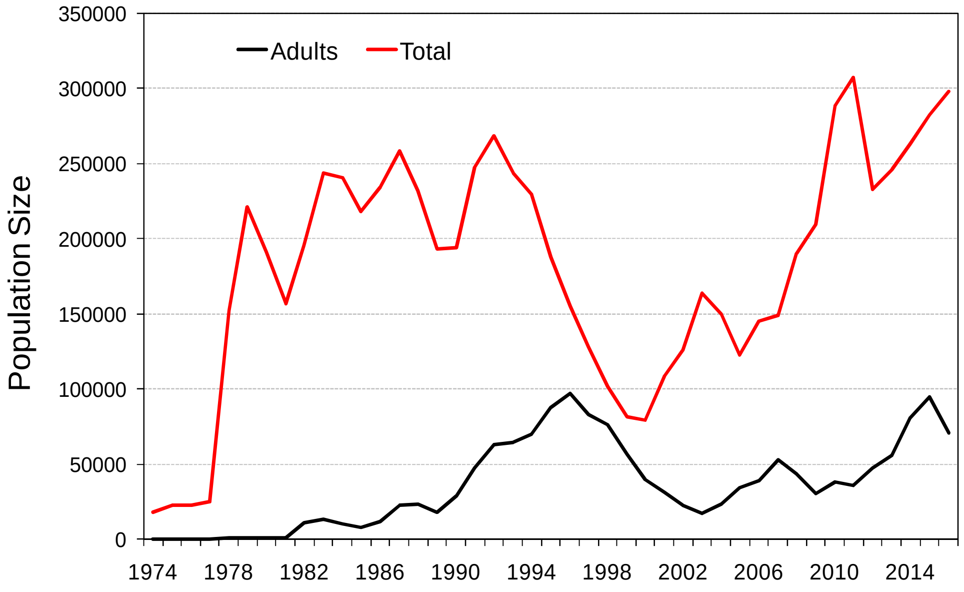


FIGURE 1.16. Projections of the Lake Erie total and adult (ages 5+) lake trout population using the CWTG lake trout model. Projections for 2012-2016 were made using low rates of sea lamprey mortality with proposed stocking rates. The model estimates the lakewide lake trout population in 2011 at 307,817 and the adult population at 35,817.

Diet

Diet information was limited to fish caught during August 2011 in the coldwater gill net assessment surveys in the eastern basin of Lake Erie. Analysis of the stomach contents of lake trout revealed diets comprised mainly of rainbow smelt and round gobies (Table 1.4). Rainbow smelt were the most prevalent diet item in both Lean

(83%) and Klondike (71%) strain lake trout. Round gobies were the second most commonly encountered prey item (Leans = 19%; Klondikes = 32%). When smelt are in good supply, they appear to be the preferred prey item for all lake trout. However, in years of lower adult smelt abundance, lake trout appear to prey more on round gobies. Klondike strain lake trout consistently have higher percentages of round gobies in their diets compared to lean strain lake trout (Coldwater Task Group 2011). Emerald shiners and yellow perch were the only other identified prey species that were encountered in 2011.

TABLE 1.4. Frequency of occurrence of diet items from non-empty stomachs of Lean and Klondike strain lake trout collected in gill nets from eastern basin waters of Lake Erie, August 2011.

PREY SPECIES	**Lean Lake Trout (N = 262)**	**Klondike Lake Trout (N = 99)**
Smelt	218 (83%)	70 (71%)
Yellow Perch	1 (<1%)	
Round Goby	49 (19%)	32 (32%)
Emerald Shiner	4 (2%)	1 (1%)
Unknown Fish	20 (8%)	7 (7%)
Number of Empty Stomachs	204	74

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Charge 2: Continue to assess the whitefish population age structure, growth, diet, seasonal distribution and other population parameters.

Andy Cook (OMNR) and Kevin Kayle (ODW)

Commercial Harvest

The total harvest of Lake Erie lake whitefish in 2011 was 616,973 pounds (Figure 2.1). Ontario accounted for 86% of the total, harvesting 530,013 pounds, followed by Ohio (13%; 82,805 lbs.), with less than 1% of the harvest in Michigan (4,155 lbs.) and none in Pennsylvania or New York (Figure 2.2). Total harvest in 2011 was 10% lower than the total harvest in 2010. Lake whitefish harvest in 2011 declined 1% in Ohio waters and 12% in Ontario from 2010.

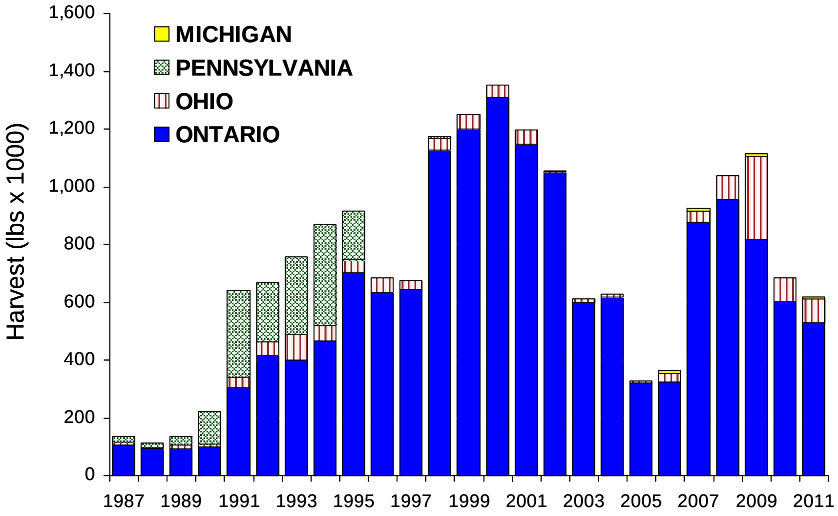

FIGURE 2.1. Total Lake Erie commercial whitefish harvest from 1987-2011 by jurisdiction. Pennsylvania ceased gill netting in 1996, and Michigan resumed commercial fishing in 2006, excluding 2008.

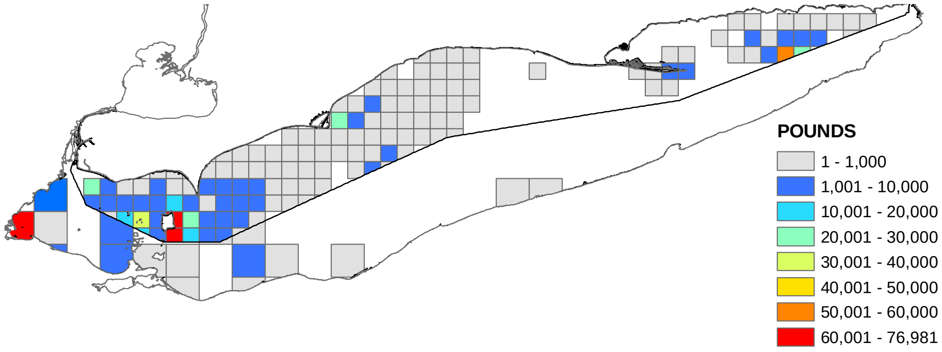

FIGURE 2.2. Lake whitefish harvest among all Lake Erie jurisdictions during 2011 by 5 minute (Ontario) and 10 minute (Michigan, Ohio) grids. No lake whitefish harvest was reported in Pennsylvania and New York.

The majority (99%) of Ontario's 2011 lake whitefish harvest was taken in gill nets. The remainder was caught in smelt trawls (1%), and harvest in impoundment gear (85 lbs.) was negligible. The largest fraction of Ontario's whitefish harvest (64%) was caught in the west basin (OE1) followed by OE5 (19%), and OE2 (15%), with the remaining harvest divided equally in OE3 (1%) and OE4 (1%). Harvest in OE1 occurred primarily from October to December (99%), whereas OE5 peaked from August to October (89%) with some harvest (11%) occurring during April and May. The majority of the lake whitefish harvest in OE2 (81%) occurred from March to May, with additional harvest during the fall. Harvest in OE3 and OE4 occurred throughout the year. In Ontario, 82% of lake whitefish were harvested from gill nets targeting whitefish, followed by fisheries targeting walleye (10%), white bass (6%), and white perch (1%), with a small portion coming from smelt trawls (1%), and a negligible harvest from yellow perch gill nets.

Ohio's lake whitefish trap net effort in 2011 occurred primarily in the western basin in November (20%) and in the central basin in May (31%) and June (14%); however, the peak harvest occurred during November (85%) and December (8%) in the western basin.

Ontario annual commercial catch rates targeting lake whitefish dropped in quota areas 2 and 3, but increased in quota area 1 (Figure 2.3). The mean catch rate of the three quota areas in 2011 decreased 14% from the 2010 mean. In the west basin (OE1), targeted gill net effort was greatest in November, while harvest was similar between October and November, and much less during December (Figure 2.4). OE1 catch rates in 2011 increased from 2010 levels during October and November, but were lower in December. Overall, Ohio commercial trap net catch rates observed for 2011 were 29% lower than 2010 and 80% lower than peak catch rates observed in 2009 (Figure 2.5).

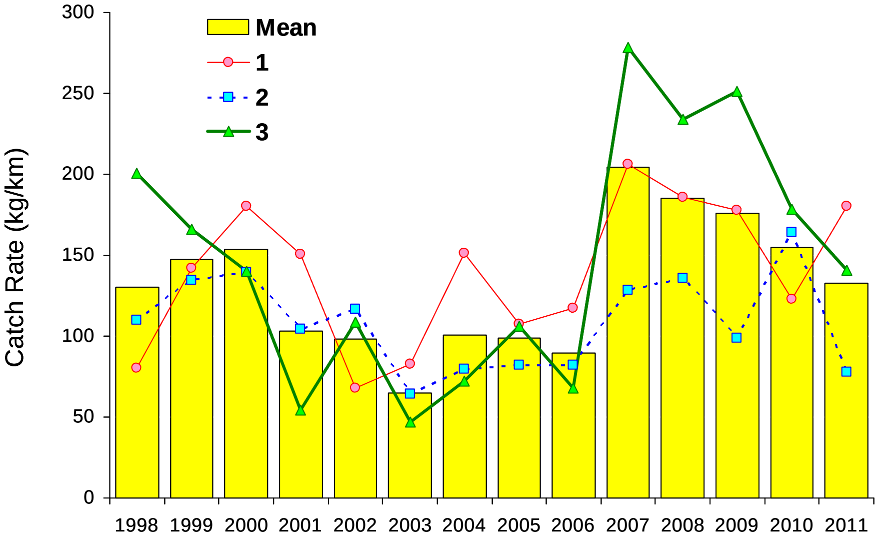

FIGURE 2.3. Ontario annual commercial large mesh gill net catch rates targeting lake whitefish by quota zone, 1998 - 2011. Bars represent averages of catch rates across quota zones. Quota zone 1 refers to the west basin, zone 2 extends eastward to the middle of the central basin. The eastern portion remaining is quota zone 3.

The landed weight of roe from Ontario's 2011 lake whitefish fishery was 25,265 pounds, most of which came from OE1 during November (59%) and October (38%). The remaining fraction of roe was collected from OE2 (2%) during October and November, and OE5 during October (1%). The approximate landed value of the roe was CDN $77,779.

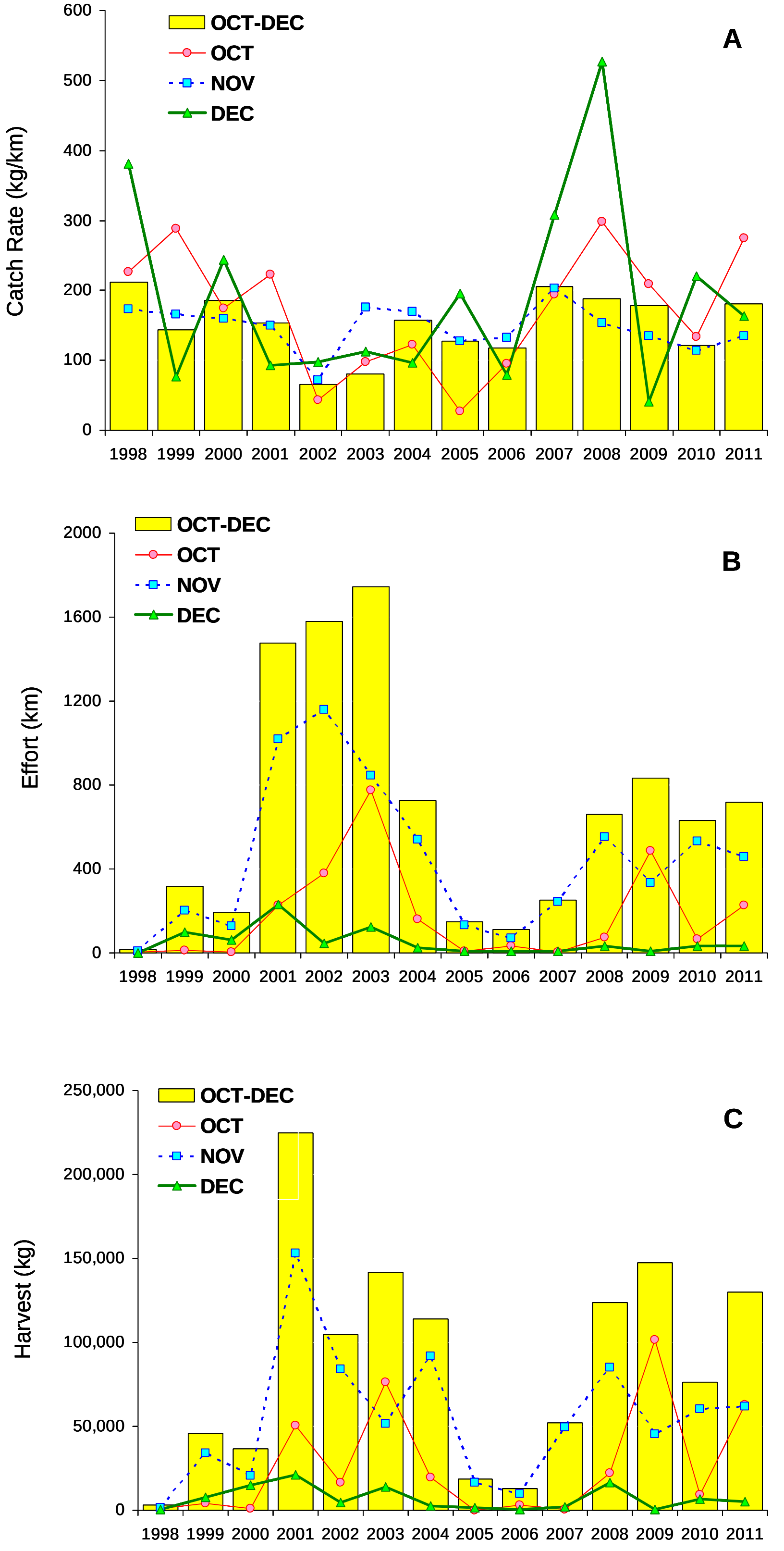

FIGURE 2.4. Targeted large mesh gill net catch rate (A), gill net effort (B) and harvest (C) for lake whitefish in the west basin for October, November, December and pooled (Oct-Dec) 1998 - 2011.

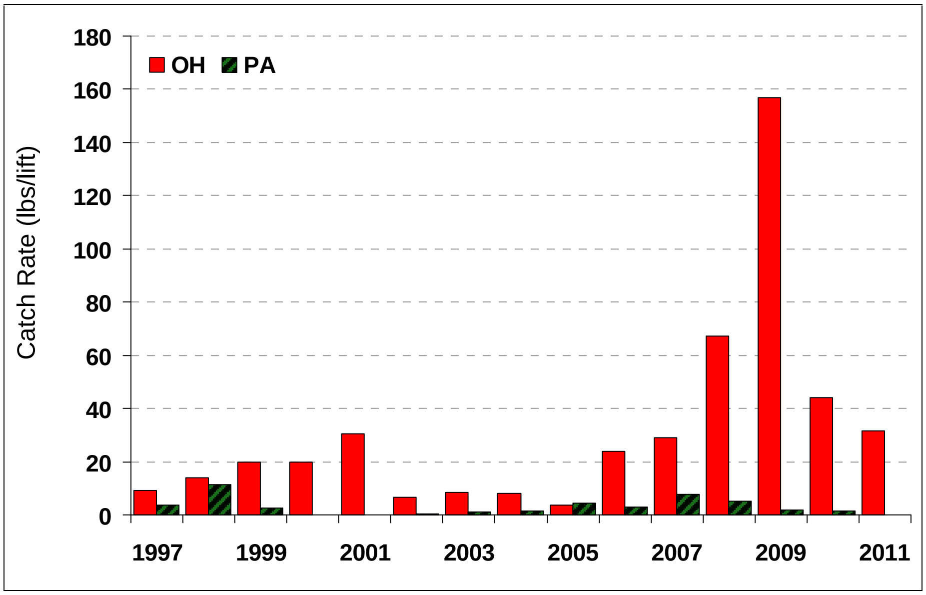

FIGURE 2.5. Ohio and Pennsylvania lake whitefish commercial trap net catch rates (pounds per lift), 1996-2011. There was no lake whitefish harvest in Pennsylvania in 2011.

Ontario's west basin fall lake whitefish fishery was dominated by age-8 fish (Figure 2.6). The strong 2003 cohort dominated catches in targeted and non-targeted (walleye) fisheries (Figure 2.7). Age-6 was the next most abundant year class (2005) and the oldest lake whitefish in Ontario's harvest was 20 (Figure 2.6 and 2.7). There was no characterization of the lake whitefish commercial fishery by age in Ohio in 2011.

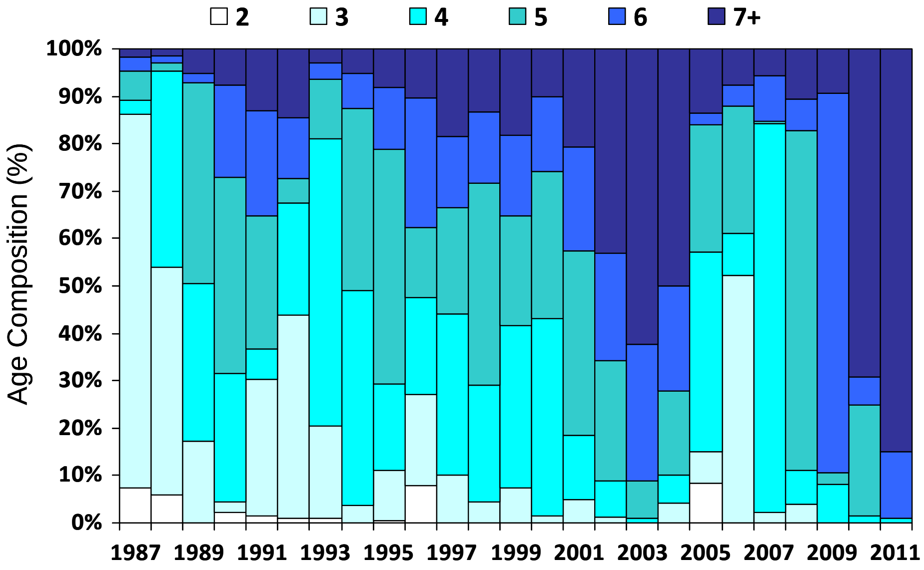

FIGURE 2.6. Ontario fall commercial whitefish harvest age composition in statistical district 1, 1986-2011. From effort with gill nets >=3 inches with whitefish in catch from October to December.

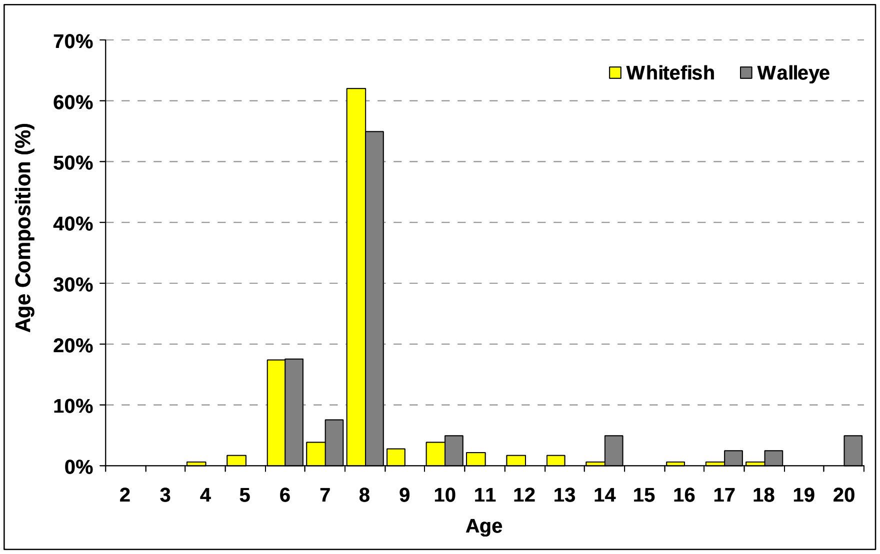

FIGURE 2.7. Age composition of lake whitefish caught commercially in Ontario waters of Lake Erie in 2011 by target species fisheries. Otoliths and scales were used to age whitefish samples. N=219.

Assessment Surveys

Lake whitefish abundance indices in the 2011 gill net assessments were generally low (Figures 2.8 and 2.9). Lake whitefish were absent in Ontario west basin, east basin, and Pennsylvania Ridge gill net surveys. Catch rates in central basin surveys were low, with a drop in the east-central basin catch rates offset by a marginal increase in the west-central basin catch rates (Figure 2.8).

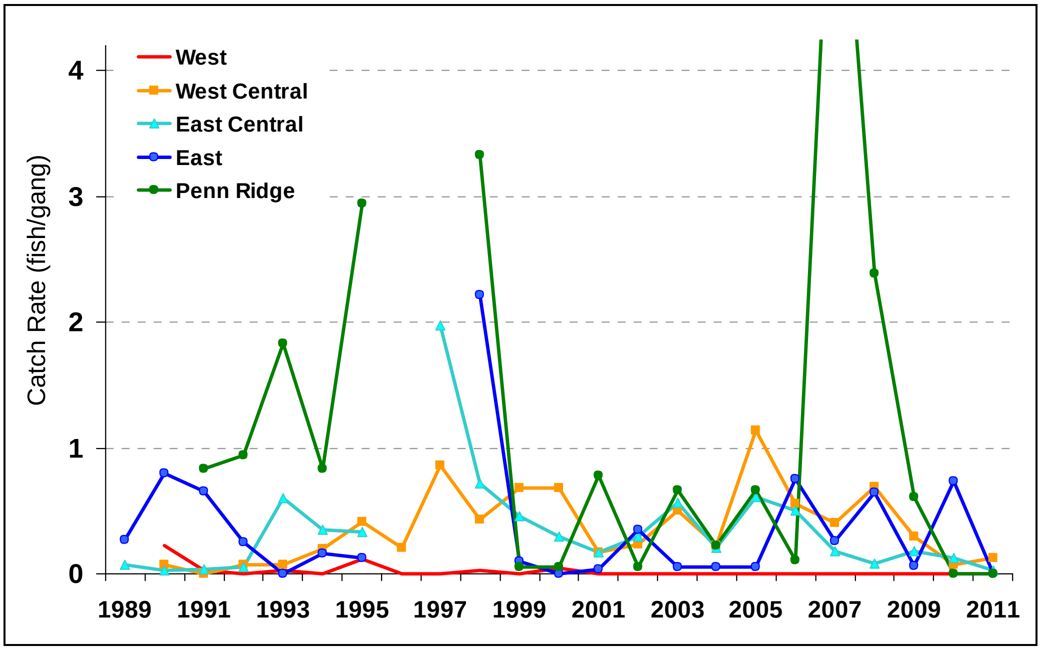

FIGURE 2.8. Catch rate (number per gang) of lake whitefish from Ontario partnership index gill netting by basin, Lake Erie, 1989 - 2011.

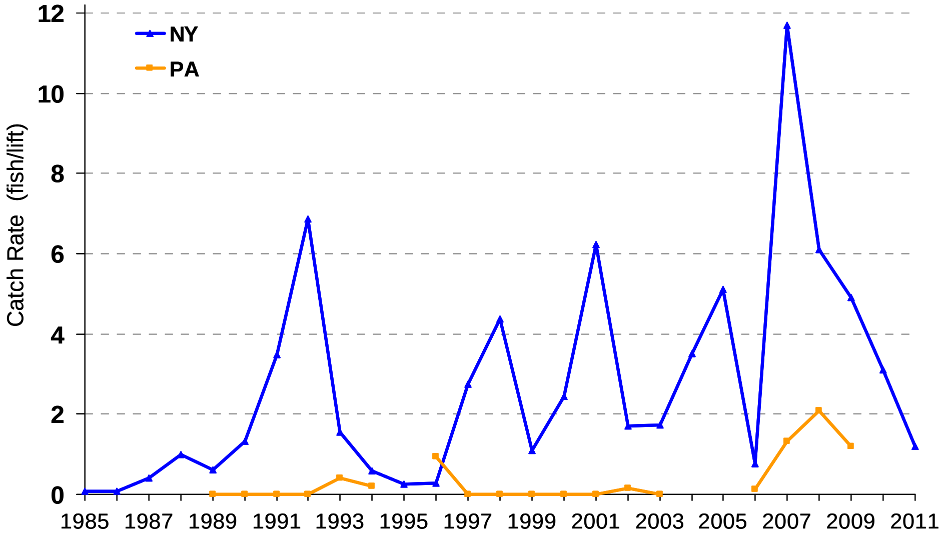

FIGURE 2.9. Catch per effort (number fish/lift) of lake whitefish caught in standard assessment gill nets from New York waters of Lake Erie, August 1985-2009 (triangles) and in Pennsylvania August assessment gill nets (squares) 1989-2009. No index sampling took place in Pennsylvania waters 1995, 2004, 2005, 2010 and 2011.

Declining lake whitefish catch rates observed since 2007 continued during the 2011 New York coldwater assessment survey (1.2 whitefish per lift; Figure 2.9). Length-frequency distributions of lake whitefish captured in Ontario partnership index gill netting reflected the dominance of older whitefish (Figure 2.10). The majority (64%) of lake whitefish sampled in the Ontario surveys were from the 2003 cohort, with the 2005, 2002, 1999 and 1995 year classes present (Figure 2.11). The youngest whitefish caught during Ontario Partnership surveys was age-6.

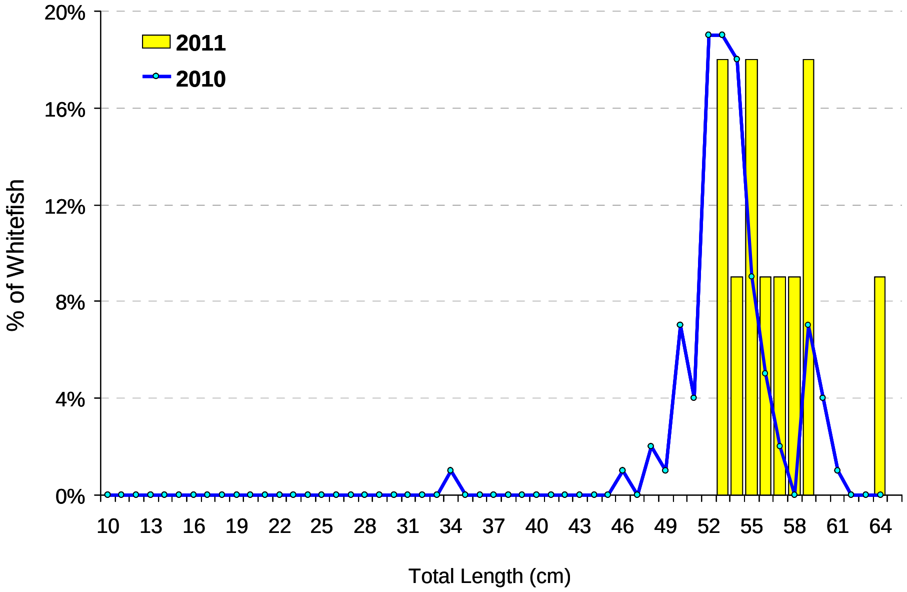

FIGURE 2.10. Length frequency distributions of lake whitefish collected during lake-wide partnership index fishing, 2010 and 2011. Standardized to equal effort among mesh sizes.

Ohio trawl surveys in the central basin of Lake Erie assess juvenile lake whitefish and describe the presence or general magnitude of year classes. These surveys can encounter migrating lake whitefish during the spring and fall. Since the strong 2003 year class, Ohio central basin (Statistical District 2 and District 3) bottom trawl surveys conducted in August and October only captured young-of-the-year (YOY) from the 2004, 2005 and 2007 year classes. In addition, yearlings from the 2004 and 2005 year classes were caught in Ohio bottom trawls. During this past year, one yearling lake whitefish was captured in a June trawl survey. The 2007-2009 and 2011 year classes were not present in the 2011 Ohio surveys. In interagency trawl and gill net assessment surveys in Ohio waters of Lake Erie during August and October 2011, a total of 24 adult lake whitefish were sampled. The 2003 year class (age-8) was most numerous (54%), followed by lake whitefish from 2002 (age-9; 13%) and 2004 cohorts (age-7; 8%). Older lake whitefish, ages-10 to -20, represented 17% of the age composition (Figure 2.12).

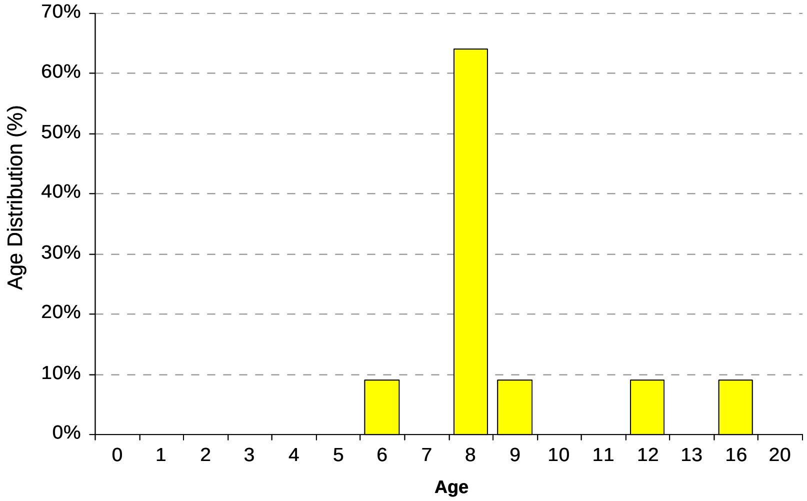

FIGURE 2.11. Age frequency distributions of lake whitefish collected during lake-wide partnership index fishing, 2011.

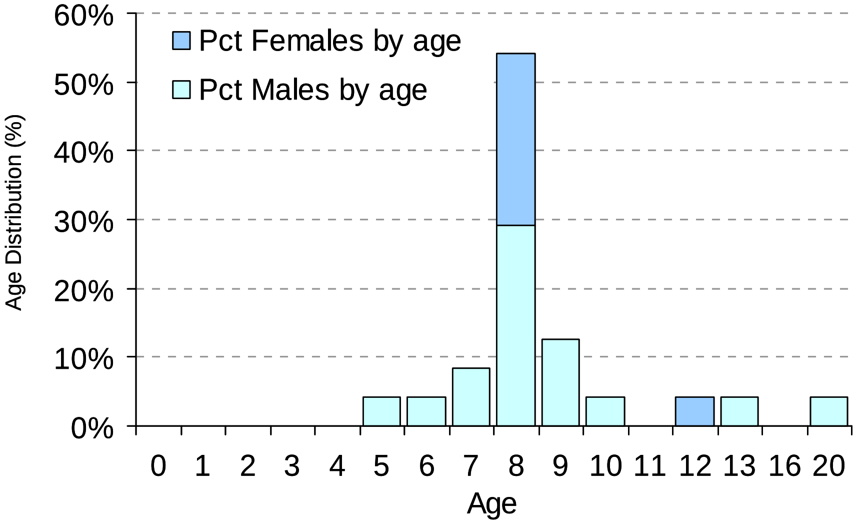

FIGURE 2.12. Age distribution of lake whitefish collected during trawl and gill net assessment surveys in Ohio waters of Lake Erie during 2011.

Growth and Diet

Lake whitefish sampled in Ohio assessment trawl and gillnet surveys in 2011 indicated that condition of age-4 and older males (mean K= 1.043) and females (mean K= 1.266) were above Van Oosten and Hile's (1947) historic condition reference values (Figure 2.13).

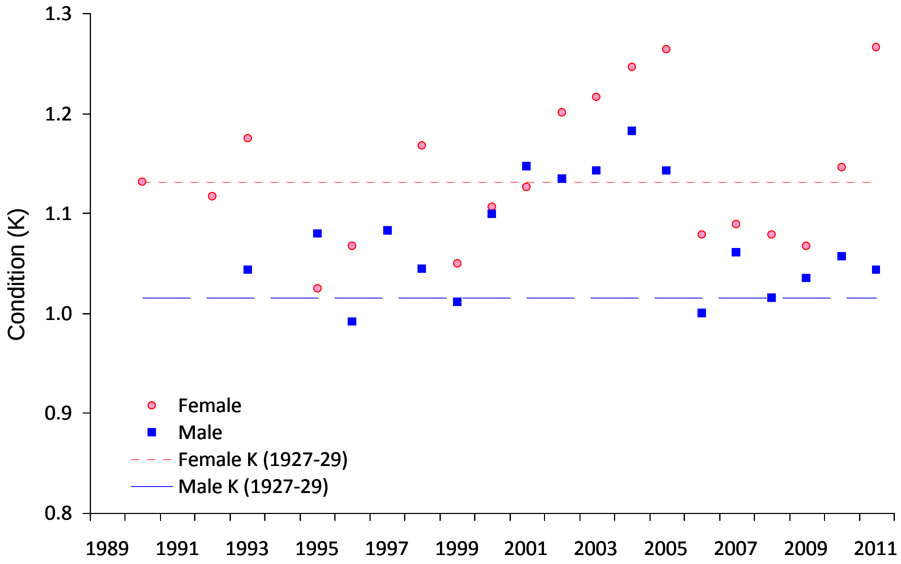

FIGURE 2.13. Mean condition (K) factor values of ages 4 and older lake whitefish sampled during Ohio assessment surveys in the central basin of Lake Erie, May-October 1990-2011. Historic mean condition (1927) presented as dashed lines from Van Oosten and Hile (1947).

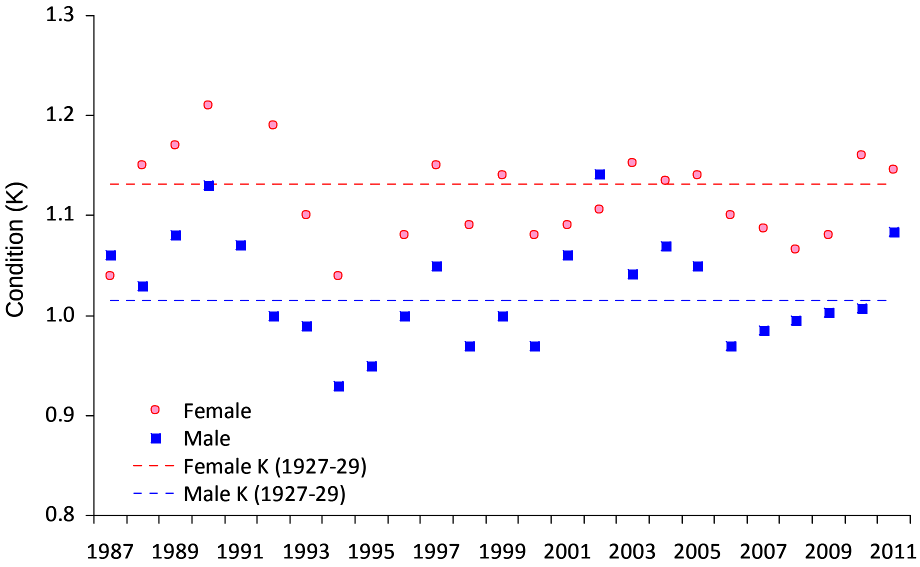

FIGURE 2.14. Mean condition (K) factor values of age 4 and older lake whitefish obtained from Ontario commercial and partnership survey data (Oct-Dec) by sex from 1987-2011. Historic mean condition (1927-29) presented as dashed lines calculated from Van Oosten and Hile (1947).

In 2011, condition of female (mean = 1.146) and male (1.131) lake whitefish assessed using Ontario fall commercial fishery and partnership gillnet survey data was above the historic average for each sex: 1.131 for females and 1.015 for males, respectively (Van Oosten and Hile 1947; Figure 2.14). Ontario lake whitefish assessed for condition analyses only included age-4 and older fish that were not spent or running, and were collected from October to December.

Lake whitefish collected from Ohio surveys in 2011 (N=30) were examined for diet composition from samples from Ohio central basin Districts 2 and 3 (Figure 2.15). Approximately 27% of the diet samples taken from lake whitefish in 2011 were empty (N=8); and all of these were in fall survey samples. Whitefish diets, expressed as percentage total dry weight of all prey taxa consumed, were composed primarily of chironomids (64%) and isopods (34%). When looking at a smaller subset of lake whitefish diets taken during fall surveys (N=11), snails (gastropods, at 47% of the total dry weight) and fingernail clams (sphaeriids, at 11% by dry weight), were also important to the lake whitefish diets as were chironomids (37% by dry weight).

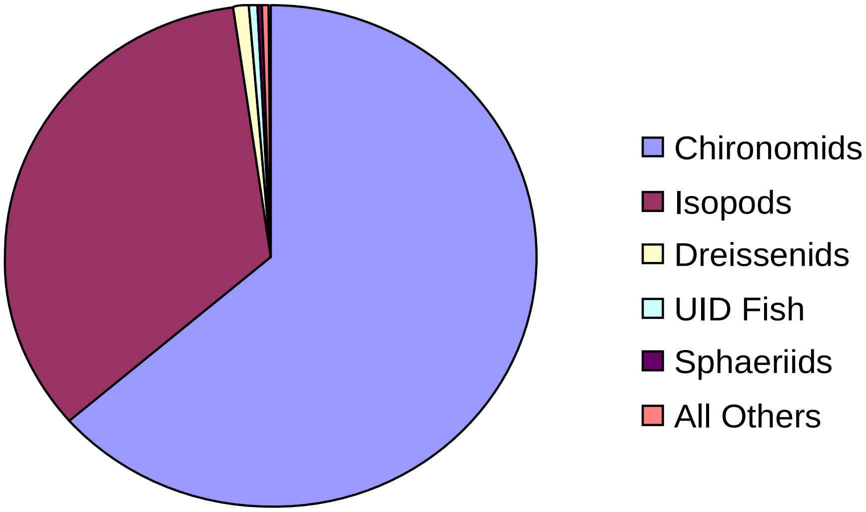

FIGURE 2.15. Diet composition (% dry weight) of lake whitefish from Ohio central basin assessment sites in 2011.

References

Van Oosten, J. and R. Hile. 1947. Age and growth of the lake whitefish, Coregonus clupeaformis (Mitchill), in Lake Erie. Transactions of the American Fisheries Society 77: 178-249.

Charge 3: Continue to assess the burbot fishery, age structure, growth, diet, seasonal distribution and other population parameters.

Larry Witzel (OMNR), Richard Kraus (USGS), and Elizabeth Trometer (USFWS)

Commercial Harvest

The commercial harvest of burbot by the Lake Erie jurisdictions was relatively insignificant through the late 1980's, generally remaining under 5,000 pounds (2,268 kg; Table 3.1). Harvest began to increase in 1990, coinciding with an increase in abundance and harvest of lake whitefish. Most commercial harvest occurs in the eastern end of the lake with minimal harvest occurring in Ohio waters and the western and central basins of Ontario waters.

TABLE 3.1. Total burbot commercial harvest (thousands of pounds) in Lake Erie by jurisdiction, 1980-2011.

Year	New York	Pennsylvania	Ohio	Ontario	Total
1980	0	2	0	0	2.0
1981	0	2	0	0	2.0
1982	0	0	0	0	0.0
1983	0	2	0	6	8.0
1984	0	1	0	1	2.0
1985	0	1	0	1	2.0
1986	0	3	0	2	5.0
1987	0	0	0	4	4.0
1988	0	1	0	0	1.0
1989	0	4	0	0.8	4.8
1990	0	15.5	0	1.7	17.2
1991	0	33.4	0	1.2	34.6
1992	0.7	22.2	0	5.9	28.8
1993	2.6	4.2	0	3.1	9.9
1994	3	12.1	0	6.8	21.9
1995	1.9	30.9	1.2	8.9	42.9
1996	3.4	2.3	1.2	8.6	15.5
1997	2.9	8.9	1.7	7.4	20.9
1998	0.2	9	1.5	9.9	20.6
1999	1	7.9	1.1	394.8	404.8
2000	0.1	3.5	0.1	30.1	33.8
2001	0.4	4.4	0	6.5	11.3
2002	0.9	5.2	0.1	3.4	9.6
2003	0.1	1.8	0.2	2.3	4.4
2004	0.5	2.4	0.9	5.4	9.2
2005	0.7	2.2	0.4	10	13.3
2006	0.9	1.7	0.3	2.4	5.3
2007	0.4	1.1	0.1	3.6	5.2
2008	0.2	0.3	0.0	1.2	1.7
2009	0.4	0.6	0.0	3.8	4.8
2010	1.4	0.1	0.0	1.8	3.2
2011	0.7	0.0	0.0	2.2	2.9

Harvest decreased in Pennsylvania waters after 1995 with a shift from a gill net to trap net commercial fishery, resulting in a substantial decrease of commercial effort (CWTG 1997). Harvest of burbot in New York is from one commercial fisher. In 1999, a market was developed for burbot in Ontario, leading the industry to actively target this species. As a result, the commercial harvest in Ontario increased dramatically (Table 3.1). However, this opportunistic market did not persist, resulting in declining annual harvests. The Ontario harvest is now a by-catch from various fisheries. Most of the burbot caught by the commercial fishing industry in 2011 was by-catch in gillnets from the lake whitefish fishery (88%) followed by the white bass fishery (8%). The total commercial harvest for Lake Erie in 2011 was 2,894 pounds (1,313 kg); a 40% decrease from 2010. In addition, some 3,577 pounds (1,622 kg) were released or discarded by Ontario commercial fishers in 2011.

Abundance and Distribution

Burbot are seasonally found in all the major basins of Lake Erie; however, the summer distribution of adult fish is restricted primarily to the 20-m and deeper thermally stratified regions of the eastern basin (Figure 3.1).

The Ontario Partnership Index Fishing Program is an annual lakewide gillnet survey of the Canadian waters of Lake Erie and has provided an additional and spatially robust assessment of fish species abundance and distribution since 1989. During the early 1990s, burbot abundance was low throughout the lake; catch rates in partnership index gill nets averaged less than 0.5 burbot/lift (Figure 3.2).

Burbot abundance increased rapidly after 1993 in the Pennsylvania Ridge area and in the eastern basin, reaching a peak of about 4 burbot/lift in 1998.

Burbot numbers in the central basin also peaked in 1998, but at a much lower catch rate of 0.5 burbot/lift. Catch rates in the Pennsylvania Ridge area during 1998 to 2004 remained high, but variable, ranging between 2.0 and 4.2 burbot/lift and then decreased to about 0.5 burbot/lift in 2005-2006. Catch rates in the eastern basin since 1998 have been variable but exhibit an overall decreasing trend. In 2011, only one burbot was captured in the central basin and abundance increased slightly in the east basin and Pennsylvania Ridge, reversing the prevailing downward trend. Despite the recent upturn, burbot numbers in eastern Lake Erie remained low relative to 1998 peak abundance (Figure 3.2).

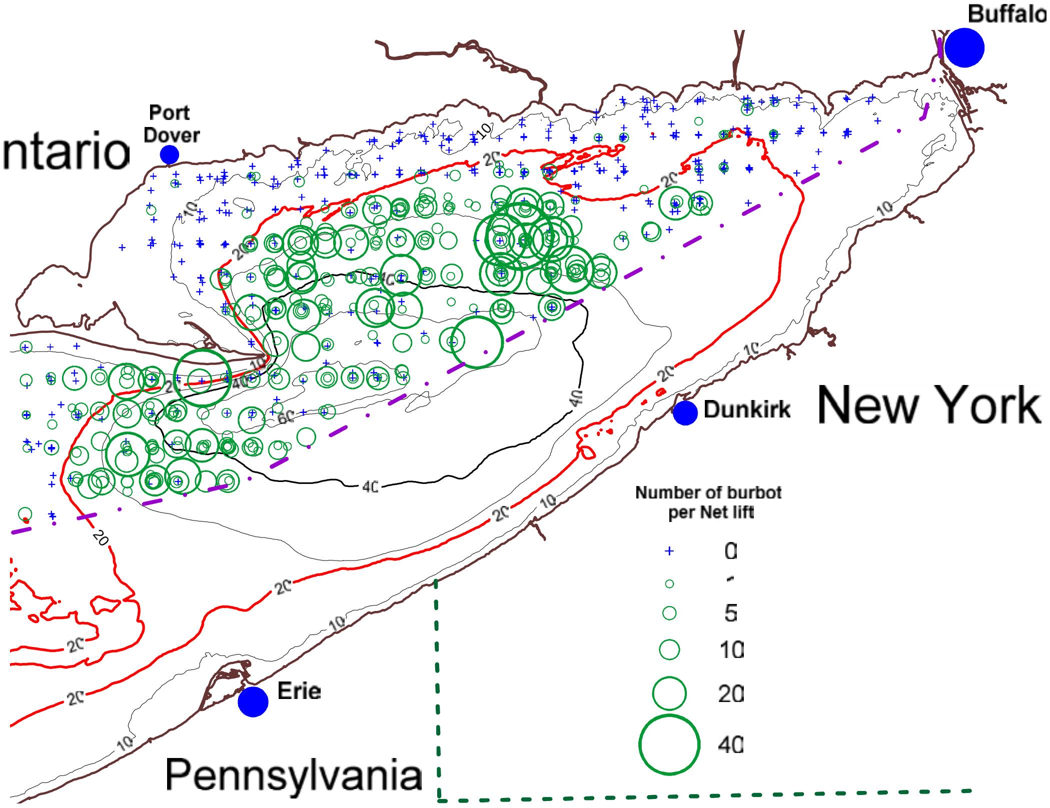

FIGURE 3.1 Distribution of burbot catches (No. per lift) in Ontario Partnership gill nets during August surveys of eastern Lake Erie, 1989 - 2011.

An examination of only the bottom sets in the Ontario Partnership assessment data for combined sample locations in the east basin and Pennsylvania Ridge show that the numeric abundance of burbot (in fish/lift) increased approximately eight-fold from 1993 to 1998, whereas the biomass CPE did not peak until 2003, some five years after maximum numeric abundance was observed (Figure 3.3). Burbot number and biomass have steadily decreased after reaching their respective peaks. Burbot abundance increased in 2011 and were similar to catch rates (numeric and biomass) observed during 2008-2009 (Figure 3.3).

Numeric abundance of burbot as determined from coldwater assessment gillnetting increased sharply after 1993, peaking in 2000 in all eastern basin jurisdictions except New York, where peak abundance was not observed until 2004 (Figure 3.4). The highest catch rates of burbot have occurred in Ontario waters during most years since 1996. Burbot numeric abundance has decreased across all eastern basin jurisdictions in recent years. Burbot catch rates increased in 2011, more so in Ontario (2.1 burbot/lift) than in New York (1.2 burbot/lift), but were still only about one-quarter of peak-year abundance. Pennsylvania waters were not surveyed in 2011.

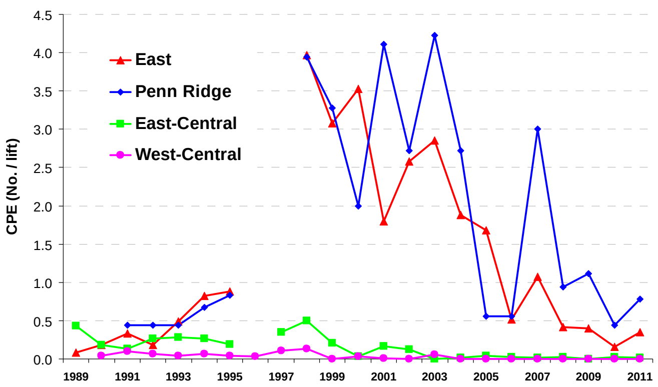

FIGURE 3.2 Burbot CPE (number of fish/lift) by basin from the Ontario Partnership surveys 1989–2011 (includes canned and bottom gill nets, all mesh sizes, except thermocline sets).

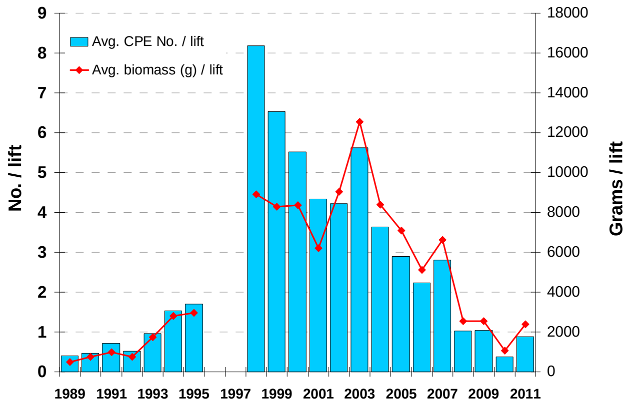

FIGURE 3.3. Average catch rate (CPE as number of fish/lift) and biomass (grams/lift) of burbot in Ontario waters of eastern Lake Erie, Ontario Partnership gillnet survey 1989–2011 (includes only bottom sets, all mesh sizes; PA-ridge and east basin sample sites).

In general, burbot biomass CPE has followed a similar pattern as numeric abundance except that burbot catches in summer coldwater gillnet assessments in Ontario and Pennsylvania did not reach maximum biomass until six or more years after maximum numeric abundance was observed (Figure 3.5). Although average burbot biomass CPE increased in Ontario (7.0 Kg/lift) and New York (3.7 Kg/lift), the 2011 catch rates were only about one-third or less of the maxima observed in these respective east basin areas (Figure 3.5). In Pennsylvania, the 2009 burbot biomass estimate was the lowest in their time series; no assessment occurred in 2010 and 2011.

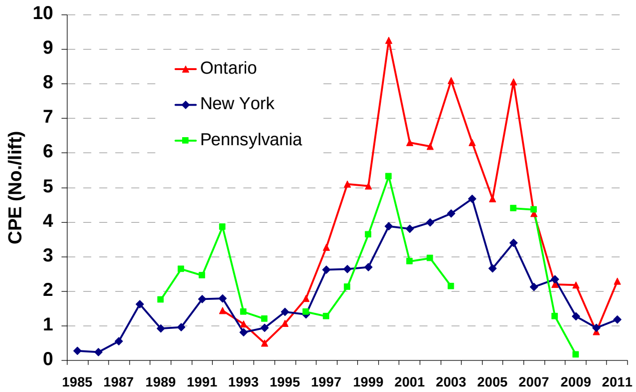

FIGURE 3.4 Average burbot catch rate (number of fish/lift) from summer coldwater gill net assessment by jurisdiction, 1985-2011. Pennsylvania waters were not surveyed in 2010 and 2011.

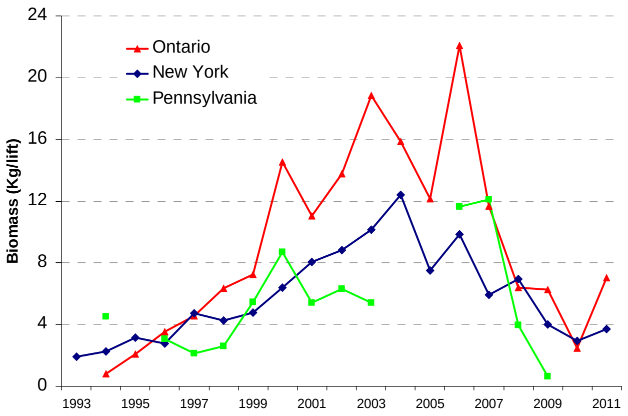

FIGURE 3.5 Average burbot biomass (kg/lift) from summer coldwater gill net assessment by jurisdiction, 1993-2011. Pennsylvania waters were not surveyed in 2010 and 2011.

Age and Recruitment

Burbot ages (from examinations of otoliths) have been estimated for fish caught in coldwater assessment gill nets in Ontario waters since 1997 and for the entire east basin survey area in 2011. The 2011 burbot catch ranged in age from 3 to 20 years (Figure 3.6). Burbot older than 12 years represented 74% of aged fish with 15 and 16 year-olds from the 1996 and 1995 year classes most abundant. Mean age of burbot has increased since 1998 and this trend continued in 2011 (Figure 3.7). Recruitment of age-4 burbot increased almost two-fold from 1997 to 2000, but was followed by an abrupt decrease in 2002 and remained poor through 2011 (Figure 3.7). A recently published analysis (Stapanian et al. 2010) suggests that recruitment during 1997-2007 was associated with abundance of yearling and older yellow perch when the burbot were age 0, and winter water temperatures during the spawning and egg development phases of burbot. Burbot have the highest reproductive success at water temperatures between 0 and 2C, and are susceptible during early life to predation by yellow perch. Despite an improvement in age-4 recruitment during 2011, ongoing low catch rates of burbot in assessment surveys, combined with increasing mean age of adults and persistent low recruitment signal continuing troubles for this population. For accurate assessment of this aging population, the use of otolith thin-sections is recommended as the best approach for accurate age determination (Edwards et al. 2011). More importantly, efforts to reduce mortality (e.g., through sea lamprey control) on the remaining spawning stock would help ensure that this population can exploit favorable conditions for recruitment in future years.

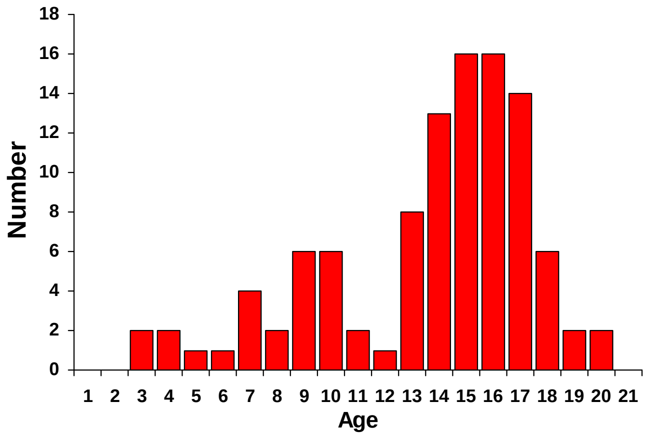

FIGURE 3.6. Age distribution of burbot caught in summer coldwater gill net assessment in eastern Lake Erie, 2011 (N=104).

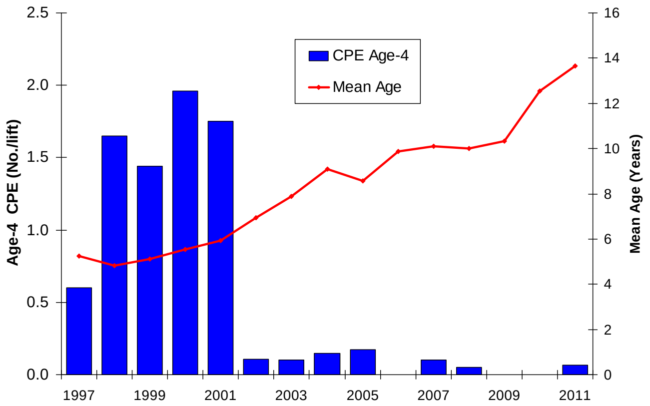

FIGURE 3.7. Mean age and average CPE of AGE-4 burbot caught in summer gill net assessment in Ontario waters of eastern Lake Erie during 1997-2011.

Growth

Mean total length of burbot increased slightly (New York) or was unchanged (Ontario) in surveyed east basin areas in 2011, continuing a trend that has predominated since the late 1990s (Figure 3.8). Average weight of burbot has followed a similar trend, increasing steadily since 1998, reaching a time-series maxima in 2009 or 2011, respectively, in New York and Ontario (Figure 3.9). These results reflect the increasing mean age of the burbot population.

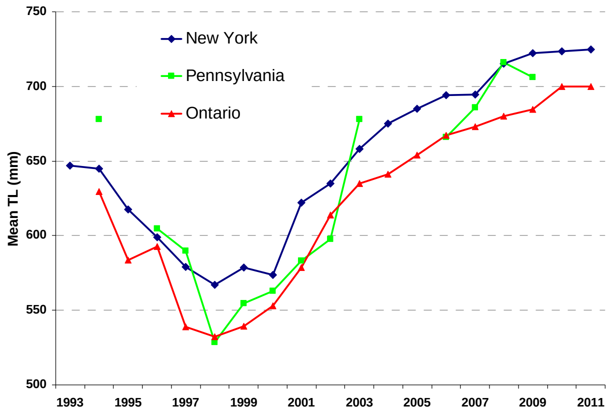

FIGURE 3.8 Average total length (TL) of burbot caught in summer gill net assessments by jurisdiction during 1993-2011. Pennsylvania waters were not surveyed in 2010 and 2011.

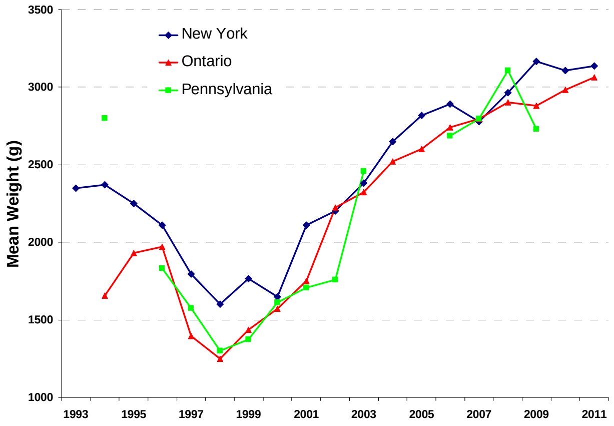

FIGURE 3.9 Average weight of burbot caught in summer gill net assessments by jurisdiction during 1993-2011. Pennsylvania waters were not surveyed in 2010 and 2011.

Diet

Diet information was limited to fish caught during August 2011 coldwater gill net assessment surveys in the eastern basin of Lake Erie. Analysis of stomach contents revealed a diet made up mostly of fish (Figure 3.10). Burbot diets continued to be diverse, with six different identifiable fish species and one invertebrate species found in stomach samples. Round goby were the dominant prey item, occurring in 50% of the burbot stomachs, followed by rainbow smelt (46% occurrence). Other identifiable taxa were found in 8% or less of the stomachs and included yellow perch, emerald shiners, alewife, white perch, and dreissenids.

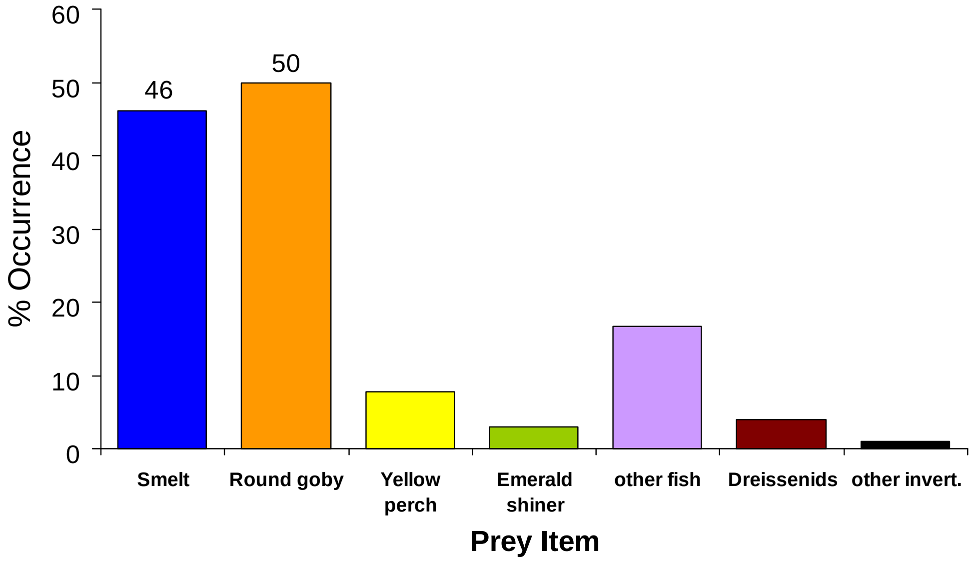

FIGURE 3.10. Frequency of occurrence of diet items from non-empty stomachs of burbot sampled in gill nets from the eastern basin of Lake Erie, August 2011. Other fish includes alewife, white perch and fish remains that could not be identified to species. Sample size is 102 stomachs.

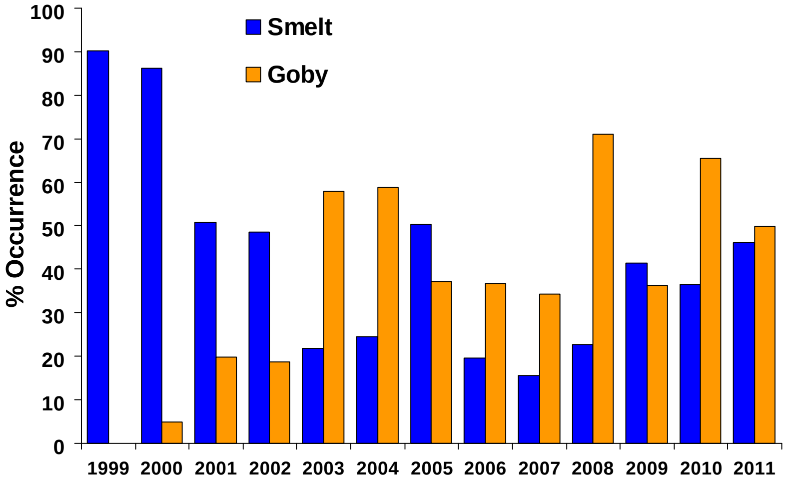

FIGURE 3.11. Frequency of occurrence of rainbow smelt and round gobies in the diet of burbot caught in gillnets set during August in the eastern basin of Lake Erie, 1999-2011.

Gobies have increased in the diet of burbot since they first appeared in the eastern basin in 1999 (Figure 3.11). They were the main diet item for burbot in six of the last eight years. Smelt were the dominant prey in 2005 and again in 2009.

To support ongoing analyses of contaminants (Hg and PCBs) in burbot, Stapanian (M.A. Stapanian, U.S. Geological Survey, Sandusky, OH USA, pers. comm.) applied analysis of variance models to recent burbot diets since the expansion of round gobies (2007-2011) and found that the main effects of sex and year and the interaction term were all insignificant.

Preliminary analyses indicate that burbot exhibit predatory control of round goby in deep water (≥ 20 m) areas of the eastern basin (Madenjian et al. 2011). Further, size-at-age of burbot has increased since round gobies became a significant component of the burbot diet (Stapanian et al. in review). This increase in size is thought to be associated with reduced competition for food among juvenile burbot during low recruitment years.

References

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Charge 4: Continue to participate in the IMSL process on Lake Erie to outline and prescribe the needs of the Lake Erie sea lamprey management program.

Tim Sullivan (USFWS), Fraser Neave (DFO), and James Markham (NYSDEC)

The Great Lakes Fishery Commission and its control agents (U.S. Fish and Wildlife Service and Fisheries and Oceans, Canada) continue to apply the Integrated Management of Sea Lamprey (IMSL) program in Lake Erie including selection of streams for lampricide treatment and implementation of alternative control methods. The Lake Erie Coldwater Task Group has provided the forum for the assemblage of sea lamprey wounding data used to evaluate and guide actions related to managing sea lamprey and for the discussion of ongoing sea lamprey and fishery management actions that impact the Lake Erie fish community.

Lake Trout Wounding Rates

A total of 40 A1-A3 wounds were found on 490 lake trout greater than 532 mm (21 inches) total length in 2011, equaling a wounding rate of 8.2 wounds per 100 fish (Table 4.1; Figure 4.1). This was a 36% decline from the 2010 wounding rate of 12.8 wounds per 100 fish and a 58% decrease over the past two years. Despite the recent decline, likely attributable to a 2008-2010 accelerated lampricide treatment program, the current wounding rate still exceeds the target rate of five wounds per 100 fish (Lake Trout Task Group 1985; Markham et al. 2008). Wounding rates have remained above target for 16 of the past 17 years following reduced sea lamprey control measures in the mid-1990's (Sullivan et al. 2003). Lake trout larger than 736 mm (29 inches) total length (TL) continue to be the preferred targets for sea lamprey with A1-A3 wounding rates more than twice as high as any other length group (Table 4.1). Conversely, small lake trout in the 432-532 mm (17-21 inch) size category only received one fresh wound in 171 fish examined (0.58 wounds/100 fish) in 2011.

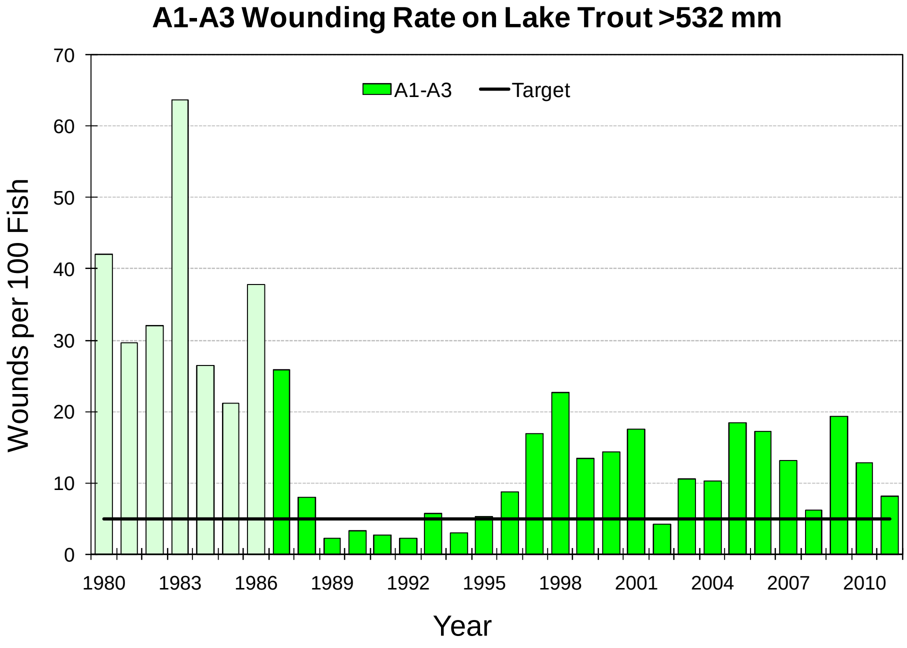

FIGURE 4.1. Number of fresh (A1-A3) sea lamprey wounds per 100 lake trout greater than 532 mm (21 inches) sampled in assessment gill nets in the eastern basin of Lake Erie, August-September, 1980-2011. The target rate is 5 wounds per 100 fish. Lighter shading indicates pre-treatment years.

TABLE 4.1. Frequency of sea lamprey wounds observed on several standard length groups of lake trout collected from assessment gill nets in the eastern basin of Lake Erie, August 2011.

Size Class Total Length (mm)	Sample Size	Wound Classification A1	A2	A3	A4	No. A1-A3 Wounds Per 100 Fish	No. A4 Wounds Per 100 Fish
432-532	171	0	0	1	11	0.6	6.4
533-634	249	4	4	5	55	5.2	22.1
635-736	173	1	1	11	98	7.5	56.6
>736	68	2	5	7	111	20.6	163.2
>532	490	7	10	23	264	8.2	53.9

Fresh A1 wounds are considered indicators of the attack rate for the current year at the time of sampling (August). The A1 wounding rate in 2011 was 1.4 wounds per adult lake trout greater than 532 mm, which was both lower than the 2010 A1 wounding rate of 2.1 wounds per 100 fish and the time series average (Table 4.1; Figure 4.2). A total of seven A1 wounds were spread across all size categories greater than 532 mm.

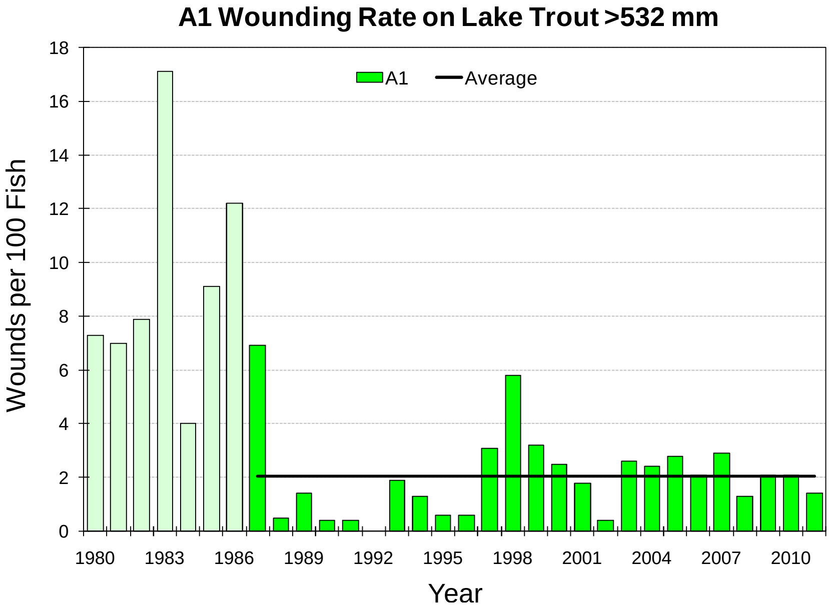

FIGURE 4.2. Number of A1 sea lamprey wounds per 100 lake trout greater than 532 mm (21 inches) sampled in assessment gill nets in the eastern basin of Lake Erie, August-September, 1980-2011. The post-treatment average includes 1987-2010. Lighter shading indicates pre-treatment years.

Cumulative attacks from past years are indicated by A4 wounds. A4 wounding rates slightly decreased in 2011 to 53.9 wounds per 100 fish (Figure 4.3). However, this was the third highest A4 wounding rate in the time series and over two times greater than the time series average of 24.2 wounds per 100 fish. Similar to last year, A4 wounds were observed across all length categories, increased in frequency with lake trout size and was an alarming 163 wounds per 100 fish in lake trout larger than 736 mm (25 inches) TL with many fish possessing multiple wounds (Table 4.1).

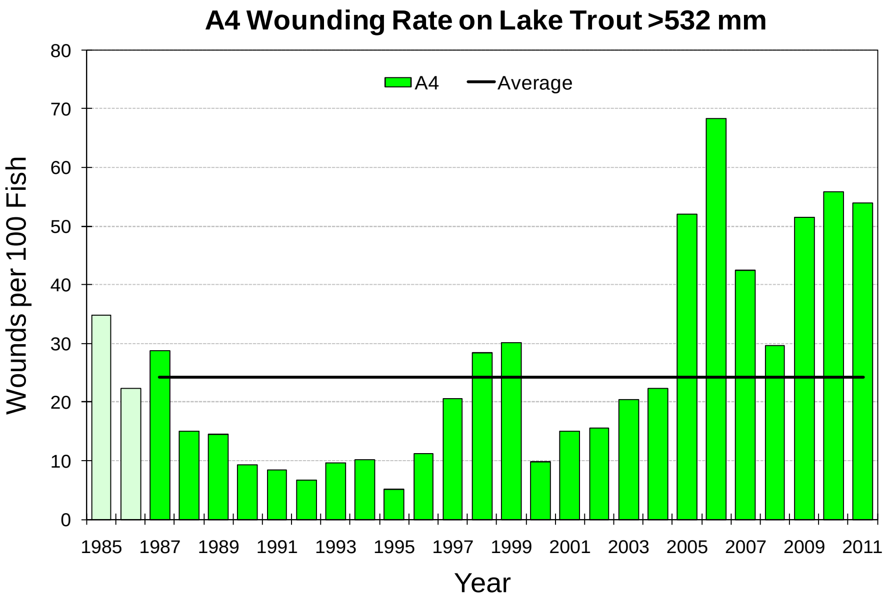

FIGURE 4.3. Number of A4 sea lamprey wounds per 100 lake trout greater than 532 mm (21 inches) sampled in assessment gill nets in the eastern basin of Lake Erie, August-September, 1985-2011. The post-treatment average includes 1987-2010. Lighter shading indicates pre-treatment years.

Finger Lakes (FL) and Klondike (KL) strain lake trout were the most sampled strains, and they accounted for the majority of the fresh (A1-A3) and healed (A4) sea lamprey wounds (Table 4.2). Overall, A1-A3 wounding rates were higher on KL strain lake trout compared to FL strain lake trout, while A4 wounds were slightly higher on FL strain fish. However, almost all lake trout >736 mm TL, which are the preferred prey size of sea lamprey, were FL strain fish. Lake Superior lake trout strains (KL, TI, AI, SUP) have higher wounding rates than Finger Lakes (FL) strain lake trout, indicative of higher susceptibility of these strains to sea lamprey attacks.

TABLE 4.2. Frequency of sea lamprey wounds observed on lake trout greater than 532 mm (21 inches), by strain, collected from assessment gill nets in the eastern basin of Lake Erie, August 2011. AI=Apostle Island, FL=Finger Lakes, KL=Klondike, LC=Lake Champlain, LE=Lake Erie, LL=Lewis Lake, SI=Slate Island, SUP=Superior, TI=Traverse Island.

Lake Trout Strain	Sample Size	Wound Classification				No. A1-A3 Wounds Per 100 Fish	No. A4 Wounds Per 100 Fish
		A1	A2	A3	A4		
AI	9	1	0	0	2	11.1	22.2
FL	269	0	4	9	146	4.8	54.3
KL	106	2	4	5	49	10.4	46.2
LC	8	0	0	0	2	0.0	25.0
LE	1	1	0	0	5	100.0	500.0
LL	2	0	1	1	4	100.0	200.0
SI	5	0	0	0	0	0.0	0.0
SUP	1	0	0	0	2	0.0	200.0
TI	18	0	0	2	22	11.1	122.2

Burbot Wounding Rates

The burbot population, once the most prevalent coldwater predator in the eastern basin of Lake Erie, has declined 80% (in relative abundance) since 2004 (see Charge 3). Coincidentally, both A1-A3 and A4 wounding rates on burbot have increased since 2004 in eastern basin waters of Lake Erie (Figure 4.4). Wounding rates on burbot increased again in 2011; A1-A3 wounds increased to 5.3 per 100 burbot while A4 wounds increased to 7.3 per 100 burbot. This was the highest A1-A3 wounding rate in the eleven year time series and the second highest A4 wounding rate.

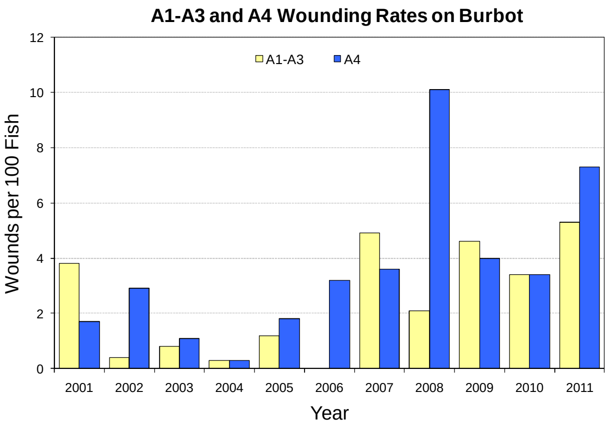

FIGURE 4.4. Number of A1-A3 and A4 sea lamprey wounds per 100 burbot (all sizes) sampled in assessment gill nets in the eastern basin of Lake Erie, August, 2001-2011.

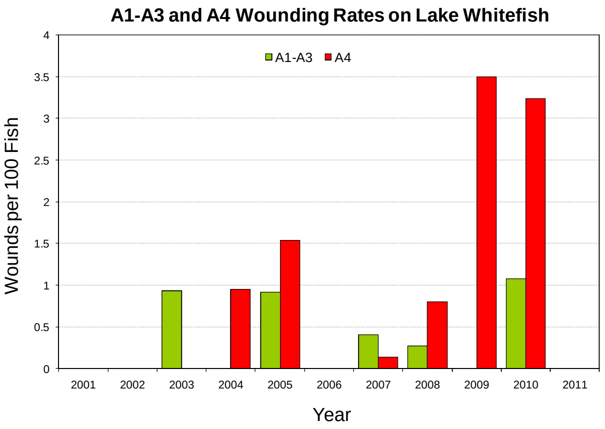

FIGURE 4.5. Number of A1-A3 and A4 sea lamprey wounds per 100 lake whitefish (all sizes) sampled in assessment gill nets in the New York waters of Lake Erie, August, 2001-2011.

Lake Whitefish Wounding Rates

Reliable counts of sea lamprey wounds on lake whitefish have been recorded in New York since 2001. Wounds on lake whitefish were first observed in 2003, coincident with depressed adult lake trout abundance (see Charge 1). No fresh (A1-A3) or healed (A4) wounds were observed on lake whitefish in 2011 assessment netting. However, the overall sample size was small due to low population abundance (see Charge 2). Wounding rates on lake whitefish are low compared to lake trout, which we speculate may be due to higher post-wounding mortality.

Steelhead Wounding Rates

Similar to burbot and whitefish, sea lamprey attacks on steelhead have not been consistently recorded in Lake Erie until recently. Unlike other coldwater species, steelhead are infrequently caught during August coldwater gill net assessment surveys, and observations of wounding must be derived from other sample collections such as tributary creel surveys or fish contaminant collections. Wounding rates on these surveys vary. In 2010, Pennsylvania began a more directed survey during their annual fall steelhead run to address this shortfall and this survey continued in 2011. A total of nine A1-A3 wounds and two A4 wounds were found on 150 adult steelhead in 2011, yielding wounding rates of 6.0 A1-A3 wounds per 100 fish and 1.3 A4 wounds per 100 fish, respectively (Table 4.3). It should be noted that an additional 16 B-type wounds were also found, which normally are not used in wounding rate calculations.

TABLE 4.3. Frequency of sea lamprey wounds observed on steelhead from various Lake Erie tributary surveys, 2003-2011.

Survey	State	Sample Size	# Wounds	Wounding Rate (%)	Comments
2003-04 Tributary Creel Survey	NY	249	31	12.5	All wounds combined
2004-05 Tributary Creel Survey	NY	89	15	16.9	All wounds combined
2007-08 Tributary Creel Survey	NY	88	12	13.6	All wounds combined
2008-09 Tributary Creel Survey	OH	418	30	7.2	13 A1-A3; 17 A4
Fall 2009 Cattaraugus Creek	NY	50	15	30.0	4 A1-A3; 11 A4
Fall 2009 Chautauqua Creek	NY	50	20	40.0	7 A1-A3; 13 A4
2009-10 Tributary Creel Survey	OH	108	11	10.2	7 A1-A3; 4 A4
Spring 2010 Cattaraugus Creek	NY	50	9	18	4 A1-A3; 5 A4
Fall 2010 Directed Wounding Survey	PA	142	26	18.3	4 A1-A3; 5 A4; 17 B1-B4
Fall 2011 Directed Wounding Survey	PA	150	27	18.0	9 A1-A3; 2 A4; 16 B1-B4

Ontario Partnership Program

The Ontario Partnership Index Fishing Program is an annual lakewide gillnet survey of the Canadian waters of Lake Erie and provides an additional and spatially robust assessment of fish species abundance and distribution. Although sea lampreys wounds have been recorded on fish species since the survey began in 1989, detailed information on type and category of wound were not recorded until 2011.

A total of 61 lake trout greater than 532 mm TL were examined for sea lamprey wounds in 2011. Altogether, eight A1-A3 wounds and two A4 wounds were recorded, yielding wounding rates of 13.1 and 3.3 wounds/100 fish, respectively. The majority of the lake trout, and wounds, were found in eastern basin waters (Figure 4.6). Sea lamprey wounds were also recorded on other fish species including gizzard shad, steelhead, white sucker, shorthead redhorse, channel catfish, smallmouth bass, and yellow perch.

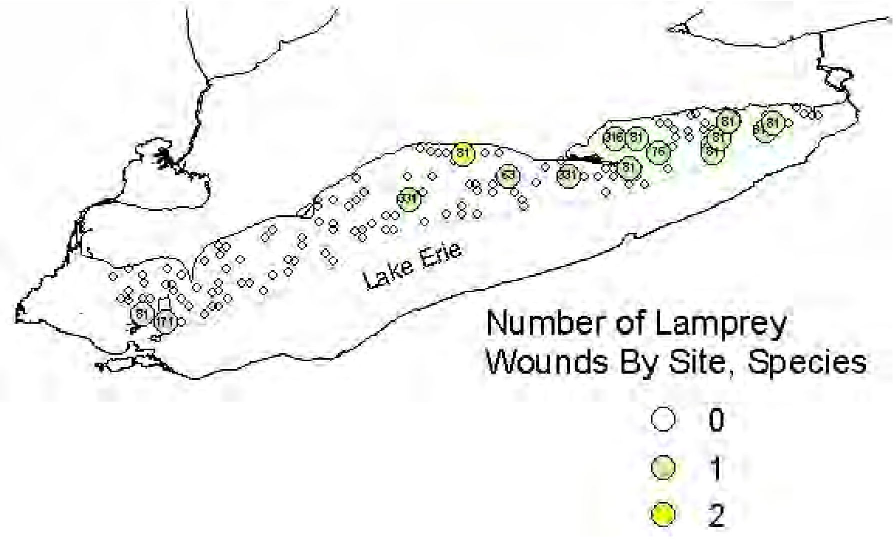

FIGURE 4.6. Number of wounds (A1-A4) on fish examined for lamprey wounds by site and species during Partnership Index gillnetting, 2011. Species codes in symbols include lake trout (81), rainbow trout (76), yellow perch (331), 171 (shorthead redhorse sucker), 316 (smallmouth bass) and channel catfish (234). Two symbols with single wounds (east basin species 81; west basin species 234) are not visible due to overlap. Total number of fish and species examined per site not shown. Includes all index and auxiliary gear.

2011 Sea Lamprey Control Actions

Following the back-to-back treatments of all streams known to be infested with lamprey in Lake Erie in 2008-2010, no streams were treated in 2011. Assessments for larval sea lamprey were conducted in 72 tributaries (61 U.S., 11 Canada) and offshore of 6 U.S. tributaries (Table 4.4). Surveys to detect new populations were conducted in 54 tributaries (49 U.S, 5 Canada). One new population was found in Chautauqua Creek, New York. Sea lamprey recruited to this stream in 2011, and hence this stream would not have been a source of parasitic lamprey to Lake Erie. Larval lampreys reside within the stream for three to four years prior to metamorphosing and migrating to the lake, so Chautauqua Creek will be considered for treatment in 2014.

The estimated number of spawning-phase sea lampreys decreased from 22,179 in 2010 to 20,638 in 2011 (Figure 4.7), a decrease of 7%. A total of 3,281 spawning-phase sea lamprey were trapped in four tributaries (2 U.S., 2 Canada).

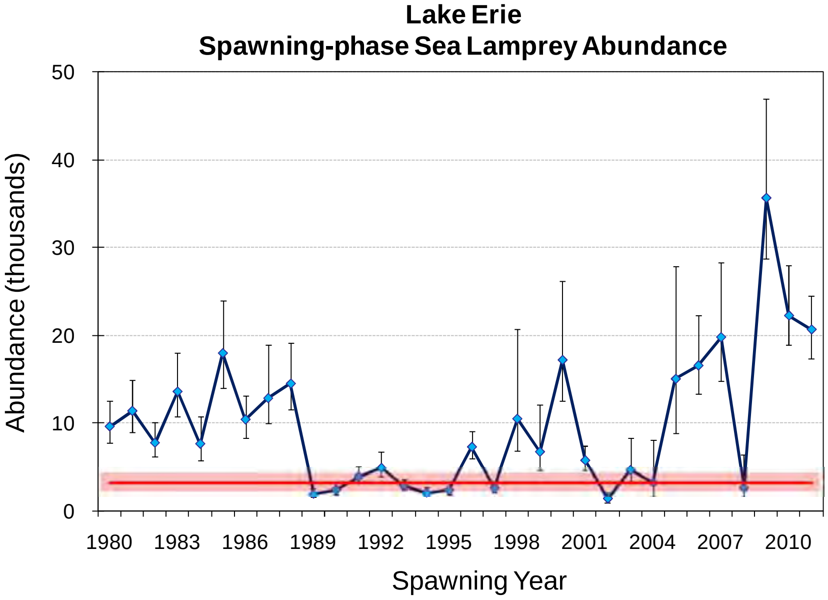

FIGURE 4.7. Lake-wide population estimates of spawning-phase sea lampreys in Lake Erie during 1980-2011 with 95% confidence intervals (black vertical lines). The target population level of 3,244 spawning adults (red horizontal line) with 95% confidence bounds (pink shading) is also shown.

A habitat-based larval sea lamprey population estimate was conducted in the St. Clair River during June. Bottom substrate was mapped and quantified using Roxann seabed classification sonar. Granular Bayluscide surveys were conducted in thirty-four 500m^2 plots throughout the river, yielding an abundance estimate of 150,000 larval sea lamprey. In addition, bottom substrate was mapped and quantified using Roxanne in the Detroit River estuary. No sea lamprey larvae were found in granular Bayluscide surveys of the estuary area.

Trapping for metamorphosed sea lamprey was conducted in the lower Detroit River between November 21st and December 22nd. A combination of floating fyke nets and stationary trawls were deployed at 20 sites in U.S. and Canadian waters. Four metamorphosed sea lampreys were collected during approximately 2500 hours of sampling effort.

Construction of the sea lamprey trap at the Scoby Hill Dam on Cattaraugus Creek began in early August 2011 and continued through the middle of December. During construction, a breach in the common dam wall between the forebay and spillway was discovered. This breach has halted work at the forebay/intake structure due to the inability to dewater the area. The majority of the work on the trapping structure in the tailrace is complete, but a re-design is necessary to supply water to the trap.

Back-to-back Treatment Evaluation

The second portion of Charge 4 is to evaluate the success of the back-to-back treatments. These treatments in 2008-2010 were very effective in reducing larval populations within treated streams. Very few residual sea lampreys were found following the treatments. Rates of re-establishment of sea lamprey in these previously infested streams appear to be substantially lower following the treatments: less than half (5 of 11 streams) have had sea lamprey larvae captured in them since treatment, but further evaluation is needed in 2012 to accurately assess post-treatment recruitment. The anticipated reduction of the lake-wide spawner population following these treatments has not been observed. This suggests sea lampreys are reproducing in another untreated source. Accordingly, efforts to detect this source have been substantially increased. Also, additional assessment work is being planned for the Huron-Erie corridor to determine if this is the source of the problem, as the St. Clair River is the only known un-treated population of sea lamprey larvae in the Lake Erie basin.

2012 Sea Lamprey Control Plans

Due to the recent back-to-back treatments during 2008 - 2010, there are no Lake Erie streams scheduled for treatment in 2012. Larval assessment surveys are scheduled for 66 streams (52 U.S., 14 Canada; Table 4.4) to continue to detect and monitor larval sea lamprey populations and to guide 2013 treatments. Adult assessment traps will be operated on four streams (2 U.S., 2 Canada) to estimate lake-wide spawning-phase abundance.

The US Army Corps of Engineers will conduct a full study to assess the feasibility of repairing or rebuilding the Harpersfield Dam on the Grand River. Construction will be completed on a trap in Cattaraugus Creek, and efforts to identify a candidate site will continue on Big Otter Creek. A bioassay study will be conducted to determine the toxicity of TFM to juvenile snuffbox and ellipse mussels, and ellipse mussel glochidia.

Trapping for metamorphosed sea lampreys in the Huron-Erie Corridor is being proposed for 2012. This is in conjunction with a proposed mark-recapture study which will seek to determine if sea lampreys produced in the St. Clair River are capable of contributing to the spawning run in the eastern basin of Lake Erie.

TABLE 4.4. Larval sea lamprey assessments of Lake Erie Tributaries during 2011 and plans for 2012.

Stream	History	Surveyed in 2011	Survey Type[1]	Results	Plans for 2012
Canada					
St. Clair River	Positive	Yes	Evaluation*	Positive	Evaluation
Thames River	Positive	No			Evaluation
Sydenham River	Negative	No			Detection
Detroit River	Negative	Yes	Detection	Negative	None
Big Creek	Negative	Yes	Detection	Negative	None
Kettle Creek	Negative	Yes	Detection	Negative	None
Catfish Creek	Positive	No			Evaluation
Silver Creek	Positive	Yes	Evaluation	Negative	None
Big Otter Creek	Positive	Yes	Ranking/Dist	Positive	Ranking
South Otter Creek	Positive	Yes	Evaluation	Negative	Evaluation
Clear Creek	Positive	No			Evaluation
Big Creek	Positive	Yes	Ranking/Dist	Positive	Ranking
Dedrich Creek	Negative	No			Detection
Forestville Creek	Positive	No			Evaluation
Normandale Creek	Positive	No			Evaluation
Fishers Creek	Positive	No			Evaluation
Youngs Creek	Positive	Yes	Evaluation	Negative	Evaluation
Lynn Creek	Negative	No			Detection
Grand River	Negative	Yes	Detection	Negative	None
Frenchman Creek	Negative	Yes	Detection	Negative	None
United States					
Buffalo River	Positive	No			Evaluation
Cattaraugus Cr.	Positive	Yes	Evaluation	Positive	Ranking
(estuary)	Positive	No			Ranking
(lentic)	Positive	No			Evaluation
Big Sister Creek	Negative	Yes	Detection	Negative	None
Silver Creek	Negative	Yes	Detection	Negative	None
Merritt Winery Cr.	Negative	Yes	Detection	Negative	None
Beaver Cr.	Negative	Yes	Detection	Negative	None
Canadaway Cr.	Positive	Yes	Evaluation	Negative	None
Delaware Creek	Positive	No			Evaluation
Swede Rd. Cr.	Negative	Yes	Detection	Negative	None
Chautauqua Cr.	Negative	Yes	Detection	Positive	Evaluation
Vorce Cr.	Negative	Yes	Detection		None
Freelings Cr.	Negative	Yes	Detection	Negative	None
Spring Cr.	Negative	Yes	Detection (Visual)	Negative	None
Doty Cr.	Negative	Yes	Detection (Visual)	Negative	None
Twenty mile Cr.	Negative	Yes	Detection	Negative	None

Stream	History	Surveyed in 2011	Survey Type[1]	Results	Plans for 2012
Dewey Cr.	Negative	Yes	Detection	Negative	None
Woodmere Rd. Cr.	Negative	Yes	Detection	Negative	None
Seven mile Cr.	Negative	Yes	Detection	Negative	None
Mill Cr. (Erie, Pa.)	Negative	Yes	Detection	Negative	None
Cascade Cr.	Negative	Yes	Detection	Negative	None
Pasadena Rd. Cr.	Negative	Yes	Detection	Negative	None
Walnut Cr.	Negative	Yes	Detection	Negative	None
Trout Run Cr.	Negative	Yes	Detection	Negative	None
Wilkins Rd. Cr.	Negative	Yes	Detection	Negative	None
Melhorn Cr.	Negative	Yes	Detection	Negative	None
Camp Sherwin Cr.	Negative	Yes	Detection	Negative	None
Elk Cr.	Negative	Yes	Detection	Negative	None
Crooked Cr.	Positive	Yes	Evaluation	Positive	Ranking
Raccoon Cr. (Pa.)	Positive	Yes	Evaluation	Negative	Evaluation
Conneaut Cr.	Positive	Yes	Evaluation	Positive	Ranking
Wheeler Cr.	Positive	Yes	Evaluation	Negative	None
Arcola Cr.	Negative	Yes	Detection	Negative	None
Grand River	Positive	Yes	Evaluation	Positive	Evaluation
Euclid Cr.	Negative	Yes	Detection	Negative	None
Beaver Cr. (Oh.)	Negative	Yes	Detection	Negative	None
Brownhelm Cr.	Unknown	Yes	Detection	Negative	None
Sunnyside Cr.	Unknown	Yes	Detection	Negative	None
Vermillion River	Negative	Yes	Detection	Negative	Detection
Huron River (Oh.)	Negative	Yes	Detection	Negative	None
Edson Cr.	Unknown	Yes	Detection	Negative	None
Sawmill Cr.	Unknown	Yes	Detection	Negative	None
Plum Br.	Unknown	Yes	Detection	Negative	None
Pipe Cr.	Unknown	Yes	Detection	Negative	None
Raccoon Cr. (Oh.)	Unknown	Yes	Detection	Negative	None
Pickerel Cr.	Unknown	Yes	Detection	Negative	None
Sandusky River	Negative	Yes	Detection	Negative	None
Sandusky R. (lentic)	Unknown	No			Detection-gB
Muddy Cr.	Unknown	Yes	Detection	Negative	None
Muddy Cr. (lentic)	Unknown	No			Detection
Portage River	Negative	Yes	Detection	Negative	None
Toussaint R.	Negative	Yes	Detection	Negative	None
Maumee R.	Negative	Yes	Detection	Negative	Detection
Ottawa R.	Unknown	Yes	Detection	Negative	None
Halfway Cr.	Negative	Yes	Detection	Negative	None
Otter Cr.	Negative	Yes	Detection	Negative	None
Plum Cr.	Negative	Yes	Detection	Negative	None

Stream	History	Surveyed in 2011	Survey Type[1]	Results	Plans for 2012
River Raisin	Negative	Yes	Detection	Negative	None
Stony Cr.	Negative	Yes	Detection	Negative	None
Huron River (Mi.)	Negative	Yes	Detection	Negative	Detection
Detroit River	Negative	Yes	Detection	Negative	Detection
Clinton River	Positive	Yes	Evaluation	Positive	Evaluation
Belle River	Positive	Yes	Evaluation	Negative	None
Pine River	Positive	Yes	Evaluation	Negative	None
Black River	Positive	Yes	Evaluation	Negative	None
St. Clair River	Positive	Yes	Evaluation	Positive	Evaluation
Van Buren Cr. #2	Negative	No			Detection
Van Buren Cr. #3	Negative	No			Detection
Hall Rd. Cr.	Negative	No			Detection
Lake Erie Park Cr.	Negative	No			Detection
Corell Cr	Negative	No			Detection
Pratt Rd. Cr.	Negative	No			Detection
Bournes Cr.	Negative	No			Detection
Rogerville Rd. Cr.	Unknown	No			Detection
Shorehaven #2 Cr.	Negative	No			Detection
Shorehaven #3 Cr.	Negative	No			Detection
Forsyth Rd. Cr.	Unknown	No			Detection
Brockaway Rd. Cr. #1	Unknown	No			Detection
Brockaway Rd. Cr. #2	Unknown	No			Detection
Ripley Cr.	Negative	No			Detection
Camp Lambec No. 2	Unknown	No			Detection
Camp Lambec No. 3	Unknown	No			Detection
Conneaut Park Cr.	Unknown	No			Detection
Kingsville on the Lake	Unknown	No			Detection
North Kingsville Cr.	Unknown	No			Detection
Camp Wingfoot Cr.	Unknown	No			Detection
N. Perry Park Cr.	Unknown	No			Detection
Cmp Roosevelt #1 Cr.	Unknown	No			Detection
Chagrin River	Positive	No			Evaluation
Black River	Negative	No			Detection
Darby Cr.	Unknown	No			Detection
Sugar Cr.	Unknown	No			Detection
Mills Cr.	Unknown	No			Detection
Cold Cr.	Negative	No			Detection
Little Pickerel Cr.	Unknown	No			Detection
Turtle Cr.	Unknown	No			Detection
Crane Cr.	Unknown	No			Detection
Bay Cr.	Negative	No			Detection

Stream	History	Surveyed in 2011	Survey Type[1]	Results	Plans for 2012
Whitewood Cr.	Negative	No			Detection
Swan Cr. (Monroe Co)	Negative	No			Detection
Mouille Cr.	Negative	No			Detection
River Rouge	Negative	No			Detection

[1] Evaluation survey – conducted to detect larval recruitment in streams with a history of sea lamprey infestation.

Detection survey – conducted to detect larval recruitment in streams with no history of sea lamprey infestation; gB denotes that Granular Bayluscide was employed.

Distribution survey – conducted to determine instream geographic distribution or to determine lampricide treatment application points.

Treatment evaluation survey – conducted to determine the relative abundance of survivors from a lampricide treatment.

Ranking survey – conducted to index the larval population to determine need for lampricide treatment the following year. Projected treatment cost is divided by the estimate of larvae > 100 mm to provide a ranking against other Great Lakes tributaries for lampricide treatment.

Biological collection – conducted to collect lamprey specimens for research purposes.

Barrier survey - conducted to determine larval recruitment upstream of barriers.

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Charge 5: Maintain an annual interagency electronic database of Lake Erie salmonid stocking for the STC, GLFC and Lake Erie agency data depositories.

Chuck Murray (PFBC) and James Markham (NYSDEC)

Lake Trout Stockings

The current lake trout stocking goal for Lake Erie (160,000 yearlings) was met for the fourth consecutive year (Figure 5.1). In 2011, lake trout were stocked in New York waters (184,259 yearlings) and Ontario waters (55,874 yearlings). Combined, the 240,133 yearlings stocked in 2011 were the second highest number of lake trout stocked into Lake Erie in a single year since rehabilitation efforts began in 1969, and the fourth consecutive year that total stocking numbers exceeded 200,000 yearlings.

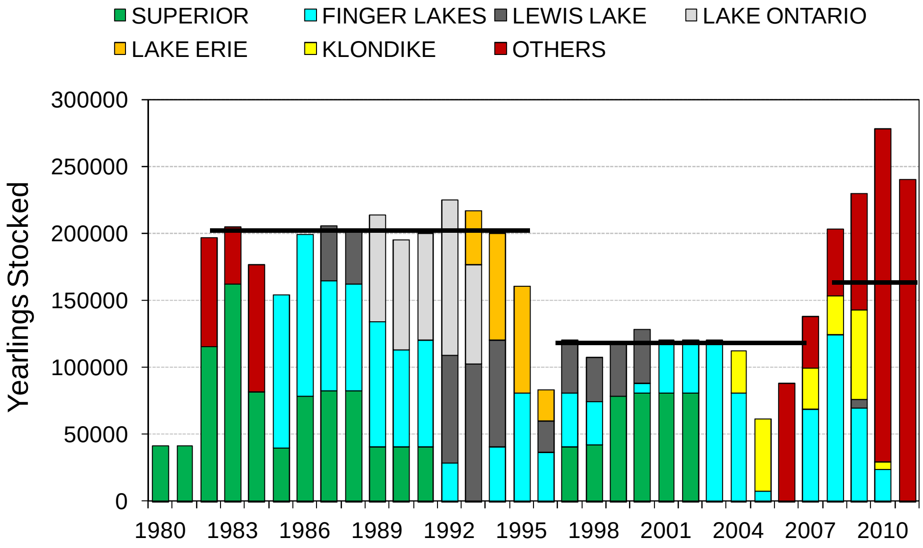

FIGURE 5.1. Yearling lake trout stocked (in yearling equivalents) in eastern basin waters of Lake Erie, 1980-2011, by strain. The current stocking goal (black line) is 160,000 yearlings per year. OTHERS = Clearwater Lake (1982-84), Slate Island (2006, 2009, 2010, 2011), Traverse Island (2007), Lake Manitou (2008), Apostle Island (2009), Lake Champlain (2009, 2010, 2011), and Michipocoten (2010).

While the Allegheny National Fish Hatchery (ANFH) remains closed for renovations, lake trout stocked in New York waters continued to be raised at White River National Fish Hatchery (WRNFH), a USFWS facility located in Vermont. These lake trout were stocked by New York State Department of Environmental Conservation (NYS DEC) staff offshore of Dunkirk in approximately 70 feet of water via the R/V ARGO between 25 April and 5 May, 2011. All of these were Lake Champlain strain fish. The WRNFH is scheduled to raise lake trout for Lake Erie until renovations at the ANFH are complete. Production is expected to be resumed at the ANFH in 2013. The Ontario Ministry of Natural Resources (OMNR) boat stocked Slate Island strain lake trout off Nanticoke Shoal from 19-21 April 2011. This was the fifth lake stocking in Ontario waters in the last six years.

Stocking of Other Salmonids

In 2011, over 2.1 million yearling trout and salmon were stocked in Lake Erie, including rainbow/steelhead trout, brown trout and lake trout (Figure 5.2). Total salmonine stocking decreased 9% from 2010 and the long-term average (1989-2010). Annual summaries for each species stocked within individual state and provincial areas are summarized in Table 5.1, and are standardized to yearling equivalents.

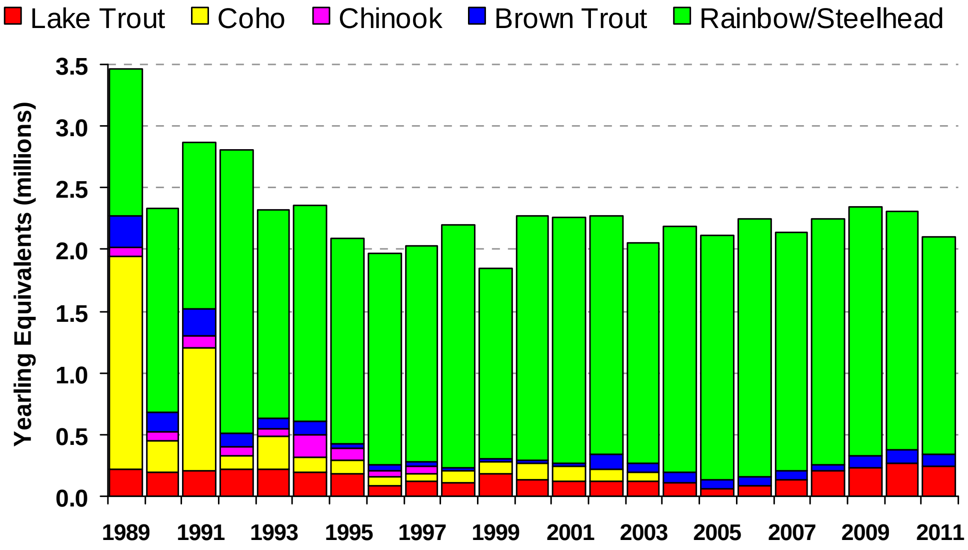

Figure 5.2. Annual stocking of all salmonid species (in yearling equivalents) in Lake Erie by all agencies, 1990-2011.

All of the US fisheries resource agencies and a few non-governmental organizations (NGO's) in Ontario and Pennsylvania currently stock rainbow/steelhead trout in the Lake Erie watershed. A total of 1,761,217 yearling rainbow/steelhead trout were stocked in 2011, accounting for nearly 84% of all salmonids stocked. This represented a 9% decrease from 2010, and 4% below the long-term average. The decrease in rainbow trout stocking is primarily due to a temporary reduction in yearling steelhead stocking by the Ohio Division of Wildlife (ODOW), due to hatchery renovations at the Castalia State Fish Hatchery. The ODOW will resume full production in 2012. Rainbow trout/steelhead stocking increased 10% in Ontario waters and 1% in Pennsylvania waters from 2010, and decreased 39% in Ohio waters, 8% in Michigan waters and 1% in New York waters from 2010. A full account of rainbow/steelhead trout stocked in Lake Erie by jurisdiction for 2011 can be found under charge 6 of this report, and details the location and strain of rainbow trout stocked across Lake Erie.

Brown trout stocking in Lake Erie totaled 100,370 yearlings in 2011. This was a 2% decrease from 2010, but an 18% increase from the long-term average. Recent increases are attributed to the stocking of yearlings and advanced fingerlings in the New York and Pennsylvania waters of Lake Erie. The purpose of these stocking efforts is the development of a trophy brown trout fishery to enhance and diversify the stream and offshore trout fisheries. Some brown trout (18%) are also stocked to provide adult trout for the opening day of trout season in Pennsylvania. Brown trout stocking is expected to continue at this rate for 2012 in both New York and Pennsylvania.

Between 22 April and 29 April the NYSDEC stocked 38,100 yearling brown trout in Cattaraugus Creek, Barcelona Harbor, Point Breeze and Dunkirk Harbor. An additional 7,440 fall fingerlings were stocked on 17 November in Dunkirk Harbor. The NYSDEC began re-emphasizing brown trout stocking in place of domestic rainbow trout in 2002 for the purposes of diversifying their tributary trout/salmon fishery and for maintaining migratory behavior of their Salmon River steelhead strain.

Between 12 April and 28 April, 17,710 adult brown trout were stocked by the PFBC to provide catchable trout for the opening of Pennsylvania trout season. Yearling and fall fingerling brown trout were also stocked in Pennsylvania waters in support of a put-grow-and-take brown trout program that was initiated in 2009. This program is currently being supported through the annual donation of 100,000 certified IPN-free eggs from the NYDEC. Various NGO's stocked 43,000 yearling brown trout in May which were adipose clipped. The PFBC stocked an additional 33,037 fall fingerlings between 27 September and 3 October; 7,825 (24%) were stocked in Presque Isle Bay and were left ventral (LV) clipped; 25,212 (76%) were stocked in nursery streams and marked with a right ventral (RV) fin clip.

TABLE 5.1. Summary of salmonid stockings in numbers of yearling equivalents, Lake Erie, 1990-2011.

	Lake Trout	Coho	Chinook	Brown Trout	Rainbow/Steelhead	Total
ONT.	--	--	--	--	31,530	31,530
NYS DEC	113,730	5,730	65,170	48,320	160,500	393,450
PFBC	82,000	249,810	5,670	55,670	889,470	1,282,620
ODNR	--	--	--	--	485,310	485,310
MDNR	--	--	--	51,090	85,290	136,380
1990 Total	**195,730**	**255,540**	**70,840**	**155,080**	**1,652,100**	**2,329,290**
ONT.	--	--	--	--	98,200	98,200
NYS DEC	125,930	5,690	59,590	43,500	181,800	416,510
PFBC	84,000	984,000	40,970	124,500	641,390	1,874,860
ODNR	--	--	--	--	367,910	367,910
MDNR	--	--	--	52,500	58,980	111,480
1991 Total	**209,930**	**989,690**	**100,560**	**220,500**	**1,348,280**	**2,868,960**
ONT.	--	--	--	--	89,160	89,160
NYS DEC	108,900	4,670	56,750	46,600	149,050	365,970
PFBC	115,700	98,950	15,890	61,560	1,485,760	1,777,860
ODNR	--	--	--	--	561,600	561,600
MDNR	--	--	--	--	14,500	14,500
1992 Total	**224,600**	**103,620**	**72,640**	**108,160**	**2,300,070**	**2,809,090**
ONT.	--	--	--	650	16,680	17,330
NYS DEC	142,700	--	56,390	47,000	256,440	502,530
PFBC	74,200	271,700	--	36,010	973,300	1,355,210
ODNR	--	--	--	--	421,570	421,570
MDNR	--	--	--	--	22,200	22,200
1993 Total	**216,900**	**271,700**	**56,390**	**83,660**	**1,690,190**	**2,318,840**
ONT.	--	--	--	--	69,200	69,200
NYS DEC	120,000	--	56,750	--	251,660	428,410
PFBC	80,000	112,900	128,000	112,460	1,240,200	1,673,560
ODNR	--	--	--	--	165,520	165,520
MDNR	--	--	--	--	25,300	25,300
1994 Total	**200,000**	**112,900**	**184,750**	**112,460**	**1,751,880**	**2,361,990**
ONT.	--	--	--	--	56,000	56,000
NYS DEC	96,290	--	56,750	--	220,940	373,980
PFBC	80,000	119,000	40,000	30,350	1,223,450	1,492,800
ODNR	--	--	--	--	112,950	112,950
MDNR	--	--	--	--	50,460	50,460
1995 Total	**176,290**	**119,000**	**96,750**	**30,350**	**1,663,800**	**2,086,190**
ONT.	--	--	--	--	38,900	38,900
NYS DEC	46,900	--	56,750	--	318,900	422,550
PFBC	37,000	72,000	--	38,850	1,091,750	1,239,600
ODNR	--	--	--	--	205,350	205,350
MDNR	--	--	--	--	59,200	59,200
1996 Total	**83,900**	**72,000**	**56,750**	**38,850**	**1,714,100**	**1,965,600**
ONT.	--	--	--	1,763	51,000	52,763
NYS DEC	80,000	--	56,750	--	277,042	413,792
PFBC	40,000	68,061	--	31,845	1,153,606	1,293,512
ODNR	--	--	--	--	197,897	197,897
MDNR	--	--	--	--	71,317	71,317
1997 Total	**120,000**	**68,061**	**56,750**	**33,608**	**1,750,862**	**2,029,281**
ONT.	--	--	--	--	61,000	61,000
NYS DEC	106,900	--	--	--	299,610	406,510
PFBC	--	100,000	--	28,030	1,271,651	1,399,681
ODNR	--	--	--	--	266,383	266,383
MDNR	--	--	--	--	60,030	60,030
1998 Total	**106,900**	**100,000**	**0**	**28,030**	**1,958,674**	**2,193,604**
ONT.			--		85,235	85,235
NYS DEC	143,320		--		310,300	453,620
PFBC	40,000	100,000	--	20,780	835,931	996,711
ODNR			--		238,467	238,467
MDNR			--		69,234	69,234
1999 Total	**183,320**	**100,000**	**0**	**20,780**	**1,539,167**	**1,843,267**
ONT.	--	--	--	--	10,787	10,787
NYS DEC	92,200	--	--	--	298,330	390,530
PFBC	40,000	137,204	--	17,163	1,237,870	1,432,237
ODNR	--	--	--	--	375,022	375,022
MDNR	--	--	--	--	60,000	60,000
2000 Total	**132,200**	**137,204**	**0**	**17,163**	**1,982,009**	**2,268,576**

TABLE 5.1. (Continued) Summary of salmonid stockings in number of yearling quivalents, 1990-2011.

	Lake Trout	Coho	Chinook	Brown Trout	Rainbow/Steelhead	Total
ONT.	--	--	--	100	40,860	40,960
NYS DEC	80,000	--	--	--	276,300	356,300
PFBC	40,000	127,641	--	17,000	1,185,239	1,369,880
ODNR	--	--	--	--	424,530	424,530
MDNR	--	--	--	--	67,789	67,789
2001 Total	**120,000**	**127,641**	**0**	**17,100**	**1,994,718**	**2,259,459**
ONT.	--	--	--	4,000	66,275	70,275
NYS DEC	80,000	--	--	72,300	257,200	409,500
PFBC	40,000	100,289	--	40,675	1,145,131	1,326,095
ODNR	--	--	--	--	411,601	411,601
MDNR	--	--	--	--	60,000	60,000
2002 Total	**120,000**	**100,289**	**0**	**116,975**	**1,940,207**	**2,277,471**
ONT.	--	--	--	7,000	48,672	55,672
NYS DEC	120,000	--	--	44,813	253,750	418,563
PFBC	--	69,912	--	22,921	866,789	959,622
ODNR	--	--	--	--	544,280	544,280
MDNR	--	--	--	--	79,592	79,592
2003 Total	**120,000**	**69,912**	**0**	**74,734**	**1,793,083**	**2,057,729**
ONT.	--	--	--	--	34,600	34,600
NYS DEC	111,600	--	--	36,000	257,400	405,000
PFBC	--	--	--	50,350	1,211,551	1,261,901
ODNR	--	--	--	--	422,291	422,291
MDNR	--	--	--	--	64,200	64,200
2004 Total	**111,600**	**0**	**0**	**86,350**	**1,990,042**	**2,187,992**
ONT.	--	--	--	--	55,000	55,000
NYS DEC	62,545	--		37,440	275,000	374,985
PFBC	--	--	--	35,483	1,183,246	1,218,729
ODNR	--	--	--	--	402,827	402,827
MDNR	--	--	--	--	60,900	60,900
2005 Total	**62,545**	**0**	**0**	**72,923**	**1,976,973**	**2,112,441**
ONT.	88,000	--	--	175	44,350	132,525
NYS DEC		--	--	37,540	275,000	312,540
PFBC	--	--	--	35,170	1,205,203	1,240,373
ODNR	--	--	--	--	491,943	491,943
MDNR	--	--	--	--	66,514	66,514
2006 Total	**88,000**	**0**	**0**	**72,885**	**2,083,010**	**2,243,895**
ONT.	--	--	--		27,700	27,700
NYS DEC	137,637	--	--	37,900	272,630	448,167
PFBC	--	--	--	27,715	1,122,996	1,150,711
ODNR	--	--	--	--	453,413	453,413
MDNR	--	--	--	--	60,500	60,500
2007 Total	**137,637**	**0**	**0**	**65,615**	**1,937,239**	**2,140,491**
ONT.	50,000	--	--	--	36,500	86,500
NYS DEC	152,751	--	--	36,000	269,800	458,551
PFBC		--	--	17,930	1,157,968	1,175,898
ODNR		--	--		465,347	465,347
MDNR		--	--		65,959	65,959
2008 Total	**202,751**	**0**	**0**	**53,930**	**1,995,574**	**2,252,255**
ONT.	50,000	--	--	--	18,610	68,610
NYS DEC	173,342	--	--	38,452	276,720	488,514
PFBC	6,500	--	--	64,249	1,186,825	1,257,574
ODNR	--	--	--	--	458,823	458,823
MDNR	--	--	--	--	70,376	70,376
2009 Total	**229,842**	**0**	**0**	**102,701**	**2,011,354**	**2,343,897**
ONT.	126,864	--	--		33,447	160,311
NYS DEC	144,772	--	--	38,898	310,194	493,864
PFBC	1,303	--	--	63,229	1,085,406	1,149,938
ODNR		--	--		433,446	433,446
MDNR		--	--		66,536	66,536
2010 Total	**272,939**	**0**	**0**	**102,127**	**1,929,029**	**2,304,095**
ONT.	55,874	--	--		36,730	92,604
NYS DEC	184,259	--	--	38,363	305,780	528,401
PFBC		--	--	62,007	1,091,793	1,153,800
ODNR		--	--		265,469	265,469
MDNR		--	--		61,445	61,445
2011 Total	**240,133**	**0**	**0**	**100,370**	**1,761,217**	**2,101,719**

Charge 6. Continue to assess the steelhead and other salmonid fisheries, age structure, growth, diet, seasonal distribution and other population parameters

Chuck Murray (PFBC), Kevin Kayle (ODW), and James Markham (NYSDEC)

Stocking

All Lake Erie jurisdictions stocked lake-run rainbow trout (or steelhead) in 2011 (Table 6.1). Yearling plants take place each spring, between February and May, when smolts average about 150 mm in length. Additionally, a small number of adult domestic and golden rainbow trout were stocked to provide a put-and-take trout fishery in Pennsylvania.

TABLE 6.1. Rainbow trout/steelhead stocking by jurisdiction and location for 2011.

Jurisdiction	Location	Strain	Number	Life Stage	Yearling Equivalents	
Michigan	Flat Rock	Manistee River, L. Michigan	61,445	Yearling	**61,445**	**Sub-Total**
Ontario	Mill Creek	Ganaraska River, L. Ontario	35,075	Yearling	35,075	
	Erieau Harbour	Ganaraska River, L. Ontario	1,650	Yearling	1,650	
	Young's Creek	Ganaraska River, L. Ontario	500	Fry	5	
					36,730	**Sub-Total**
Pennsylvania	Conneaut Creek	Domestic	375	Adult	375	
	Conneaut Creek (East Branch)	Domestic	210	Adult	210	
	Temple Run	Domestic	56	Adult	56	
	Conneaut Creek	Golden	2	Adult	2	
	Fourmile Creek	Golden	20	Adult	20	
	Sevenmile Creek	Golden	10	Adult	10	
	Sixmile Creek	Golden	20	Adult	20	
	Bear Creek	Trout Run, L. Erie	24,000	Yearling	24,000	
	Conneaut Creek	Trout Run, L. Erie	90,000	Yearling	90,000	
	Crooked Creek	Trout Run, L. Erie	73,200	Yearling	73,200	
	Elk Creek	Trout Run, L. Erie	247,050	Yearling	247,050	
	Fourmile Creek	Trout Run, L. Erie	18,300	Yearling	18,300	
	Godfrey Run	Trout Run, L. Erie	46,800	Yearling	46,800	
	Presque Isle Bay	Trout Run, L. Erie	82,350	Yearling	82,350	
	Raccoon Creek	Trout Run, L. Erie	23,400	Yearling	23,400	
	Sevenmile Creek	Trout Run, L. Erie	36,600	Yearling	36,600	
	Trout Run	Trout Run, L. Erie	74,250	Yearling	74,250	
	Twelvemile Creek	Trout Run, L. Erie	36,600	Yearling	36,600	
	Twentymile Creek	Trout Run, L. Erie	146,400	Yearling	146,400	
	Walnut Creek	Trout Run, L. Erie	192,150	Yearling	192,150	
					1,091,793	**Sub-Total**
Ohio	Chagrin River	Manistee River, L. Michigan	60,537	Yearling	60,537	
	Conneaut Creek	Manistee River, L. Michigan	44,719	Yearling	44,719	
	Grand River	Manistee River, L. Michigan	60,871	Yearling	60,871	
	Rocky River	Manistee River, L. Michigan	61,058	Yearling	61,058	
	Vermilion River	Manistee River, L. Michigan	38,284	Yearling	38,284	
					265,469	**Sub-Total**
New York	Erie Basin Marina	Domestics	1,000	Yearling	1,000	
	Barcelona Harbor	Domestics	15,000	Fall Fing	530	
	18 Mile Creek	Washington	23,130	Yearling	23,130	
	18 Mile Creek (South Branch)	Washington	23,130	Yearling	23,130	
	Buffalo Creek	Washington	17,340	Yearling	17,340	
	Buffalo River Net Pens	Washington	11,560	Yearling	11,560	
	Canadaway Creek	Washington	23,130	Yearling	23,130	
	Cattaraugus Creek	Washington	104,070	Yearling	104,070	
	Cattaraugus Creek	Skamania	9,400	Yearling	9,400	
	Cayuga Creek	Washington	11,560	Yearling	11,560	
	Cazenovia Creek	Washington	11,560	Yearling	11,560	
	Chautauqua Creek	Washington	46,250	Yearling	46,250	
	Silver Creek	Washington	11,560	Yearling	11,560	
	Walnut Creek	Washington	11,560	Yearling	11,560	
					305,780	**Sub-Total**
					1,761,217	**Grand Total**

TABLE 6.2. Rainbow trout fin-clip summary for Lake Erie, 1999-2011.

Year Stocked	Year Class	Michigan	New York	Ontario	Ohio	Pennsylvania
1999	1998	RP	ADRP	RV; AD; ADRV	-	-
2000	1999	RP	RV	LP	-	-
2001	2000	RP	AD	-	-	-
2002	2001	RP	ADLV	-	-	-
2003	2002	RP	RV	LP	-	-
2004	2003	RP	-	LP	-	-
2005	2004	RP	ADLP	RP	-	-
2006	2005	-	-	LP	-	-
2007	2006	-	ADLP	-	-	-
2008	2007	-	ADLP	-	-	-
2009	2008	RP	-	-	-	-
2010	2009	-	-	-	-	-
2011	2010	-	ADLP	-	-	-

AD=adipose; RP= right pectoral; RV=right ventral; LP=left pectoral; LV=left ventral

A total of 1,761,217 yearling steelhead/rainbow trout were stocked in 2011, representing a 9% decrease from 2010 and a 4% decrease below the long-term (1989-2010) average. Nearly all of the rainbow trout stocked in Lake Erie originated from naturalized Great Lakes strains. A Lake Erie strain accounted for 62% of the strain composition, followed by a Lake Ontario strain (19%), a Lake Michigan strain (19%), and a small amount (0.1%) of rainbow trout that were of domestic origin. New York fin-clipped 9,400 Skamania strain steelhead trout in 2011 (Table 6.2).

Exploitation

While harvest by boat anglers represents only a fraction of the total estimated harvest, it remains the only annual estimate of steelhead harvest tabulated by most Lake Erie agencies. All agencies provide annual measurements of open lake summer harvest by boat anglers, whether by creel surveys or by angler diary reports. These provide some measure of the relative abundance of adult steelhead in Lake Erie.

TABLE 6.3. Estimated harvest by open lake boat anglers in Lake Erie, 1999-2011.

Year	Ohio	Pennsylvania	New York	Ontario	Michigan	Total
1999	20,396	7,401	1,000	13,000	100	41,897
2000	33,524	11,011	1,000	28,200	100	73,835
2001	29,243	7,053	940	15,900	3	53,139
2002	41,357	5,229	1,600	75,000	70	123,256
2003	21,571	1,717	400	N/A*	15	23,703
2004	10,092	2,657	896	18,148 **	0	13,645
2005	10,364	2,183	594	N/A*	19	13,160
2006	5,343	2,044	354	N/A*	0	7,741
2007	19,216	4,936	1,465	N/A*	68	25,685
2008	3,656	1,089	647	N/A*	39	5,431
2009	7,662	857	96	N/A*	150	8,765
2010	3,911	5,155	109	N/A*	3	9,178
2011	2,996	1,389	92	N/A*	3	4,480
1999-2010 Average	17,195	4,278	758	33,025	47	33,286

* no creel data collected by OMNR in 2003, 2005-2011

** 2004 OMNR sport harvest data is July and August, Central basin waters only

Rainbow trout harvest by open lake boat anglers varied greatly across jurisdictions. Low directed effort at rainbow trout in the open water fishery and small sample sizes can lead to wide variations in annual estimates. The estimated harvest from the summer open-water boat angler fishery in 2011 was 4,480 steelhead in all US waters; a 51% decrease from the estimated 2010 steelhead harvest (Table 6.3). Annual declines in harvest were greatest in Pennsylvania (-73%), followed by Ohio (-23%) and New York (-17%).

Trends in harvest rates were contrasting; 2011 steelhead boat angler harvest rate in Ohio waters (0.43 steelhead/angler hour) increased exponentially from 2010 and was nearly three times higher than the average of 0.14 steelhead/angler hour in the 1999-2010 time series. Conversely, the 2010 harvest rate in Pennsylvania (0.03 steelhead/angler hour) dropped to less than one quarter the long-term average of 0.13 steelhead/angler hour. The 2011 rainbow trout harvest rate of 0.07 steelhead/angler hour by Ontario anglers (areas combined) also decreased from 2010, but declines were not as significant. Small amounts of targeted effort for steelhead and small numbers of interviews contributing to the catch rate statistics confound these results. Combined harvest rates in 2011 across all reporting agencies (0.18 steelhead/angler hour) were 50% above the long term interagency average of 0.12 steelhead/angler hour (Figure 6.1).

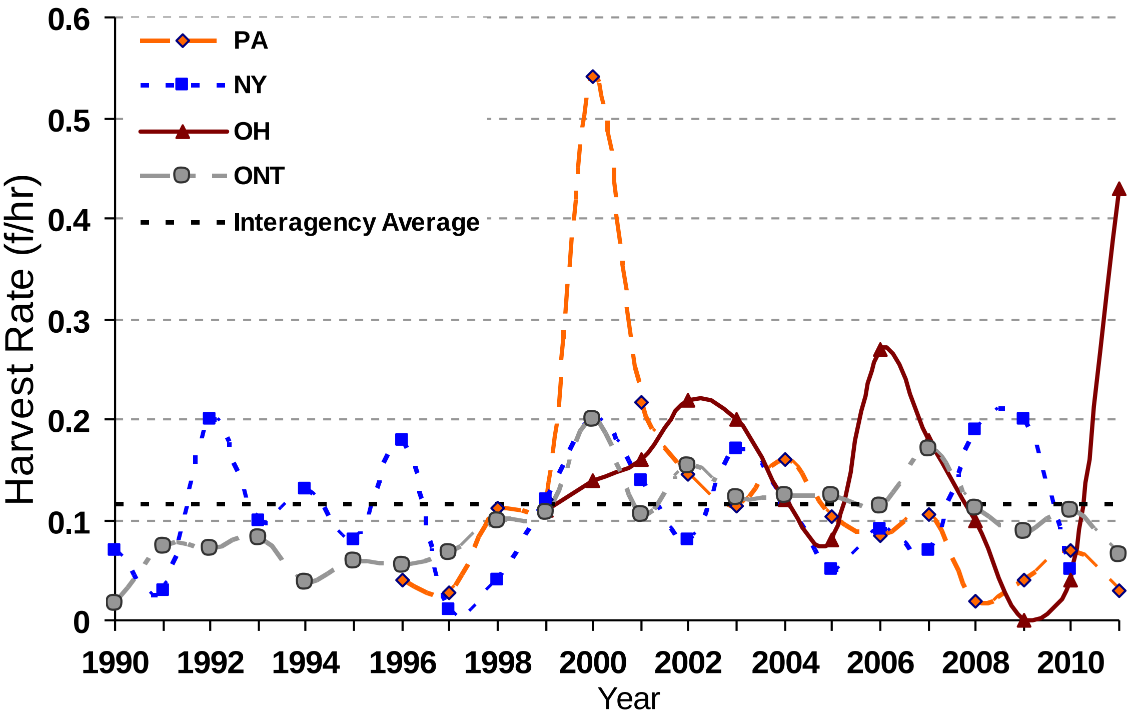

FIGURE 6.1. Targeted steelhead harvest rates (fish/angler hour) in Lake Erie by open lake boat anglers in Ohio, Pennsylvania, New York and Ontario 1990 – 2011.

The Ontario Ministry of Natural Resources did not conduct open water angler surveys during 2011 that could provide comprehensive estimates of rainbow trout harvest, effort or catch rates in open lake waters of Lake Erie. However, they collected angler diary reports that detail trends over time by area of the lake. In 2011, diarists reported 100 targeted rainbow trout trips in west-central basin and 52 targeted trips in the east-central basin waters of Lake Erie. Only one trip targeting rainbow trout was recorded through the diary program in the east basin for 2011 and no rainbow trout were caught.

Angler diary reports from Ontario show that rod-hours for rainbow trout increased in the west central basin for the first time in five years (Figure 6.2). Catch rates in the west central basin (0.13 fish/rod-hour) were 46% lower than 2010 values, but remained near the long-term average (0.15 fish/rod-hour).

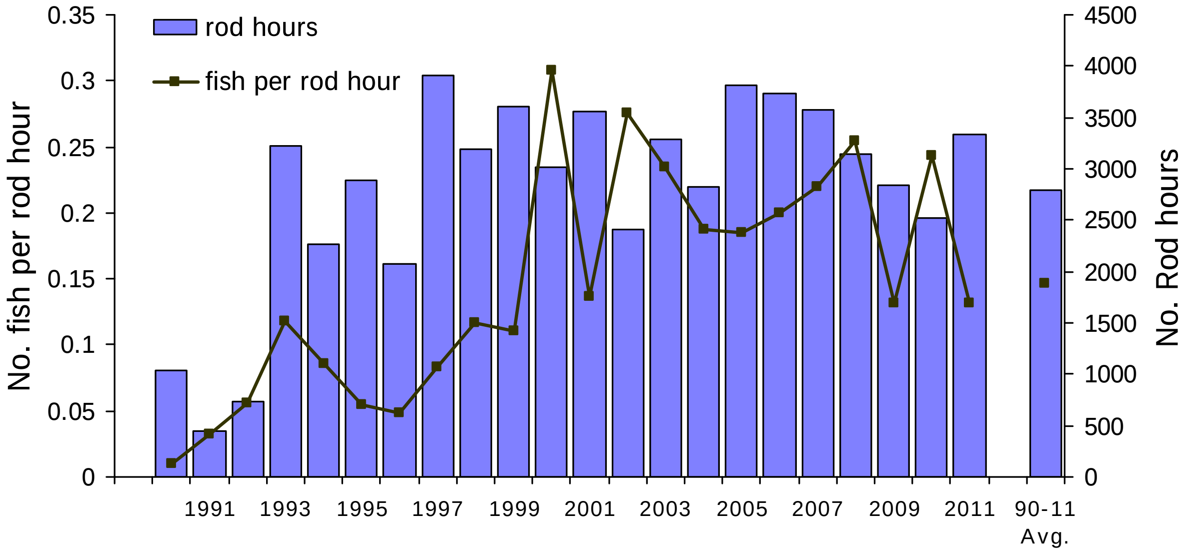

FIGURE 6.2. Targeted steelhead effort and catch rates in Lake Erie's west-central basin as reported in angler diaries by open lake boat anglers in Ontario from 1990 - 2011.

Rod hours for rainbow trout increased in the east central basin for the second consecutive year (Figure 6.3). Rainbow trout catch rates by Ontario diarists in the east-central basin (0.06 fish/rod hour) were 24% lower than 2010, and were slightly lower than the long-term average (0.08 fish/rod hour).

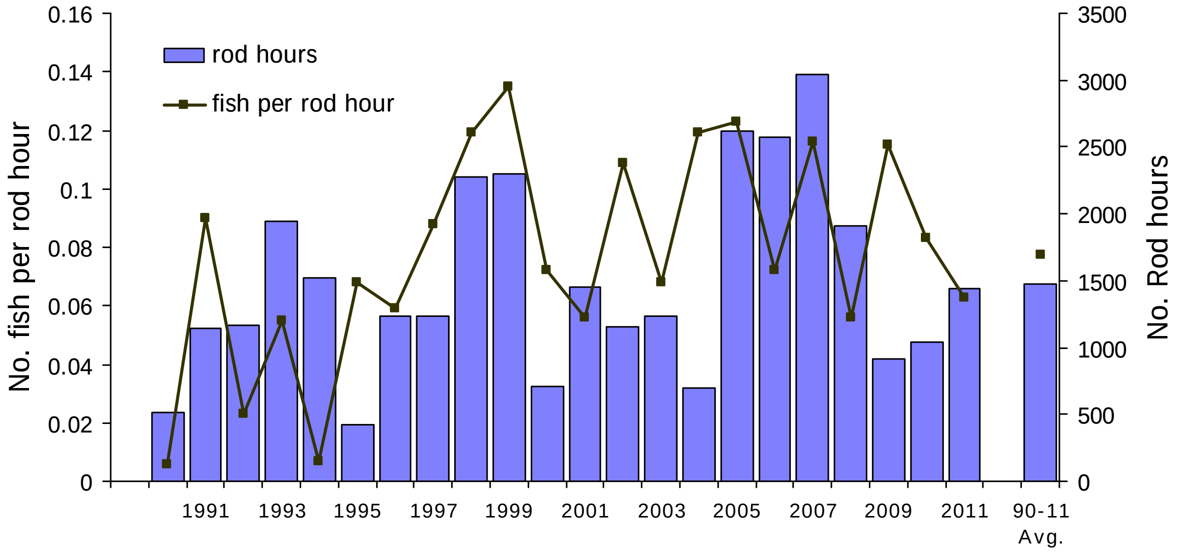

FIGURE 6.3. Targeted steelhead effort and catch rates in Lake Erie's east-central basin as reported in angler diaries by open lake boat anglers in Ontario from 1990 - 2011.

Tributary Creel Surveys

The Lake Erie tributaries are the focal point of the steelhead fishery. Unfortunately, data on this segment of the sport fishery is fragmented, preventing a comprehensive review of annual trends in targeted effort and catch rate by stream anglers across all areas of Lake Erie.

An angler diary program maintained by the NYSDEC Lake Erie Fisheries Unit provides the best review of annual catch rates by tributary anglers through 2010. This data shows that catch rates by steelhead anglers in New York streams had steadily increased throughout most of the last two decades and peaked in 2006. Catch rates remained high through 2008, but sharply declined in 2009 and 2010 (Figure 6.4). Diary cooperator catch rates in 2010 were 0.52 steelhead/hour, declining 33% over the past two years. Despite the decline, catch rates remained slightly above the long-term average of 0.47 steelhead/angler hour.

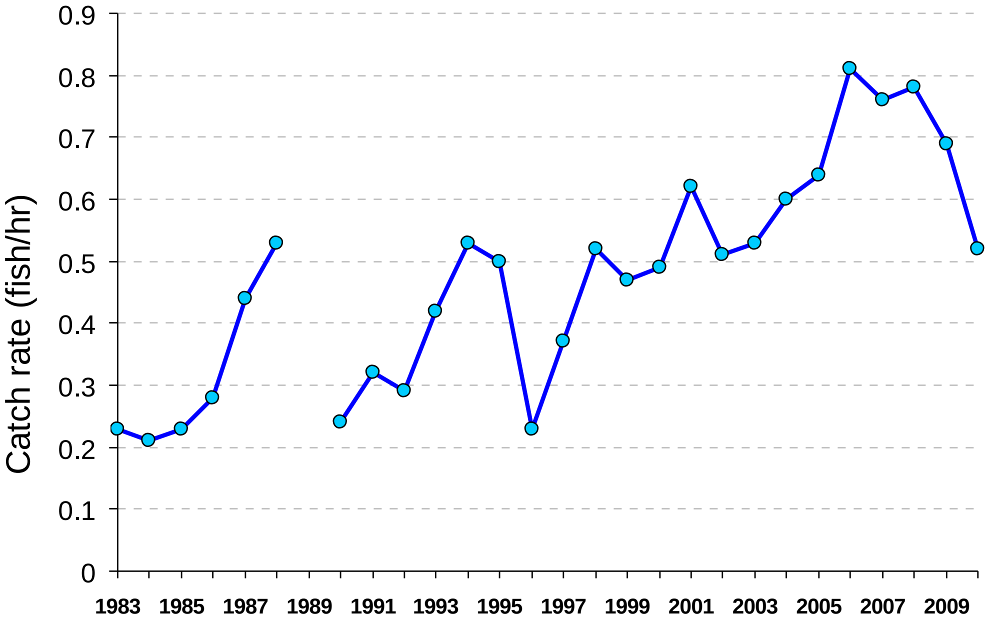

FIGURE 6.4. Targeted steelhead catch rates (fish/angler hour) in Lake Erie tributaries by New York angler diary cooperators, 1983-2010.

Sources of Adult Steelhead Trout in Lake Erie Tributaries

Concluding a study of adult steelhead trout spawning distribution patterns in Lake Erie tributaries, researchers at Bowling Green State University (Ohio Sea Grant funding) found that many of the steelhead trout caught by fisherman in NY tributaries come from OH and PA stocking programs. John Farver and Jeff Miner with PhD student, Chris Boehler, used the unique chemical signatures in the otoliths of steelhead trout smolts released from hatcheries (MI, OH, PA, NY) and naturally reproduced fish from NY and ONT tributaries to identify the sources of adult steelhead in rivers from MI to NY. As expected, relatively few (~15%) adult steelhead trout caught in OH and PA tributaries were strays stocked as smolts in other states (or were of unknown origin), but different results were found in NY and MI streams (Figure 6.5). In NY tributaries, approximately 75% of the adult steelhead trout collected were stocked as smolts into OH and PA streams (i.e., from OH and PA hatchery stock). They hypothesize that this may occur because 1) OH and PA stock about 70% of the almost two million smolts placed in Lake Erie tributaries each year, 2) OH and PA stock numerous streams near river mouths, and sometimes over extended periods (Feb-April); high flow occurring at the time of some stockings may force many newly-stocked smolts into Lake Erie shortly after stocking and thus affect straying, 3) NY-stocked smolts are relatively small (110-130 mm) compared to desirable stocking sizes based on literature (>160 mm), so the fate of these NY-stocked fish is not clear, and 4) the NY-stocked fish are stocked upstream where they may compete with naturally reproduced steelhead trout fingerlings. In the Huron River (MI), 45% of adults clearly assign to the MI hatchery source, while remaining fish assign to Ontario (Grand River), NY, or their origin was unknown. They suspect that some of these strays may have come from Lake Huron sources, but a lack of source chemical signatures prevents clarification.

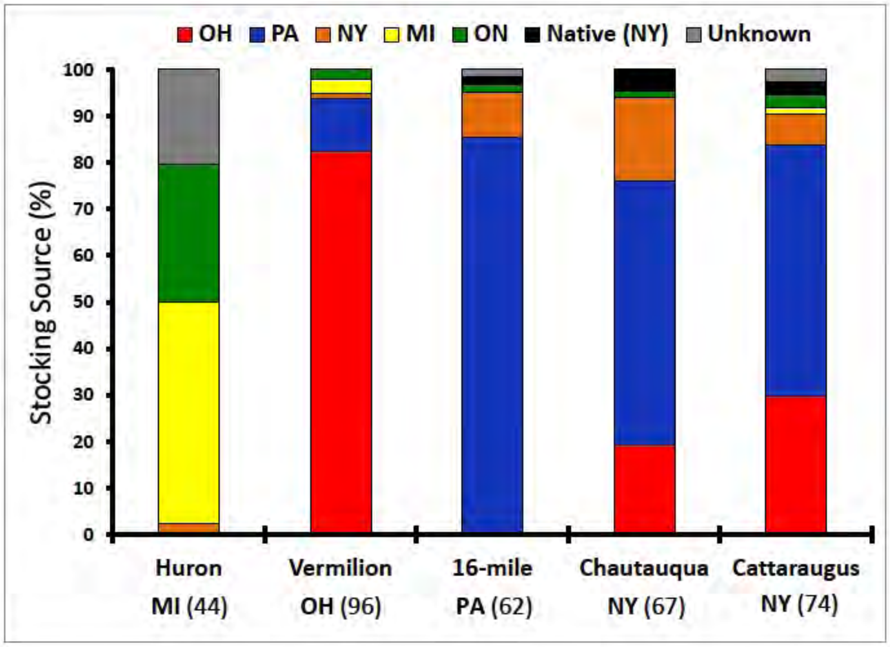

FIGURE 6.5. Origin of adult steelhead trout in five Lake Erie tributaries, determined by otolith chemical signatures from stocked and native (naturally reproduced in streams) smolts. Sample sizes are in parentheses and consist of adults collected in both spring and fall spawning runs. Ontario-identified adults are based on yearling fish collected in the Grand River, ON.

Charge 7: Prepare Lake Erie Cisco Management Plan. Report on the status of Cisco in Lake Erie and potential for re-introduction and/or recovery.

Elizabeth Trometer (USFWS), Tom MacDougall and Kurt Oldenburg (OMNR),
Jim Markham (NYSDEC) and Richard Kraus (USGS)

Cisco (formerly lake herring; *Coregonus artedi*) is indigenous to the Great Lakes and historically supported one of the most productive fisheries in Lake Erie (Scott and Crossman 1973, Trautman 1981). Cisco is considered extirpated in Lake Erie, although commercial fishermen report it periodically (Table 7.1, Figure 7.1). Their demise was mainly through over-fishing, although habitat degradation and competition likely contributed to recruitment failure (Greeley 1929, Hartman 1973, Scott and Crossman 1973). Siltation of spawning shoals, low dissolved oxygen, and chemical pollution are a few factors contributing to habitat degradation (Hartman 1973). The cisco collapse also coincided with the introduction of both rainbow smelt (*Osmerus mordax*) and alewife (*Alosa psuedoharengus*), and the expansion of these exotic species in the 1950s may have prevented any recovery of cisco through competition and predation (Selgeby et al. 1978, Evans and Loftus 1987).

Numerous investigators have shown that alewife and smelt have negative effects on coregonid populations in the north-temperate lakes (Ryan et al. 1999). When alewife and smelt stocks are depressed, it creates an opportunity for coregonids to have stronger year classes. There is some evidence to indicate that this has occurred for whitefish (Oldenburg et al. 2007). Cisco should also be favored by these conditions. Rainbow smelt abundance declined sharply in the 1990's and continues to remain relatively low (Ryan et al. 1999 and Forage Task Group 2012). Alewife have never been persistently abundant in Lake Erie due to overwinter temperatures that frequently prove lethal (Ryan et al. 1999). The apparent natural recovery from historic lows of other coldwater species (i.e. lake whitefish and burbot) together with the current, relatively low abundance of rainbow smelt had suggested an opportunity for the recovery of cisco in Lake Erie. Unfortunately, recruitment problems identified in both of whitefish and burbot over the past 10+ years have called into question the success of their recovery and thus qualified the potential for cisco to recover on their own. It should be recognized that, although rainbow smelt population abundance in Lake Erie has declined from past decades, densities of this offshore pelagic feeder are still relatively high compared to other predator species (Forage Task Group 2012).

Cisco – Recent Observations

Commercial fishermen have reported cisco in 10 of the last 15 years. It is difficult to assess relative abundance from these reports however as they represent the passive surrendering of bycatch by two commercial fishers who recognize their importance. Recent reports and collections are summarized in Table 7.1 with locations shown in Figure 7.1. Although there were no reports of cisco in 2009, four were reported from the commercial fishery in both 2010 and 2011. While young cisco (age 1 and 2) were observed in the early part of the 2000's, none have been observed lately. The most recent year class confirmed is that of 2003, although the two collected in 2011 are estimated to be of 2005 and 2008 year class.

Surveys complete during 2010 and 2011 in the Huron-Erie corridor have collected young coregonids (Figure 1). Two cisco larvae were collected (12.0 mm TL) on May 11/12 2010 (Edward Roseman, USGS-GLSC, pers. comm.). One was collected in the St. Clair River off Pine River at the wall in the shipping channel by the town of Clair, MI. The other cisco larvae was taken in the North Channel, just downstream of the Mid-Channel split near Algonac, MI. Positive identification was verified by genetic analysis. In December 2011, eight young coregonids (51-71 mm TL) were collected in floating fyke nets in the Livingstone Channel of the Detroit River just downstream of Wyandotte, MI (Peter Hrodey, USFWS, pers. comm.). Their taxonomic identification is presently unknown and awaiting confirmation from genetic testing.

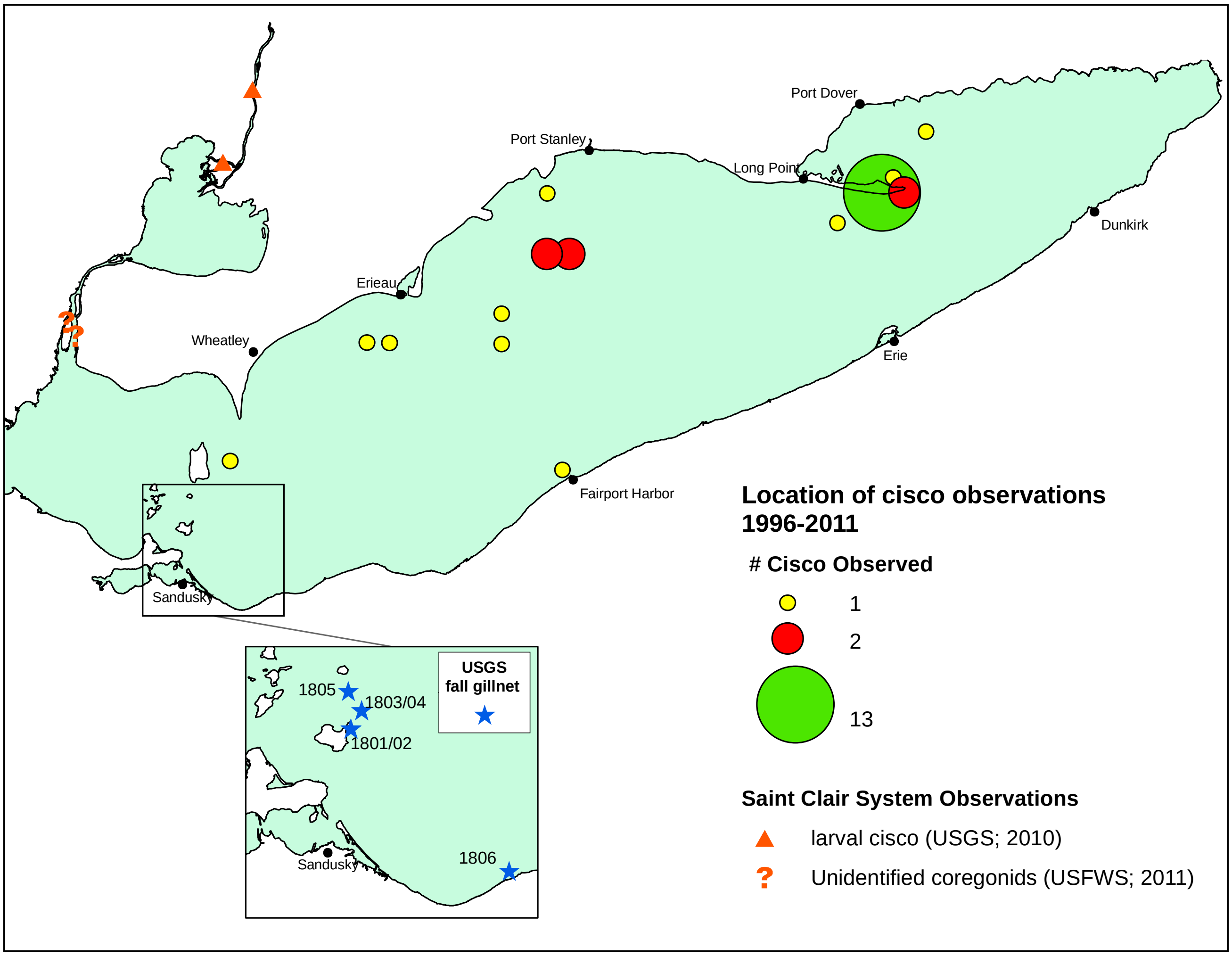

FIGURE 7.1. Cisco in Lake Erie and the Lake St. Clair system. Relative abundance of adult specimens from the commercial fishery and agency surveys is indicated with proportional, colored circles; Observations of planktonic larval and juvenile specimens from the Huron Erie Corridor are shown in orange; Gillnet sites (set numbers shown) from USGS fall 2011 surveys, near Kelley's Island and Vermillion OH, are indicated with blue stars in the inset.

TABLE 7.1. Sampling details from a selection of cisco captured during commercial and fishing efforts, 1996-2011.

Observation Year	Basin	Year Class	Sex	Number
1996	Central	1991	F	1
1999	Central	1998	F, M	3
	East	1997	F	1
		1998	F, M	2
2002	East	1996*	F	1
		2001*	F	1
2003	Central	1998*	U	1
		2001	M	1
		2002	M	1
	East	1999*	F	1
2004	East	U	U	1
2005	Central	2001	F	2
2007	East	2000	F	2
2008	Central	2001	F, M	2
2010	West	2001	F	1
	East	1998	F	1
		2001	F	1
		2003	M	1
2011	East	2008*	U	2
		2005*	U	2

* indicates age extrapolated from total length measure

F = female; M = male; u = unknown

Rehabilitation Efforts

Efforts to address the re-establishment of cisco in Lake Erie have been ongoing for a number of years and are highlighted in previous annual reports of the Coldwater Task Group. In an effort to determine if a remnant cisco stock still exists in Lake Erie, nine cisco specimens gathered over the past several years from Lake Erie were sent to the USGS Leetown Science Center, Northern Appalachian Research Laboratory for genetic analysis using microsatellite markers. Recent and museum specimen cisco from Lake Erie and other Great Lakes, including archived Lake Erie specimens from 1955-1965, were compared to determine if the Lake Erie specimens are genetically distinct from other Great Lakes stocks (i.e. remnant population) or are strays from other populations.

The results of this research indicate that the recently caught cisco are genetically most similar to Lake Erie specimens from 1950s and 1960s, suggesting that a remnant of the original Lake Erie stock may exist (Rocky Ward, USGS Northern Appalachian Research Laboratory, Wellsboro, unpublished data). The extant surviving cisco that is most similar to the Lake Erie remnant is from Lake Huron. The implications of these findings pose difficult management decisions for restoration efforts involving stocking with cisco from other sources of broodstock. However, the current stocks may not be large enough to re-establish themselves as a significant forage fish in the eastern basin of Lake Erie.

In recognizing that stocking is one possible outcome of the management decision process, and realizing that a long lead time is necessary between the decision to stock and the first stocking event, proactive disease testing of potential broodstock from viable sources has begun. Positive results for BKD from Lake Superior bloaters in 2005 have eliminated this lake as a potential source of cisco broodstock gametes. Ciscoes collected from eastern Lake Ontario from November 2006 through 2009 were screened for various diseases by the NYSDEC Fish Disease Control Unit. Tests for VHS, IHN, IPN, BKD, heterosporis, and furunculosis were all negative for these fish.

Negative results are required for three consecutive years before the collection of broodstock or gametes can be considered. There is a need to investigate the possibility of using Lake Huron or Lake Michigan stocks as a source of broodstock.

Management Plan

The Lake Erie Coldwater Task Group was charged with preparing a Lake Erie cisco management plan at the Lake Erie Committee Annual meeting in March of 2007. Preparation of the management plan began in fall 2007; however, after several drafts, the exercise has stalled due to several outstanding issues which include:

- Do recently observed specimens represent a remnant stock?
- What is the population trend of cisco currently inhabiting Lake Erie? (There have been no directed surveys for cisco in Lake Erie. Occurrences in fishery catches are very likely unrecognized or underreported)
- Do Lake Erie cisco face different constraints than other coregonids which have shown evidence of recovery (e.g. whitefish; 1990s)
- Do we stock? Should we stock on top of a possible remnant population? If so, what is the best broodstock?
- What are the genetic implications of stocking on a remnant population? Is there currently a genetic bottleneck?

Efforts toward addressing the two basic issues (accurate assessment of the current Lake Erie population and characterizing the population as to its relation to the historic stock) continued in 2011. As a strategy to address outstanding questions, the task group sought the advice of external cisco experts from around the Great Lakes, beginning with a conference call in May of 2011 and followed by email correspondence. One goal of these discussions was to better understand how cisco are sampled elsewhere and determine whether the spatial and temporal distribution of fishing and scientific sampling efforts on Lake Erie would be effective for capturing cisco. These exchanges highlighted the fact that current fisheries assessments on Lake Erie may not be sufficient for detecting and assessing the presence and abundance of cisco. Based on assessments in the upper great lakes, cisco are most vulnerable when in spawning aggregations from mid-October through December in shallow areas (<10m) associated with historic cisco and whitefish spawning. It was discovered that many of the historical spawning sites for cisco in Lake Erie, especially around the islands in the western basin, are not currently targeted by scientific monitoring or commercial fishing.

2011 Sampling of Historic Cisco Spawning Sites

At the request of the CWTG, USGS personnel set a few gill nets near Kelley's Island and Vermilion, OH, to characterize the fish assemblage at historical cisco spawning locations (Figure 7.1). Sites in these areas included the northeast site of Kelley's Island, Kelley's Island Shoal, Gull Island Shoal, and hard bottom areas southwest of the mouth of the Vermilion River. This sampling was done in conjunction with ongoing walleye gill net comparison studies, and therein constrained spatially and temporally to areas adjacent to planned walleye gill net sets. Sites were sampled during late October and early November, corresponding with early cisco spawning period for Lake Erie. The gill nets used for sampling cisco spawning sites consisted of 6-ft high by 50-ft long of monofilament mesh panels ranging from 1.75 to 3 inches. Net panels were arranged in random order and there were unequal numbers of each mesh size (1.75" n=4, 2" n=5, 2.25" n=3, 2.5" n=4, 2.75" n=4, 3" n=3) for a total length of 1150 feet.

Gill nets were set overnight on bottom at 6 locations (Figure 7.1) ranging between 10 and 12 feet depth. Water temperature ranged between 10C and 12C. The catches were primarily comprised of white perch, gizzard shad, white bass, walleye, and suckers (Table 7.2). Historically, cisco utilized the same or similar spawning areas as lake whitefish. That only a few lake whitefish were captured (n=5), provides ambiguous evidence that these sites are currently utilized by whitefish for spawning. Additional sampling of shallow historic cisco spawning areas is being considered. Maumee Bay is highlighted as a current spawning area for lake whitefish, and potentially suitable for cisco spawning.

Limited November gillnetting by OMNR, targeting lake trout on Nanticoke Shoal in the eastern basin of the lake, did capture one pre-spawn whitefish, thus providing another potential location for future fall assessments.

TABLE 7.2. Species composition of gill net samples from historical cisco spawning locations.

Species	%	catch per lift
White perch (+hybrids)	27.9	65.8
Gizzard shad	23.4	55.2
White bass	21.5	50.6
Walleye	17.7	41.8
Shorthead redhorse	5.2	12.2
White sucker	1.4	3.4
Channel cat	1.1	2.6
Lake whitefish	0.4	1.0
Smallmouth bass	0.4	1.0
Freshwater drum	0.3	0.6
Rock bass	0.3	0.6
Yellow perch	0.3	0.6
Black crappie	0.1	0.2
Quillback	0.1	0.2
Total Count	1179	

2011 Genetics Assessment Research Strategy

To further our understanding of the genetic relationships among historic and contemporary Lake Erie and Lake Huron cisco populations, task group members have recently partnered with Wendy Stott (USGS Great Lakes Science Centre) to develop a research strategy that will: i) revisit the question of whether recent observations represent a true remnant stock (see above) and ii) determine the similarity of any remnant stocks and historical stocks to potential sources of broodstock from Lake Huron. This work will build on the previous genetic examination (above). It will utilize the previous samples and will greatly increase the sample size by incorporating tissue samples collected from the commercial fishery in the interim as well as DNA extracted from a large archive of historic scale samples. The investigators are currently seeking funding for this work.

Additional Cisco Samples in 2012

As Maumee Bay is recognized as a known spawning location and which supports a significant commercial fishery for lake whitefish, it may be possible to enlist the assistance of commercial fishermen to deliberately look for cisco in their catches. In addition, OMNR has initiated talks with the Ontario Commercial Fisheries Association to solicit additional samples from the Ontario commercial fisheries, to date the most consistent source of samples. We are hopeful that this may result in both additional samples for genetic analysis and identify additional locations for standardized assessment.

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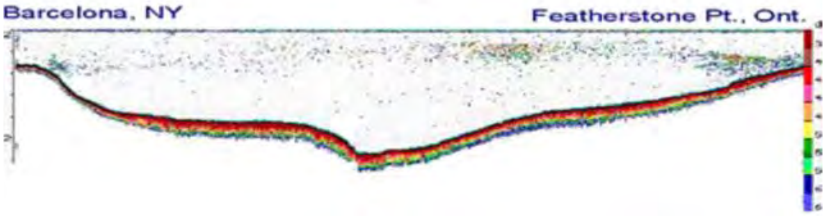
Report of the
Lake Erie
Forage Task Group

March 2012



Members:

Jim Markham	- New York Department of Environmental Conservation, (NYS DEC) {Co-Chair}
Mike Hosack	- Pennsylvania Fish and Boat Commission, (PFBC) {Co-Chair}
John Deller	- Ohio Department of Natural Resources, (ODNR)
Patrick Kocovsky	- United States Geological Survey - Great Lakes Science Center (USGS)
Tom MacDougall	- Ontario Ministry of Natural Resources, (OMNR)
Alicia Pérez-Fuentetaja	- The State University of New York, (SUNY- Buffalo State College)
Elizabeth Trometer	- United States Fish and Wildlife Service, (USFWS)
Eric Weimer	- Ohio Department of Natural Resources, (ODNR)
Larry Witzel	- Ontario Ministry of Natural Resources, (OMNR)

Presented to:

Standing Technical Committee
Lake Erie Committee
Great Lakes Fishery Commission

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1.0 Charges to the Forage Task Group in 2011-2012

1. Continue to describe the status and trends of forage fish and invertebrates in each basin of Lake Erie.
2. Continue the development of an experimental design to facilitate forage fish assessment and standardized interagency reporting.
3. Continue hydroacoustic assessment of the pelagic forage fish community in Lake Erie, incorporating new methods in survey design and analysis while following the GLFC‟s Great Lakes Hydroacoustic Standard Operating Procedures where possible/feasible.
4. Continue the interagency lower-trophic food web monitoring program to produce annual indices of trophic conditions which will be included with the annual description of forage status.

2.0 Status and Trends of Forage Fish Species

2.1 Synopsis of 2011 Forage Status and Trends

General Patterns

- Relative forage abundance was low to moderate in 2011
- Age-0 rainbow smelt increased in the East, and decreased in the Central and West.
- Gizzard shad was above average in East and Central, below average West
- Predator growth was above average in East and Central basins
- Phosphorus levels decreased in east basin, but increased in west and central basins

Eastern Basin

- Forage fish abundance during 2011 was high in New York (NY) and below average in Ontario (ON)
- Age-0 rainbow smelt increased basin-wide; 2011 year class was moderate
- Yearling-and-older (YAO) rainbow smelt density decreased (NY) or remained about the same (ON) in 2011; abundance was below average basin-wide
- Age-0 yellow perch abundance indices were mixed; 2011 year class strength ranked moderately strong (ON) to below average. (NY)
- Age-0 alewife abundance remained below avg.
- Age-0 gizzard shad decreased in 2011 from record high density; above average density basin-wide
- Record high numbers of emerald shiners in New York survey; all age groups below avg. abundance in Ontario
- Spottail shiner remained at low densities throughout basin
- Round goby densities increased (ON) or stayed the same (NY)
- Average length of age-0 rainbow smelt decreased; YAO smelt were about the same size as in 2010; both age groups were below average size in 2011
- Predator diets were diverse, dominated by fish species, primarily rainbow smelt and round goby
- Predator growth remained good; age-2 to -6 smallmouth bass remained at or near record long length-at-age in Long Pt. Bay, ON, and age 2 and 3 bass cohorts in NY near maximum mean lengths
- Lake trout growth remained high and stable.
- Mean density of YAO smelt-size acoustic targets was 9398 fish/hectare in 2011, a 5% decrease from the 2010 and 34% lower than the 2009 estimate
- Yearling-and-older and older smelt-size acoustic targets were most dense in the south half of the basin, west and north of Dunkirk, NY

Central Basin

- Low to moderate forage fish abundance throughout the basin in 2011
- Age-0 and YAO forage density increased from 2010, but was below average
- Rainbow smelt and emerald shiner abundance were below average
- Age-0 yellow perch abundance decreased from 2010 and was below average
- Age-0 gizzard shad increased in west and was well above average
- Round goby abundance was well above average
- Mean length of forage species decreased from 2010, but remained at or above average
- Mean length of walleye was above average for fish up to age 6
- Predator diets were predominantly rainbow smelt, gizzard shad and emerald shiners

West Basin

- Forage abundance and biomass were at low levels
- Age-0 gizzard shad catches increased from 2010, but were still below long term mean
- Age-0 and YAO rainbow smelt catches remain low
- Age-0 emerald shiner decreased from 2010; YAO emerald shiner increased; both were below long-term mean
- Age-0 white perch decreased 69% from 2010, lowest since 2002
- Round gobies increased in 2011, third lowest since first year of invasion (1997)
- Age-0 yellow perch increased from 2010 and walleye recruitment decreased; both were below long-term mean; white bass recruitment decreased and was below long-term mean
- Size of age-0 walleye, yellow perch, white bass, white perch, and smallmouth bass were all near long term means
- Fall walleye diets showed reliance on gizzard shad and emerald shiners

2.2 Eastern Basin (L. Witzel, J. Markham and D. Einhouse)

Rainbow smelt are the principal prey fish species of piscivores in the offshore waters of eastern Lake Erie (Figure 2.2.1). In 2011, rainbow smelt once again was the most abundant forage species captured in fall index bottom trawl surveys in Ontario (OMNR) and the second most abundant forage species in New York (NYS DEC); the PFBC did not perform any bottom trawl assessment in Pennsylvania waters of the east basin during 2011 (Table 2.2.1). Yearling-and-older (YAO) rainbow smelt abundance was average in New York and below average in Ontario with approximately 90% of YAO-members from the 2010 year class (age-1). Age-0 rainbow smelt abundance was about three times greater in New York compared to Ontario; 2011 density estimates were slightly above average in New York, but only about one-half of the long-term average for Ontario‟s trawl time series. The mean length of age-0 (59 mm FL) rainbow smelt decreased in 2011 (Figure 2.2.2). The mean length of age-1 (101 mm FL) smelt was unchanged from 2010 and remained smaller than average (1984-2010 avg. = 103 mm).

The contribution of non-smelt fish species to the forage fish community of eastern Lake Erie was dominated in 2011 by emerald shiner, age-0 yellow perch, and round goby in Ontario and by emerald shiner, trout perch, round goby, and age-0 yellow perch in New York (Table 2.2.1). Emerald shiner were caught in record high numbers in New York waters, in part due to a single very large trawl catch. Emerald shiner were below average density in Ontario. Spottail shiner abundance remained low throughout all eastern basin regions in 2011 (Table 2.2.1). Episodic high catches of age-0 alewife have been observed in agency trawl assessments, but not in recent years (2000, 2002 in NY, 1999 in ON). Age-0 alewife abundance was below the long-term average for all surveyed areas in 2011. Age-0 gizzard shad abundance increased in Ontario and decreased in New York in 2011 after reaching a record high numeric density in New York last year.

Round goby emerged as a new species among the eastern basin forage fish community during the late 1990‟s. Round goby numbers continued to increase at a rapid rate and by 2001 were the most or second-most numerically abundant species caught in agency index trawl gear across areas surveyed in eastern Lake Erie. Annual round goby abundance estimates from 2000 to 2007 were variable and increasing. Round goby densities have decreased since 2007 and the 2010 estimate ranks as the lowest index observed in Ontario and the second lowest in New York since 2000. The recent decreasing trend in goby abundance was interrupted in 2011 by an increase in Ontario and no significant change in New York (Table 2.2.1).

Rainbow smelt have remained the dominant prey of angler-caught walleye sampled each summer since 1993. Beginning in 2001 prey fish other than rainbow smelt made a small, but measurable, contribution to the walleye diet. Collections beginning in 2006, and continuing in 2007 and 2008, were especially noteworthy because several other prey fish species contributed measurably to walleye diets. Round goby remain the largest component of the diet of adult smallmouth bass caught in New York gill net surveys since 2000. Gobies were first observed in the summer diet of yellow perch in Long Point Bay in 1997 and have been the most common prey fish species found in perch stomachs since about 2002.

Fish species continue to comprise the majority of the diets of both lake trout and burbot caught in experimental gill net surveys during August in the eastern basin of Lake Erie. Rainbow smelt have been the dominant food item in Lean Strain lake trout since coldwater surveys began in the early 1980s in Lake Erie, occurring in 85 – 95% of the stomachs. However, in years of low YAO rainbow smelt abundance such as 2006 and 2010, round goby became prominent in the diets of both Lean and Klondike Strain lake trout. Smelt dominated lake trout diets again in 2011, occurring in 83% of Lean Strain and 71% of Klondike Strain lake trout. Round goby were the only other prominent forage species, occurring in 19% of Lean Strain and 32% of Klondike Strain fish. Round goby occurred more frequently in the diets of Klondike than Lean Strain lake trout during all seven years since 2005 that Klondike Strain individuals have been collected in coldwater index gill nets.

The occurrence of rainbow smelt in burbot stomachs containing food increased to 46% in 2011 (37% in 2010) and was coincident with a decrease in occurrence of round goby from 65% to 50%. Gobies have increased in the diet of burbot since this invasive species first appeared in the eastern basin in 1999. They were the main diet item for burbot in six of the last eight years.

Mean length of age-2 and age-3 smallmouth bass cohorts sampled in 2011 autumn gill net collections (New York) have remained stable over the past 4 years and are among the highest in the 31-year history of this survey. Beginning in the late 1990‟s coincident with the arrival of round goby, several age classes of smallmouth bass in Long Point Bay, Ontario have exhibited a trend of increasing length-at-age. In 2011, length-at-age for each of age-2 to age-6 smallmouth bass cohorts remained at or near maximum values observed during the 26-year time series of OMNR"s Long Point Bay gillnet survey. Length-at-age trends from New York"s juvenile walleye (age-1 and age-2) assessment were near long-term average sizes. Mean size-at-age (length and weight) of lake trout in 2011 were consistent with the recent 10-year average (2001 – 2010) and k condition coefficients remain high. Klondike strain lake trout have significantly lower growth rates compared to Lean strain lake trout. Lake trout growth in Lake Erie continues to be stable and among the highest in the Great Lakes.

2.3 Central Basin (J. Deller)

Routine bottom trawl surveys in the central basin began in Ohio in 1990 and Pennsylvania in 1982. The Pennsylvania Fish and Boat Commission was unable to survey the central basin during 2011. In 2011, overall forage abundance in the Ohio waters was 1716 fish per hectare (Figure 2.3.1). The 2011 index increased from 2010, and can be attributed to increases in both age-0 and YAO age groups. The increases from 2010 densities were moderate, and as a result, the overall forage abundance was below the long-term average.

Rainbow smelt and emerald shiners are the primary forage species in the central basin. For both species, age-0 and YAO age groups were below average in most areas of the central basin (Tables 2.3.1 and 2.3.2). Age-0 emerald shiners in western Ohio waters were the only index above the long-term average. Basin-wide indices for age-0 rainbow smelt and emerald shiners were low to moderate, respectively. Yearling-and-older indices for rainbow smelt increased from 2010, but were well below the long-term average. Emerald shiner YAO indices increased in western Ohio, but decreased in eastern Ohio relative to 2010. Basin wide, YAO indices for rainbow smelt and emerald shiners were moderate based on the 10 year time series. The highest densities for rainbow smelt were found in eastern Ohio waters, while emerald shiner densities were highest in the west.

Round goby first appeared in central basin trawl surveys in 1994. Since then, round goby densities have tended to be higher in eastern areas of the basin relative to western areas. This trend continued in 2011, with densities of both age-0 and YAO age groups (Tables 2.3.1 and 2.3.2). Round goby indices in 2011 increased basin wide for both age-0 and YAO age groups compared to 2010. In most areas of the central basin, round goby indices were well above average and were some of the highest indices in the time series. Round goby densities have been increasing in most areas of the basin since 2009.

Age-0 gizzard shad indices in Ohio waters are generally higher in the west areas relative to the east. This trend continued in 2011 with gizzard shad indices increasing in the west and decreasing in the east from 2010 (Table 2.3.1). Gizzard shad abundance in western Ohio increased to a record high density in 2011. Alewife has not been caught in the central basin since 2007, despite being regularly encountered in western Ohio prior to 2004.

Age-0 yellow perch indices decreased basin wide from 2010 and were below average (Table 2.3.1). Yearling-and-older yellow perch indices decreased from 2010 in the west, but increased in the east (Table 2.3.2). Yearling-and-older yellow perch were well below average in the west, and slightly above average in the east. Age-0 white perch indices increased in the west and decreased in the east from 2010. Yearling-and-older white perch indices increased in the west, but were the same as 2010 in the east. Basin wide, both age-0 and YAO white perch densities were below average.

Central basin diets of walleye and white bass from the fall gillnet survey in Ohio continue to be comprised of gizzard shad, rainbow smelt and emerald shiners. Adult walleye diets were in eastern Ohio waters were comprised of emerald shiner (40%), gizzard shad (30%) and rainbow smelt (28%). Adult walleye in western Ohio waters consumed more gizzard shad (79%) compared to walleye in eastern Ohio. The remaining diet of walleye in western Ohio was emerald shiner (15%), rainbow smelt (2.5%) and unidentified fish (2.5%). The composition of age-1 walleye diets was similar to adult walleye but contained a slightly higher proportion of emerald shiners in both east and west areas of Ohio. Basin wide, adult white bass consumed primarily emerald shiners (84% east; 78% west), with minor contributions from round goby, gizzard shad and rainbow smelt. Round goby continue to comprise over 50% of central basin smallmouth bass diets in the fall.

Mean length of walleye collected in Ohio"s fall gillnet survey in 2011 was above average up to age-6 and have been above average since 2009. White bass size at age is generally at or below average in western Ohio and at or above average in eastern Ohio waters for all ages. Basin wide, white bass mean size decreased in 2011 for each age up to age-3 from 2010. Mean lengths-at-age of yellow perch from fall surveys in Ohio declined from 2010 and were below average for all age groups. Mean size of most age-0 forage and predator species declined from 2010, but remained at or above average. The only decreasing trend in mean length of age-0 was for rainbow smelt. Rainbow smelt have been decreasing in mean length since 2009 and have been below average four of the last 5 years. The only increase in age-0 mean length from 2010 was for smallmouth bass. Age-0 smallmouth bass have been increasing in mean length since 2008 and have been above average in seven of the last eight years.

During 2011, Lower Trophic Level Assessment samples were collected from May through September in the central basin. These data are included in the Forage Task Group"s LTLA database.

2.4 West Basin (E. Weimer and R. Kraus)

History

Interagency trawling has been conducted in Ontario and Ohio waters of the western basin of Lake Erie in August of each year since 1987, though missing effort data from 1987 has resulted in the use of only data since 1988. This interagency trawling program was developed to measure basin-wide recruitment of percids, but has been expanded to provide basin-wide community abundance indices. In 1992, the Interagency Index Trawl Group (ITG) recommended that the Forage Task Group (FTG) review its interagency trawling program and develop standardized methods for measuring and reporting basin-wide community indices. Historically, indices from bottom trawls had been reported as relative abundances, precluding the pooling of data among agencies. In 1992, in response to the ITG recommendation, the FTG began the standardization and calibration of trawling procedures among agencies so that the indices could be combined and quantitatively analyzed across jurisdictional boundaries. SCANMAR was employed by most Lake Erie agencies in 1992, by OMNR and ODNR in 1995, and by ODNR alone in 1997 to calculate actual fishing dimensions of the bottom trawls. In the western basin, net dimensions from the 1995 SCANMAR exercise are used for the OMNR vessel, while the 1997 results are applied to the ODNR vessel. In 2002, ODNR began interagency trawling with the new vessel R/V Explorer II, and SCANMAR was again employed to estimate the net dimensions in 2003. In 2003, a trawl comparison exercise among all western basin research vessels was initiated, and fishing power correction (FPC; Table 2.4.1) factors have been applied to the vessels administering the western basin Interagency Trawling Program (Tyson et al. 2006). Presently, the FTG estimates basin-wide abundance of forage fish in the western basin using information from SCANMAR trials, trawling effort distance, and catches from the August interagency trawling program. Species-specific abundance estimates (number/ha or number/m3) are combined with length-weight data to generate a species-specific biomass estimate for each tow. Arithmetic mean volumetric estimates of abundance and biomass are extrapolated by depth strata (0-6m, >6m) to the entire western basin to obtain a FPC-adjusted, absolute estimate of forage fish abundance and biomass for each species. For reporting purposes, species have been pooled into three functional groups: clupeids (age-0 gizzard shad and alewife), soft-finned fish (rainbow smelt, emerald and spottail shiners, other cyprinids, silver chub, trout-perch, and round gobies), and spiny-rayed fish (age-0 for each of white perch, white bass, yellow perch, walleye and freshwater drum).

2011 Results

In 2011, low levels of hypolimnetic dissolved oxygen were present during the August trawling survey. Hypoxic conditions have been observed during the last three years of interagency bottom trawl assessment at a few of the sampling sites in the west basin. Due to concerns about the potential effects of hypoxia on the distribution of juvenile percids and other species, representatives from task groups, the Standing Technical Committee, researchers from the Quantitative Fisheries Center at Michigan State University and Ohio State University (OSU) developed an interim policy for the assignment of bottom trawl status. Informed by literature (Eby and Crowder 2002, Craig and Crowder 2005) and field study (ODNR /OSU/USGS) concerning fish avoidance of hypoxic waters, an interim policy was agreed upon whereby bottom trawls that occurred in waters with dissolved oxygen less than or equal to 2 mg per liter would be excluded from analyses. The policy has been applied retroactively from 2009. Currently, there is no consensus among task groups on the best way to handle this sort of variability in the estimation of year-class strength in Lake Erie. In part, this situation is hampered by a lack of understanding of how fish distribution changes in response to low dissolved oxygen. This interim policy will be revisited in the future following an improved understanding of the relationship between dissolved oxygen and the distribution of fish species and their various life stages in Lake Erie. Please refer to the Habitat Task Group Report, section 2c, for current research on fish distribution changes in response to seasonal hypoxia (Habitat Task Group 2012). In 2011, three of the 36 Ontario sites surveyed in August had bottom dissolved oxygen levels less than 2 mg/l, while none of the 37 sites in Ohio waters were below this threshold. In total, data from 70 sites were used in 2011 (Figure 2.4.1).

Total forage abundance decreased 55% in 2011 compared to 2010, the lowest level since 1999 (Figure 2.4.2). Declines in soft-rayed fish and spiny-rayed fish (down 28% and 66%, respectively) were responsible for this trend; clupeids increased 6-fold compared to 2010. Because of the composition of the forage fish community in 2011, total forage biomass declined 35%, to levels similar to 2009 (Figure 2.4.3). Relative biomass of clupeid, soft-rayed, and spiny-rayed species was 16%, 4%, and 80%, respectively, and differed from their respective historic averages of 29%, 8%, and 63%. Mean length of most age-0 sportfish in 2011 decreased compared to 2010 (Figure 2.4.4). Lengths of select age-0 species include walleye (137 mm), yellow perch (66 mm), white bass (79 mm), white perch (63mm), and smallmouth bass (79 mm). These lengths are near long-term averages (137 mm, 67 mm, 68 mm, 58 mm, and 79 mm, respectively).

Spatial maps of forage distribution were constructed using FPC-corrected site-specific catches (number/ha) of the functional forage groups (Figure 2.4.5). Abundance contours were generated using kriging techniques to interpolate abundance among trawl locations. Clupeid catches were highest around Sandusky Bay. Soft-rayed fish were most abundant near the mouth of the Detroit River. Spiny-rayed abundance was highest at the mouth of the Detroit River (driven by a high age-0 yellow perch catch at one site in Ontario), but fairly well spread across the west and south portions of the basin. Relative abundance of the dominant species includes: age-0 white perch (54%), age-0 gizzard shad (21%), and age-0 yellow perch (8%). Total forage abundance averaged 2,288 fish/ha across the western basin, decreasing 55% from 2010, below the long-term average (5,219 fish/ha). Clupeid density was 473 fish/ha (average 1,090 fish/ha), soft-rayed fish density was 245 fish/ha (average 568 fish/ha), and spiny-rayed fish density was 2,288 fish/ha (average 3,562 fish/ha).

Recruitment of individual species is highly variable in the western basin. Age-0 yellow perch (178.0/ha) increased relative to 2010, while age-0 walleye (6.5/ha) decreased (Figure 2.4.6); both remain well below long-term means. The increase in the yellow perch index is largely driven by a high catch at one site near the Detroit River in Ontario. Age-0 white perch (1244.6/ha) decreased sharply to the lowest index since 2002. Age-0 white bass (70.1/ha) decreased well below the long term mean, as did age-0 smallmouth bass (0.8/ha). Age-0 and yearling-and-older (YAO) rainbow smelt remained low in 2011 (2.8/ha and 1.0/ha, respectively). Age-0 gizzard shad (473.3/ha) increased dramatically relative to 2010, yet remained below the long term mean, while alewife remain missing (Figure 2.4.7). Catches of age-0 emerald shiners (22.4/ha) and YAO emerald shiners (24.1/ha) remain below long term means. Catches of round gobies (50.0/ha) increased from 2010, but are well below their mean abundance since their discovery in 1997. Catches of yearling and adult yellow perch and age-0 freshwater drum declined in 2011. Overall, 2011 catches of age-0 and YAO shiners declined or remained similar to 2010 (Figure 2.4.8). Lengths of age-0 walleye, yellow perch, white perch, and smallmouth bass all declined in 2011, while age-0 white bass lengths were unchanged relative to 2010.

Adult walleye diets taken from fall gillnet catches were dominated by gizzard shad (91%) and unidentified fish remains (9%) in the western basin. Yearling walleye relied on gizzard shad (56%), emerald shiner (20%) and unidentified fish remains (24%). In 2011, spring and autumn diet analysis of age-2-and-older yellow perch showed benthic macroinvertebrates had the greatest occurrence (94.2 and 90.2 % respectively) with Chironomidae, *Dreissena sp*., and *Hexagenia sp.* found most often. Zooplankton were also found in spring and autumn diet content (25.0 and 26.8% respectively) with *Leptodora kindtii* occurring most in the spring (16.3%) and *Bythotrephes sp.* occurring most in the autumn (18.3%). Fish were found within the diet contents least frequently, representing 16.3% of the diet items in the spring and 15.9% in the autumn, with round gobies found most often (10.6 and 8.5% respectively). Historically, zooplankton occurrence was considerably higher in the spring and benthic macroinvertebrate occurrence highest in the fall. However, in 2011, no noticeable difference was found between the occurrence of zooplankton, benthic macroinvertebrates, and fishes in the diet analysis of age-2-and-older yellow perch in Lake Erie between spring and autumn diet content analysis.

Average basin-wide water temperature for Ohio waters was cooler in 2011 than the previous year, with peak surface temperature (27.2°C) recorded on July 27. Spring warming rate (May 5 to June 3) was 0.25°C per day, lower than 2010. Seasonally averaged basin wide Secchi depth declined from 2010, averaging 1.2 m [range 0.1m (September 9) to 4.0m (July 11)]. Western basin bottom dissolved oxygen levels averaged 8.0 mg/l [range 0.5 (July 27) to 11.5mg/l (May 5)], similar to the previous year. Ecological indices useful in interpreting the state of the western basin resource are discussed in Section 5.0 (“Interagency lower trophic level monitoring”).

Table 2.2.1 Indices of relative abundance of selected forage fish species in Eastern Lake Erie from bottom trawl surveys conducted by Ontario, New York, and Pennsylvania for the most recent 10-year period. Indicies are reported as arithmetic mean number caught per hectare (NPH) for the age groups young-of-the-year (YOY), yearling-and-older (YAO), and all ages (ALL). Long-term averages are reported as the mean of the annual trawl indices for the three most recent completed decades. Agency trawl surveys are described below. Pennsylvania FBC (PA-Fa) did not conduct a fall index trawl survey in 2006, 2010, and 2011 and the 2008 survey was a reduced effort of four tows sampled in a single day.

	Age	Trawl	Year										Long-term Average by decade		
Species	**Group**	**Survey**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2000's**	**1990's**	**1980's**
Smelt	**YOY**	ON-DW	509.2	326.9	148.2	1293.0	991.3	1256.0	0.9	132.2	7058.1	142.5	1391.5	431.7	1278.2
	YOY	NY-Fa	1580.4	1416.6	64.9	2128.9	2889.6	507.9	1259.6	1146.1	1733.4	1606.6	1524.9	1450.9	NA
	YOY	PA-Fa	NA	NA	47.7	15.1	260.2	NA	47.9	12.3	592.2	98.0	138.2	550.8	7058.1
	YAO	ON-DW	277.1	222.7	1654.3	77.3	232.8	136.2	7.6	565.6	205.8	5.9	360.7	358.6	814.7
	YAO	NY-Fa	640.1	997.8	3016.6	546.5	176.9	162.9	395.2	2624.1	282.1	117.0	753.4	581.6	NA
	YAO	PA-Fa	NA	NA	407.2	1.8	1006.3	NA	0.0	12.3	32.4	6.5	164.5	378.0	2408.6
Emerald Shiner	**YOY**	ON-DW	70.3	117.6	54.8	16.0	29.3	452.3	645.7	20.3	3388.0	9.5	463.2	52.3	16.9
	YOY	ON-OB	1.1	0.0	0.0	0.5	1.2	12.4	1.1	258.3	0.0	0.2	27.6	3.2	16.2
	YOY	NY-Fa	2930.1	62.9	48.5	3.7	150.9	778.5	291.4	7.8	229.7	19.5	194.0	112.4	NA
	YOY	PA-Fa	NA	NA	1063.0	0.0	81.7	NA	0.5	0.0	1163.4	74.4	264.8	41.0	118.3
	YAO	ON-DW	201.1	30.7	40.1	95.2	149.8	4200.3	139.0	891.2	204.7	247.8	819.0	37.7	33.5
	YAO	ON-OB	16.1	0.0	4.8	3.0	84.3	499.6	0.1	73.8	6.7	13.6	72.0	4.6	3.0
	YAO	NY-Fa	1826.2	20.6	156.4	18.2	84.8	925.5	151.4	284.2	444.5	466.4	290.8	105.4	NA
	YAO	PA-Fa	NA	NA	1360.3	0.0	4713.1	NA	52.5	0.0	157.6	105.6	710.4	14.5	45.6
Spottail Shiner	**YOY**	ON-OB	2.5	3.0	3.7	37.8	35.2	19.8	58.7	43.8	74.1	16.6	119.3	815.9	570.6
	YOY	ON-IB	0	0.0	0.0	0.0	0.5	0.1	1.0	0.2	0.4	0.0	0.5	113.9	608.0
	YOY	NY-Fa	0.7	6.5	0.1	0.3	0.1	0.5	0.5	0.1	13.2	1.0	5.6	19.9	NA
	YOY	PA-Fa	NA	NA	1.1	0.0	0.0	NA	0.0	0.0	0.0	0.0	0.1	4.0	2.0
	YAO	ON-OB	0.5	2.1	3.3	7.5	4.1	10.4	3.2	10.4	5.9	12.0	10.8	74.6	30.7
	YAO	ON-IB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.1	2.0	10.3
	YAO	NY-Fa	29.0	10.4	5.1	1.5	0.0	4.1	4.3	2.5	4.8	34.2	6.4	4.0	NA
	YAO	PA-Fa	NA	NA	0.0	0.0	0.0	NA	0.0	0.0	0.0	0.8	0.1	7.9	12.4
Alewife	**YOY**	ON-DW	2.1	0.9	0.1	2.3	1.0	78.6	0.1	0.3	0.5	35.3	22.5	231.2	19.6
	YOY	ON-OB	6.8	0.0	1.9	11.9	44.6	711.8	11.0	1.5	17.6	12.2	82.1	88.5	36.5
	YOY	NY-Fa	12.4	15.4	0.0	5.6	22.2	30.8	27.7	4.4	3.9	617.6	94.3	52.0	NA
	YOY	PA-Fa	NA	NA	0.0	0.0	8.0	NA	0.0	0.0	2.5	0.8	1.3	7.7	16.6
Gizzard Shad	**YOY**	ON-DW	18.9	13.3	0.4	86.5	34.6	1.4	1.7	0.2	68.6	3.2	21.3	7.5	15.3
	YOY	ON-OB	3.4	3.8	0.0	4.0	22.0	28.7	1.9	1.0	5.1	1.6	7.6	13.4	18.7
	YOY	NY-Fa	15.0	40.9	5.3	10.8	11.7	14.1	3.7	0.6	27.8	5.5	11.9	4.2	NA
	YOY	PA-Fa	NA	NA	0.0	0.0	0.0	NA	0.0	0.0	0.0	0.8	0.1	0.9	74.3
White Perch	**YOY**	ON-DW	0.0	1.6	0.6	5.4	0.1	0.9	0.1	0.0	16.2	0.0	2.9	1.8	5.4
	YOY	ON-OB	0.0	0.0	0.0	2.1	0.7	1.2	0.4	0.2	14.6	0.0	2.8	17.6	31.1
	YOY	NY-Fa	36.5	157.3	20.2	431.5	34.6	91.9	99.8	1.0	37.7	6.2	74.3	29.4	NA
	YOY	PA-Fa	NA	NA	598.5	0.7	444.6	NA	51.2	0.0	523.9	0.0	256.0	101.1	NA
Trout Perch	**All**	ON-DW	0.0	0.3	0.8	0.8	0.8	1.1	0.0	1.7	2.7	0.7	0.9	0.6	2.4
	All	NY-Fa	654.3	461.6	517.0	996.4	561.2	519.4	1317.3	545.9	1392.6	886.0	826.0	410.0	NA
	All	PA-Fa	NA	NA	558.8	0.6	156.9	NA	198.5	160.3	256.6	0.0	152.1	50.9	NA
Round Goby	**All**	ON-DW	125.4	9.7	43.6	452.6	973.2	93.3	66.9	323.8	158.8	127.0	235.9	0.0	0.0
	All	ON-OB	103.3	67.6	91.2	63.4	73.9	32.7	28.0	94.4	114.2	150.9	86.9	0.1	0.0
	All	ON-IB	114.6	135.1	280.5	211.8	263.0	34.0	21.0	95.4	28.6	56.2	120.0	0.1	0.0
	All	NY-Fa	165.8	173.3	502.6	466.8	1293.2	846.5	707.0	1094.5	613.4	135.9	651.7	35.9	0.0
	All	PA-Fa	NA	NA	350.1	441.6	2043.8	NA	887.8	927.5	387.3	43.9	1094.6	30.3	0.0

"**NA**" denotes that reporting of indices was Not Applicable or that data were Not Available.

Ontario Ministry of Natural Resources Trawl Surveys

ON-DW	Trawling is conducted weekly during October at 4 fixed stations in the offshore waters of Outer Long Point Bay using a 10-m trawl with 13-mm mesh cod end liner. Indices are reported as NPH; 80's Avg. is for the period 1984 to 1989; 90's Avg. is for the period 1990 to 1999; 00's Avg. is for the period 2000 to 2009.
ON-OB	Trawling is conducted weekly during September and October at 3 fixed stations in the nearshore waters of Outer Long Point Bay using a 6.1-m trawl with a 13-mm mesh cod end liner. Indices are reported as NPH; 80's Avg. is for the period 1984 to 1989; 90's Avg. is for the period 1990 to 1999; 00's Avg. is for the period 2000 to 2009.
ON-IB	Trawling is conducted weekly during September and October at 4 fixed stations in Inner Long Point Bay using a 6.1-m trawl with a 13-mm mesh cod end liner. Indices are reported as NPH; 80's Avg. is for the period 1984 to 1989; 90's Avg. is for the period 1990 to 1999; 00's Avg. is for the period 2000 to 2009.

New York State Department of Environment Conservation Trawl Survey

NY-Fa	Trawling is conducted at approximately 30 nearshore (15-30 m) stations during October using a 10-m trawl with a 9.5-mm mesh cod end liner. Indices are reported as NPH; 90's Avg. is for the period 1992 to 1999; 00's Avg. is for the period 2000 to 2009.

Pennsylvania Fish and Boat Commission Trawl Survey

PA-Fa	Trawling is conducted at nearshore (< 22 m) and offshore (> 22 m) stations during October using a 10-m trawl with a 6.4-mm mesh cod end liner. Indices are reported as NPH; 80's Avg. is for the period 1984 to 1989; 90's Avg. is for the period 1990 to 1999; 00's Avg. is for the period 2000 to 2009.

Table 2.3.1 Relative abundance (arithmetic mean number per hectare) of selected age-0 species from fall trawl surveys in the central basin, Ohio and Pennsylvania, Lake Erie, from 2001-2011. Ohio West (OH West) is the area of the central basin from Huron, OH, to Fairport Harbor, OH. Ohio East (OH East) is the area of the central basin from Fairport Harbor, OH to the Ohio-Pennsylvania state line. PA is the area of the central basin from the Ohio-Pennsylvania state line to Presque Isle, PA.

		Year											
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
Species	Survey												
Yellow	OH west	114.6	6.0	149.0	8.7	37.8	10.0	167.0	37.3	1.3	41.1	8.7	57.3
Perch	OH east	13.6	2.5	47.5	1.9	156.2	18.9	177.8	52.8	0.5	96.3	14.1	56.8
	PA	388.4	11.9	788.0	2.4	-	-	10.0	863.4	14.2	-	-	296.9
White	OH west	779.7	293.0	310.1	759.7	1002.5	440.4	1381.2	544.9	506.1	254.8	368.3	627.2
Perch	OH east	57.6	5.9	61.8	108.0	2034.5	46.1	1095.9	91.6	34.6	190.3	84.8	372.6
	PA	26.6	80.7	173.8	2.4	-	-	17.8	199.0	146.5	-	-	92.4
Rainbow	OH west	2.3	274.7	1753.9	352.1	10.7	94.3	98.1	635.2	293.5	776.2	42.4	429.1
smelt	OH east	0.0	218.1	2914.1	388.9	44.4	570.7	702.4	3997.7	0.3	421.6	256.1	925.8
	PA	377.4	152.9	177.6	20.9	-	-	35.1	552.2	23.4	-	-	191.4
Round	OH west	43.9	37.8	22.6	13.9	37.2	19.0	26.9	17.4	25.9	28.4	102.8	27.3
Goby	OH east	39.6	64.7	57.5	173.9	148.1	46.3	273.1	26.3	1.0	41.8	258.9	87.2
	PA	1577.8	289.3	75.3	1011.3	-	-	227.8	227.1	72.2	-	-	497.3
Emerald	OH west	50.5	39.4	477.6	7.0	567.1	587.2	52.6	36.3	6.1	8.8	414.5	183.3
Shiner	OH east	2.2	0.5	903.1	0.8	279.8	1115.1	63.7	20.2	1.7	234.9	105.4	262.2
	PA	8.5	38.1	81.8	0.0	-	-	0.8	0.0	303.2	-	-	61.8
Spottail	OH west	5.9	1.6	0.0	0.0	0.2	0.0	3.1	3.7	0.6	0.0	0.6	1.5
Shiner	OH east	0.7	0.2	0.5	0.0	1.1	0.2	0.5	0.2	0.0	0.0	0.4	0.3
	PA	0.0	0.0	0.0	0.0	-	-	0.0	0.0	0.0	-	-	0.0
Alewife	OH west	50.8	59.7	0.1	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	11.5
	OH east	0.0	1.1	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.5
	PA	0.0	0.4	0.0	0.0	-	-	0.0	0.0	0.0	-	-	0.1
Gizzard	OH west	60.3	24.6	402.6	0.6	12.3	32.7	195.0	35.7	50.9	2.6	770.3	81.7
Shad	OH east	1.8	12.3	20.4	0.3	15.7	30.7	15.5	63.1	3.9	8.5	4.0	17.2
	PA	0.0	0.0	0.0	0.0	-	-	0.0	0.0	0.0	-	-	0.0
Trout-	OH west	2.0	1.4	2.0	20.3	0.1	0.2	0.8	0.3	0.3	0.7	1.6	2.8
perch	OH east	0.0	0.3	1.4	1.4	1.6	0.1	5.4	0.1	0.2	1.4	2.7	1.2
	PA	7.8	45.6	78.0	6.7	-	-	10.9	126.1	28.1	-	-	43.3

- The Pennsylvania Fish and Boat Commission was unable to sample in 2005, 2006, 2010 and 2011.

Table 2.3.2 Relative abundance (arithmetic mean number per hectare) of selected yearling-and-older species from fall trawl surveys in the central basin, Ohio and Pennsylvania, Lake Erie, from 2001-2011. Ohio West (OH West) is the area of the central basin from Huron, OH, to Fairport Harbor, OH. Ohio East (OH East) is the area of the central basin from Fairport Harbor, OH to the Pennsylvania state line. PA is the area of the central basin from the Ohio-Pennsylvania state line to Presque Isle, PA.

		Year											
Species	Survey	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Mean
Yellow Perch	OH west	5.7	51.7	3.2	216.5	18.3	4.2	19.8	56.6	20.7	11.9	5.5	40.9
	OH east	0.4	38.3	1.2	45.2	132.3	12.5	37.0	26.4	139.4	12.4	50.5	44.5
	PA	41.3	37.5	75.6	18.3	-	-	27.4	76.4	120.9	-	-	56.8
White Perch	OH west	21.7	91.5	28.2	83.9	34.1	32.4	27.1	76.5	42.0	32.6	25.0	47.0
	OH east	0.4	176.2	12.0	27.0	20.1	38.5	16.8	36.6	282.3	44.8	45.1	65.5
	PA	2.4	38.5	28.6	6.2	-	-	0.8	4.2	63.3	-	-	20.6
Rainbow Smelt	OH west	55.6	45.3	29.4	320.5	89.8	8.9	40.4	9.6	419.4	18.0	35.8	103.7
	OH east	3.3	320.9	370.3	1360.2	30.8	17.3	532.4	64.9	109.1	56.9	176.0	286.6
	PA	0.0	6.2	22.1	9.9	-	-	10.7	3.5	408.0	-	-	65.8
Round Goby	OH west	54.8	39.2	25.4	27.0	33.6	20.4	26.3	57.9	58.0	44.0	63.7	38.7
	OH east	88.4	54.3	127.1	148.8	263.0	78.9	185.6	167.8	19.3	36.0	123.8	116.9
	PA	55.2	238.3	59.1	767.0	-	-	361.1	326.6	75.9	-	-	269.0
Emerald Shiner	OH west	106.3	233.9	54.9	1.5	233.6	162.7	418.7	495.0	99.5	51.5	171.6	185.8
	OH east	0.7	133.2	432.0	0.4	479.6	451.1	27.8	1159.4	167.8	375.1	145.2	322.7
	PA	0.0	107.4	217.5	0.0	-	-	769.5	28.0	171.5	-	-	184.8
Spottail Shiner	OH west	3.5	6.6	1.6	5.3	0.3	1.2	2.3	2.3	3.1	0.0	23.5	2.6
	OH east	1.1	5.9	1.0	0.2	3.8	0.7	0.6	2.9	0.0	0.0	4.1	1.6
	PA	0.0	2.2	0.0	0.0	-	-	0.0	0.0	0.0	-	-	0.3
Trout-perch	OH west	3.2	27.2	12.2	14.0	13.5	3.3	5.5	4.8	0.8	0.7	3.9	8.5
	OH east	2.2	8.5	2.9	7.7	76.2	4.8	6.7	8.4	1.5	5.0	8.9	12.4
	PA	0.6	81.2	50.9	5.2	-	-	16.0	61.7	127.3	-	-	49.0

- The Pennsylvania Fish and Boat Commission was unable to sample in 2005, 2006, 2010 and 2011.

Table 2.4.1. Mean catch-per-unit-effort (CPUE) and fishing power correction factors (FPC) by vessel-species-age group combinations. All FPCs are calculated relative to the R.V. Keenosay.

Vessel	Species	Age group	Trawl Hauls	Mean CPUE (#/ha)	FPC	95% CI	Apply rule [a]
R.V. Explorer	Gizzard shad	Age 0	22	11.81	2.362	-1.26-5.99	Y
	Emerald shiner	Age 0+	50	67.76	1.494	0.23-2.76	Y
	Troutperch	Age 0+	51	113.20	0.704	0.49-0.91 z	Y
	White perch	Age 0	51	477.15	1.121	1.01-1.23 z	Y
	White bass	Age 0	50	11.73	3.203	0.81-5.60	Y
	Yellow perch	Age 0	51	1012.15	0.933	0.62-1.24	N
	Yellow perch	Age 1+	51	119.62	1.008	0.72-1.30	N
	Walleye	Age 0	51	113.70	1.561	1.25-1.87 z	Y
	Round goby	Age 0+	51	200.27	0.423	0.22-0.63 z	Y
	Freshwater drum	Age 1+	51	249.14	0.598	0.43-0.76 z	Y
R.V. Gibraltar	Gizzard shad	Age 0	29	14.22	1.216	-0.40-2.83	Y
	Emerald shiner	Age 0+	43	51.30	2.170	0.48-3.85	Y
	Troutperch	Age 0+	45	82.11	1.000	0.65-1.34	N
	White perch	Age 0	45	513.53	0.959	0.62-1.30	N
	White bass	Age 0	45	21.88	1.644	0.00-3.28	Y
	Yellow perch	Age 0	45	739.24	1.321	0.99-1.65	Y
	Yellow perch	Age 1+	45	94.56	1.185	0.79-1.58	Y
	Walleye	Age 0	45	119.17	1.520	1.17-1.87 z	Y
	Round goby	Age 0+	45	77.36	0.992	0.41-1.57	N
	Freshwater drum	Age 1+	45	105.21	1.505	1.10-1.91 z	Y
R.V. Grandon	Gizzard shad	Age 0	29	70.87	0.233	-0.06-0.53 z	Y
	Emerald shiner	Age 0+	34	205.43	0.656	-0.04-1.35	Y
	Troutperch	Age 0+	35	135.93	0.620	0.42-0.82 z	Y
	White perch	Age 0	36	771.40	0.699	0.44-0.96 z	Y
	White bass	Age 0	36	34.92	0.679	0.43-0.93 z	Y
	Yellow perch	Age 0	36	1231.63	0.829	0.58-1.08	Y
	Yellow perch	Age 1+	36	123.35	0.907	0.58-1.23	Y
	Walleye	Age 0	36	208.59	0.920	0.72-1.12	Y
	Round goby	Age 0+	36	161.78	0.501	0.08-0.92 z	Y
	Freshwater drum	Age 1+	36	58.82	2.352	1.51-3.19 z	Y
R.V. Musky II	Gizzard shad	Age 0	24	8.80	1.885	-1.50-5.26	Y
	Emerald shiner	Age 0+	47	32.29	3.073	0.36-5.79	Y
	Troutperch	Age 0+	50	62.35	1.277	0.94-1.62	Y
	White perch	Age 0	50	255.71	2.091	1.37-2.81 z	Y
	White bass	Age 0	46	8.35	4.411	0.90-7.92	Y
	Yellow perch	Age 0	50	934.03	1.012	0.77-1.26	N
	Yellow perch	Age 1+	50	34.94	3.452	1.23-5.67 z	Y
	Walleye	Age 0	50	63.70	2.785	2.24-3.33 z	Y
	Round goby	Age 0+	49	66.87	1.266	0.39-2.14	Y
	Freshwater drum	Age 1+	49	1.60	93.326	48.39-138.26 z	Y

z - Indicates statistically significant difference from 1.0 (α=0.05); [a] Y means decision rule indicated FPC application was warranted; , N means decision rule indicated FPC application was not warranted

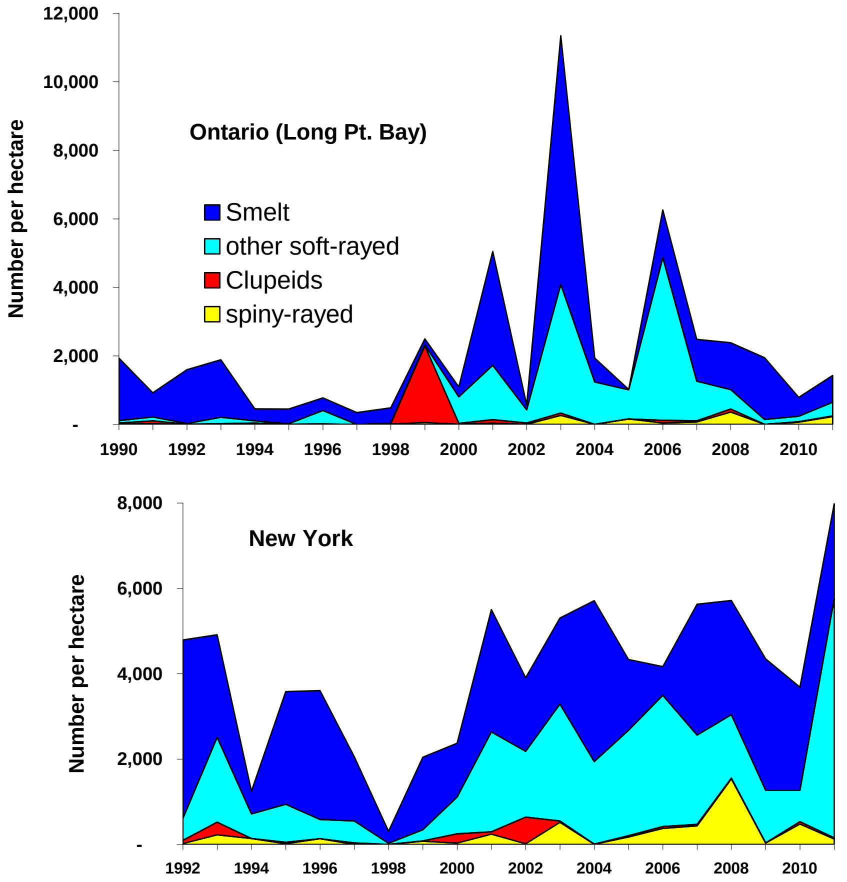

Figure 2.2.1 Mean density of prey fish (no./ha) by functional group in the Ontario and New York waters of the eastern basin, Lake Erie, 1990-2011.

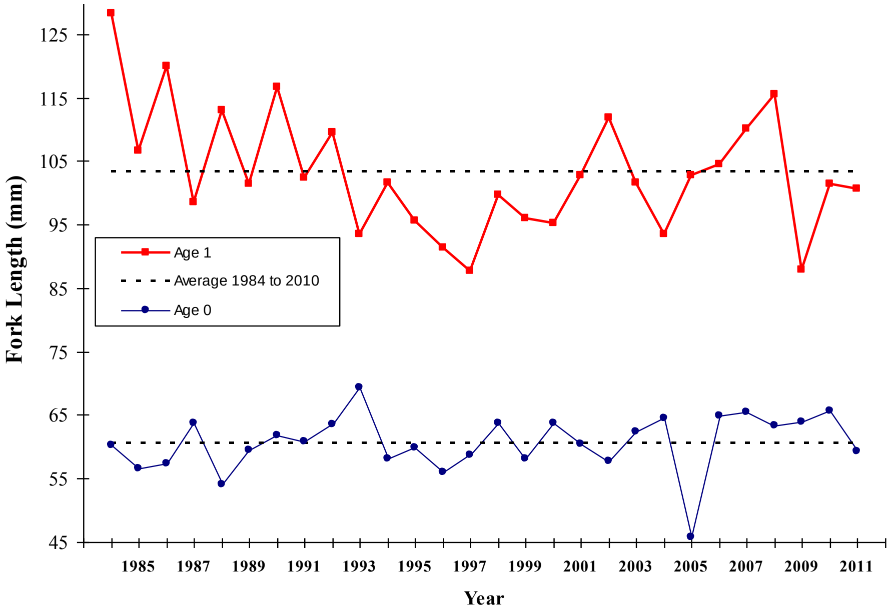

Figure 2.2.2 Mean fork length of age 0 and 1 rainbow smelt from OMNR index trawl surveys in Long Point Bay, Lake Erie, October 1984 to 2011.

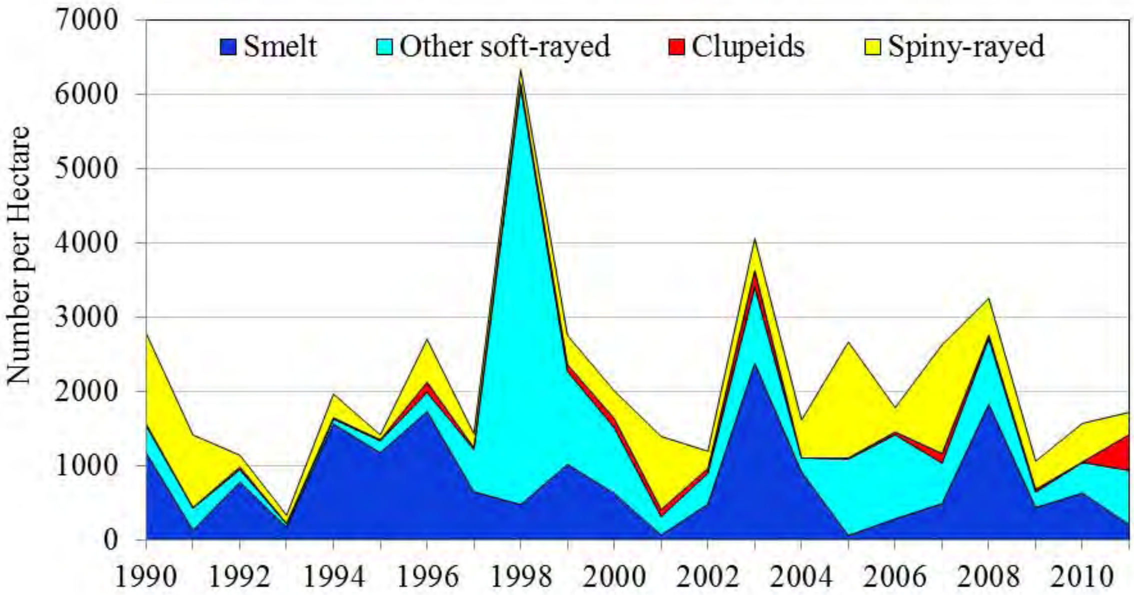

Figure 2.3.1 Mean density of prey fish (no./ha) by functional group in the Ohio waters of the central basin, Lake Erie, 1990-2011.

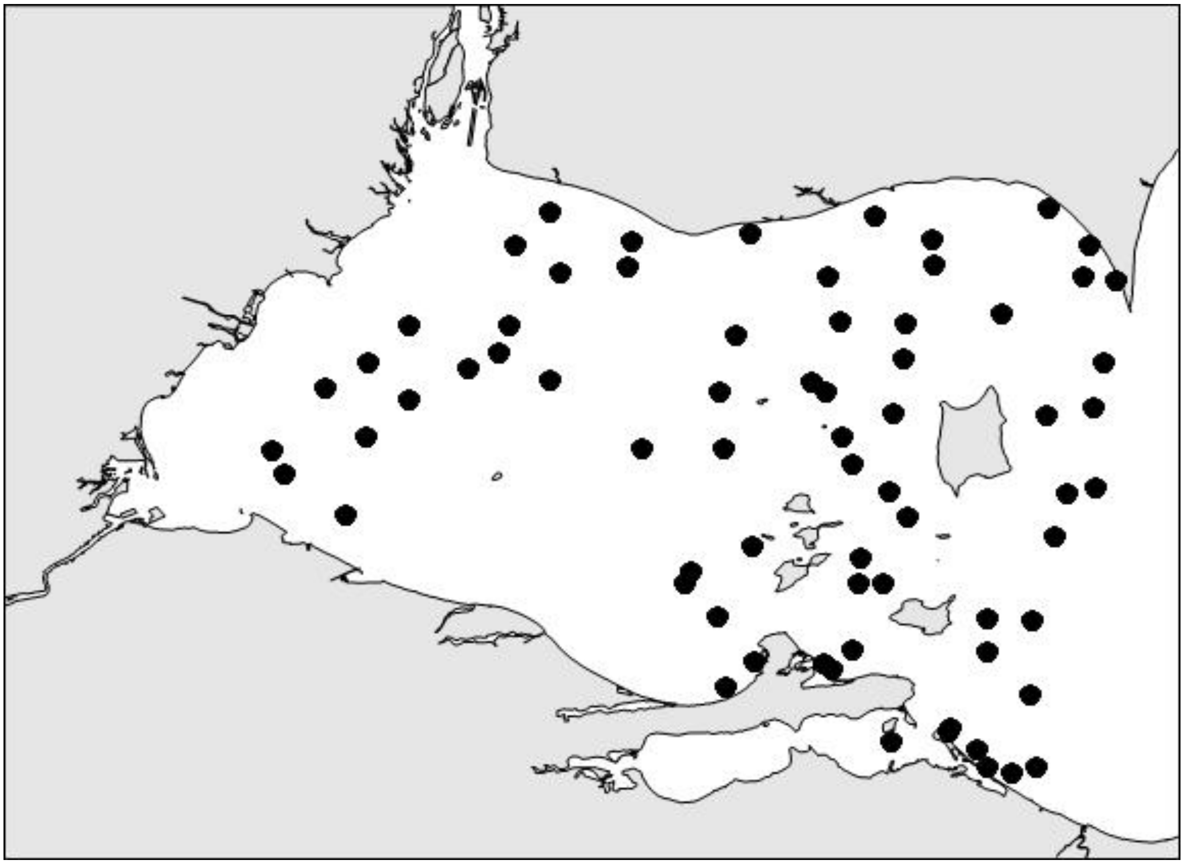

Figure 2.4.1. Trawl locations for the western basin interagency bottom trawl survey, August 2011.

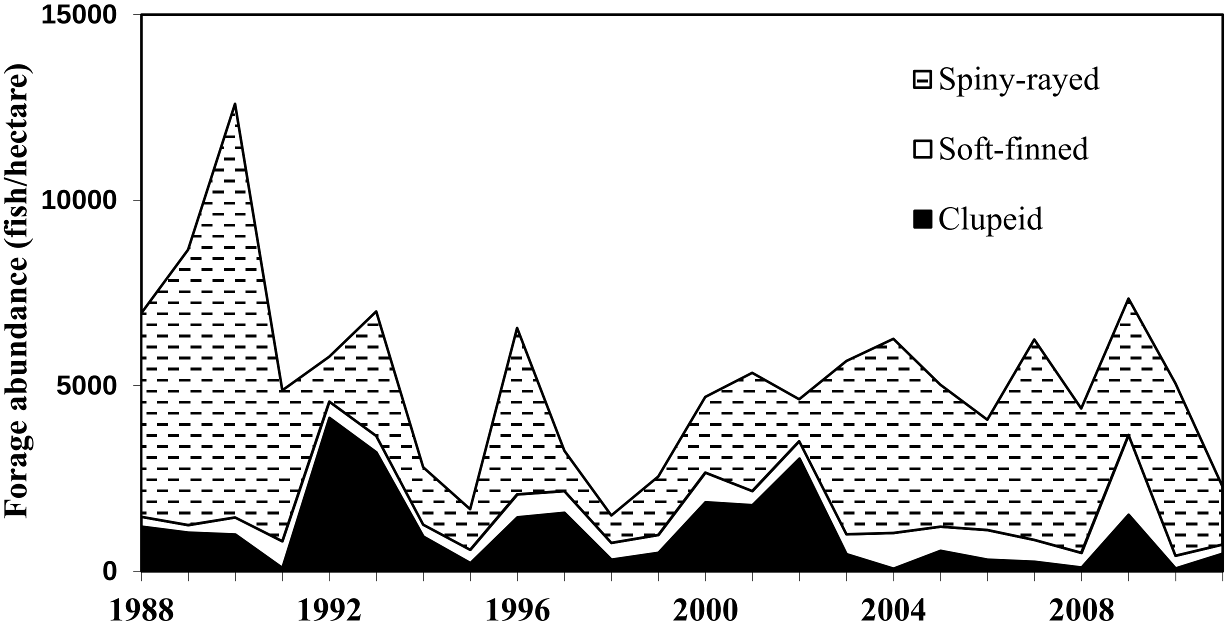

Figure 2.4.2. Mean density (no. / ha) of prey fish by functional group in western Lake Erie, August 1988-2011.

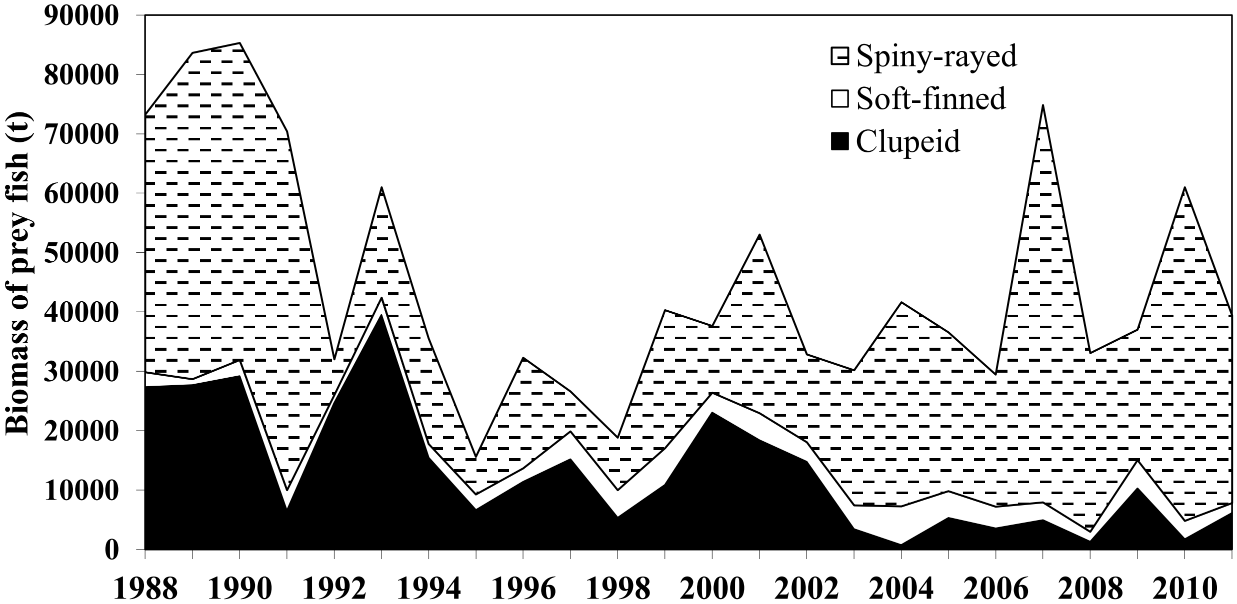

Figure 2.4.3. Mean biomass (tonnes) of prey fish by functional group in western Lake Erie, August 1988-2011.

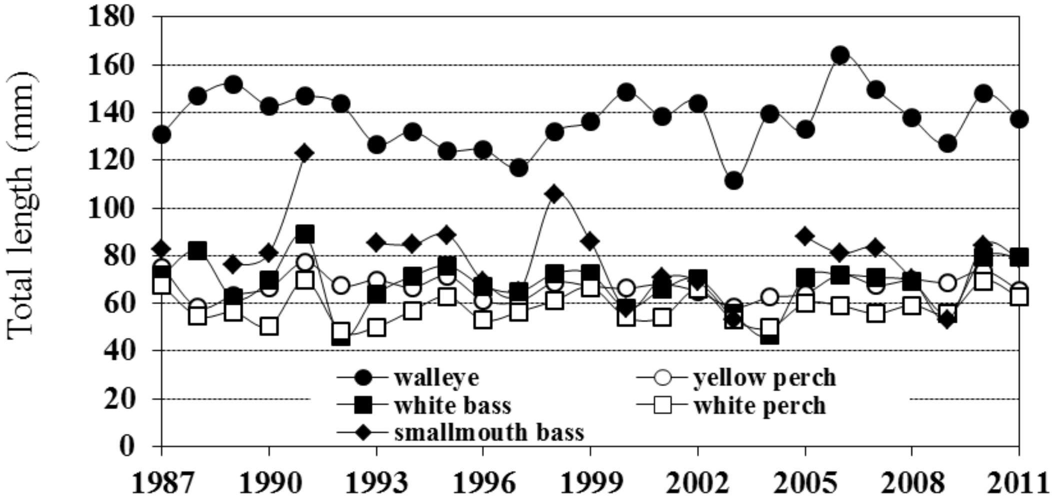

Figure 2.4.4. Mean total length (mm) of select age-0 fishes in western Lake Erie, August 1987- 2011.

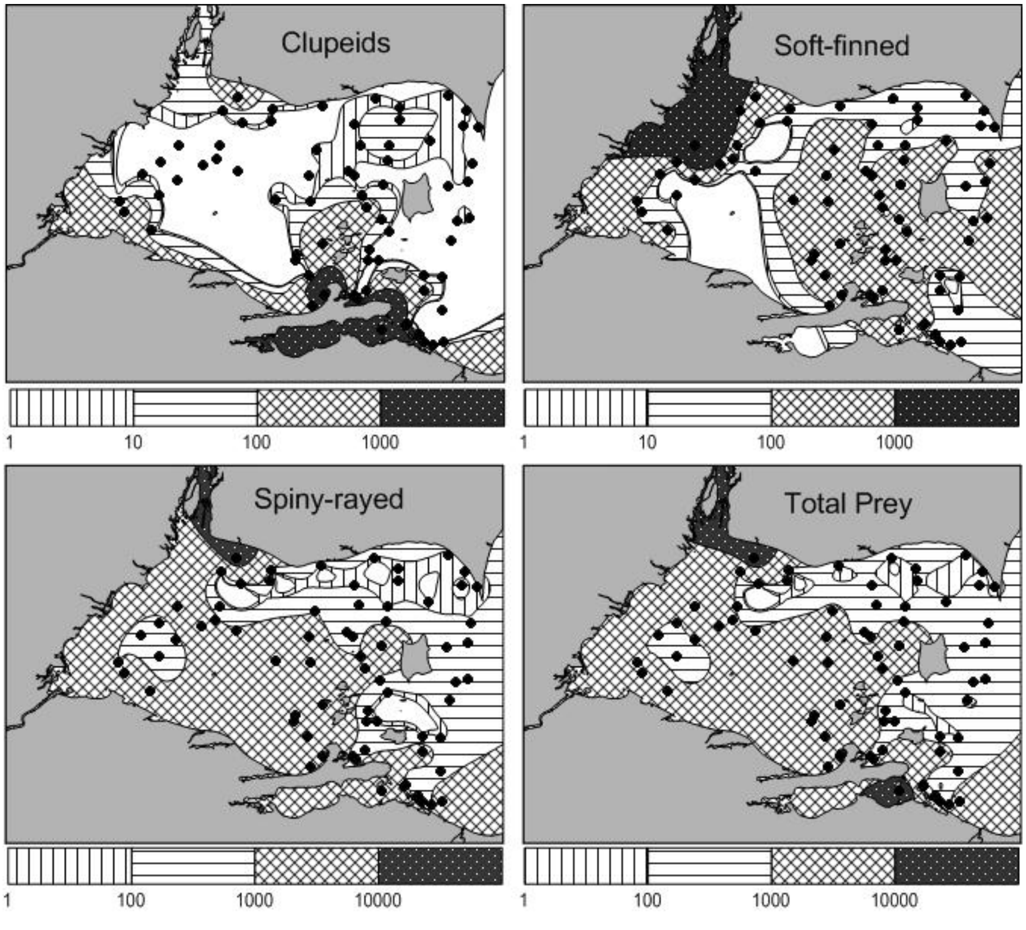

Figure 2.4.5. Spatial distribution of clupeids, soft-finned, spiny-rayed, and total forage abundance (individuals per hectare) in western Lake Erie, 2011. Black dots are trawl sites, and contour levels vary with the each functional fish group.

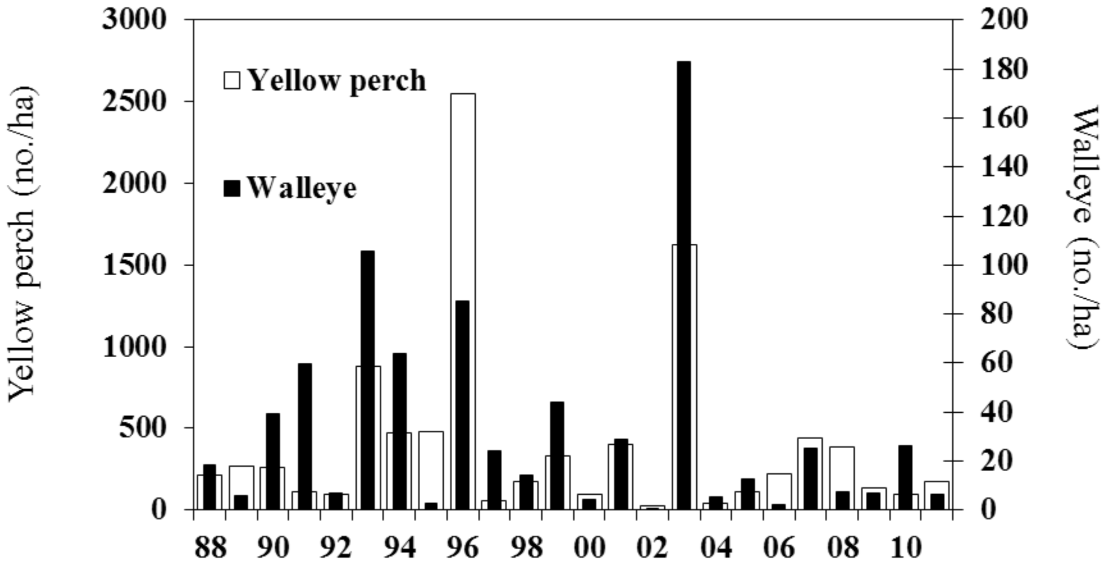

Figure 2.4.6. Density of age-0 yellow perch and walleye in the western basin of Lake Erie, August 1988-2011.

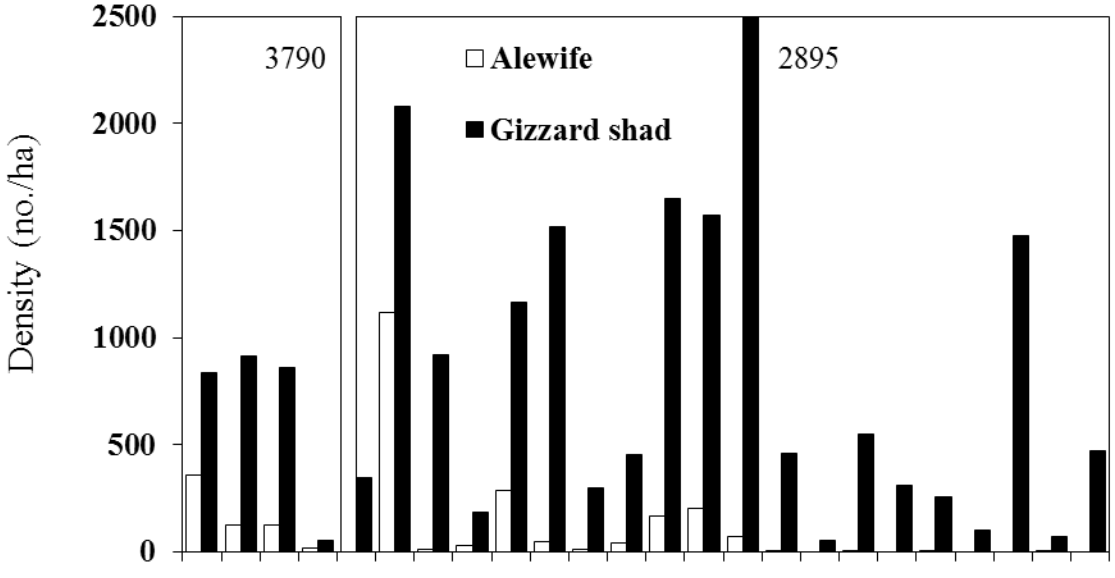

Figure 2.4.7. Density of age-0 alewife and gizzard shad in the western basin of Lake Erie, August 1988-2011.

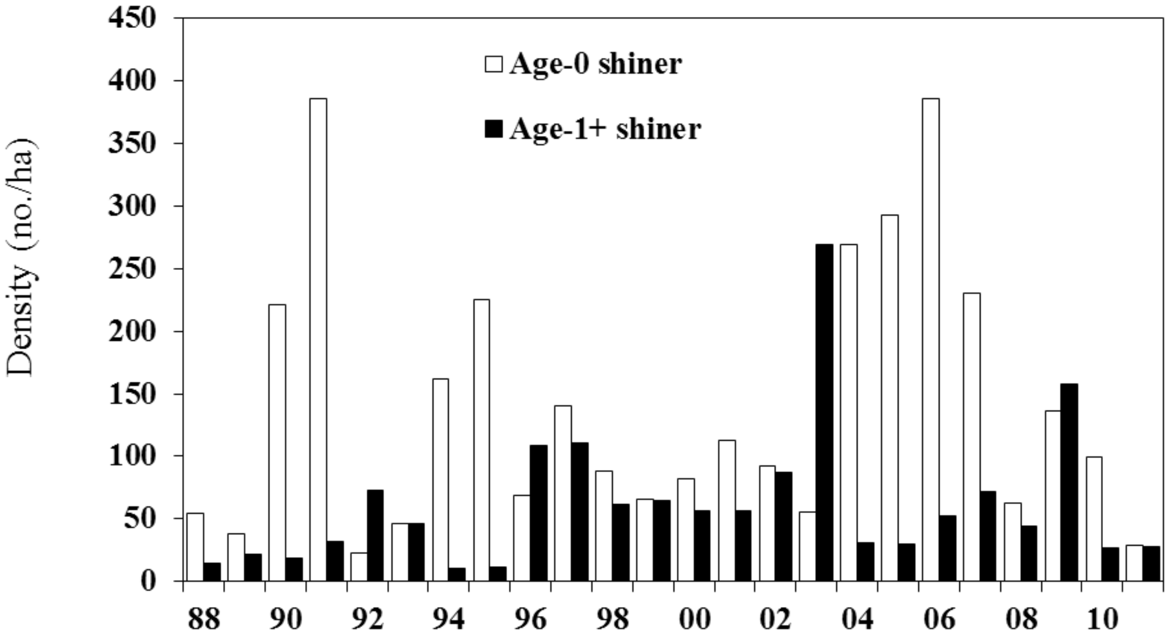

Figure 2.4.8. Density of age-0 and age-1+ shiners (*Notropis* spp.) in the western basin of Lake Erie, August 1988-2011.

3.0 Interagency Trawling Program

An ad-hoc Interagency Index Trawl Group was formed in 1992 to examine the interagency index trawl program in western Lake Erie and recommend standardized trawling methods for assessing fish community indices; and second, to lead the agencies in calibration of index trawling gear using SCANMAR acoustical instrumentation. Before dissolving in March 1993, the ITG recommended the Forage Task Group continue the work on interagency trawling issues. Progress on these charges is reported below

.

3.1 Summary of Species CPUE Statistics

The FTG has been estimating basin-wide abundance of forage fish in the western basin using information from SCANMAR trials, trawling effort distance, and catches from the August interagency trawling program since 1988. The latest improvement to the survey incorporated the FPC factors that were developed from the trawl comparison exercise conducted in 2003 (Tyson et al. 2006). The August interagency survey was adopted by western basin agencies as the standard assessment for basin-wide fish community abundance. Data from the interagency survey is now incorporated into the western basin, *Status and Trends of Forage Fish Species,* Section 2.4.

3.3 Trawl Comparison Exercise

In 2003, a west basin trawl calibration exercise occurred that applied fishing power corrections to all trawling vessels in the western basin (Tyson et al. 2006). This exercise allowed western basin agencies the ability to compile all their trawling data together on an even scale, thus giving managers an entire view of forage fishes across the basin and an enhanced percid recruitment index.

To date, this has only been done in the Western basin. Trawl calibration exercises have been planned in the east and central basins involving vessels from ON, NY, PA, and OH with an overall goal of an enhanced recruitment index similar to the west basin survey. However, recent budget issues and logistics have stalled this exercise.

In 2012, the USGS-Sandusky office will launch a new vessel, and this may offer an opportunity to standardize trawls across the entire lake. This exercise would involve using the new Musky as the standard vessel in the western basin, and then using this boat in more central locations in both the central and eastern basins for calibration exercises.

Plans for this exercise are underway with possible implementation beginning in 2013.

4.0 Hydroacoustic Survey Program

4.1 East Basin Acoustic Survey (L. Witzel and D. Einhouse)

Introduction

Beginning in 1993, a midsummer East Basin fisheries acoustic survey was implemented to provide a more comprehensive evaluation of the distribution and abundance of rainbow smelt. This initiative has been pursued under the auspices of the Lake Erie Committee's FTG, and is a collaboration of neighboring East Basin Lake Erie jurisdictions and Cornell University's Warmwater Fisheries Unit through coordinated management efforts facilitated by the Great Lakes Fishery Commission (GLFC).

One of the more prominent advancements in the development of an acoustic survey program was achieved when Lake Erie"s FTG was successful in being awarded a grant to purchase a modern signal processing and data management system for inter-agency fisheries acoustic surveys on Lake Erie (Einhouse and Witzel 2003). The new data processing system (Echoview) arrived in 2002. In 2003, Lake Erie representatives from New York State Department of Environmental Conservation and the Ontario Ministry of Natural Resources also attended a training workshop to attain proficiency in this new software. The newly trained biologists then hosted a second workshop to introduce this signal processing system to the Lake Erie FTG. During 2005 FTG members upgraded the Lake Erie acoustic hardware system through the purchase of a Simrad EY60 GPT/transducer. In 2008, 2009, and 2010 several members of Lake Erie"s FTG participated in an ongoing series of workshops, devoted to the development of Standard Operating Procedures (SOP) for hydroacoustic surveys in the Great Lakes region (Parker-Stetter et al 2009, Rudstam et al. 2009). Completion of the 2008 workshop represented a benchmark event toward implementation of the SOP"s in Lake Erie basin acoustic surveys, and specifically for the East Basin, then proceeding to re-processing an acoustic data series beginning in 1997 and applying new standards. A primary focus of the 2009 workshop was to compare present-day acoustic methods used in various acoustic assessments across the Great Lakes with results from following the SOP and further publications by the principal investigators within this study group are anticipated (Kocovsky et al. in review). Additional GLFC funds were awarded to the Great Lake Acoustic Study Group to convene a workshop that will begin the development of standard protocols for conducting acoustic assessment-based ground-truth trawling operations. This latest workshop was successfully completed at the Lake Erie Biological Station USGS Great Lakes Science Center, Sandusky, Ohio during September 27 – October 1, 2010.

Survey Methods and Acoustic Series Standardized Analysis

Procedures for the east basin acoustic survey have now been completed largely through the support of GLFC sponsored project "Study group on fisheries acoustics in the Great Lakes". At this time the principal investigators for Lake Erie"s east basin survey are incorporating the new SOP for each survey year, and then re-computing fish densities based on these new standards. Among these standard data processing elements is the use of the N_v index (Sawada *et al.* 1993), a type of data quality control filter for examining estimates of fish abundance in densely concentrated areas to diminish possible bias associated with extrapolating abundance based on mean in-situ target strength (Rudstam et al. 2003). Additionally, a standard objective method has now been developed to ascribe passive noise thresholds for each survey transect. A complete description of our data collection and processing methods will be forthcoming in a separate document with accompanying results for the entire split-beam time series of this acoustic survey (since 1997).

At this writing the acoustic data series from 1998 to 2003 and from 2007 to 2011 has been re-processed and analyzed using our new survey standards. We previously reported results for the 1999 to 2003 survey years in the 2009 Forage Task Group annual report (Forage Task Group 2009). In this report we highlight results for the five most recent east basin survey years 2007 to 2011.

In general, standard survey procedures have been in-place for offshore transect sampling of eastern Lake Erie since 1993. This midsummer, mobile nighttime survey is implemented as an interagency program involving multiple vessels to collect acoustic signals of pelagic fish density and distribution, with an accompanying mid-water trawling effort to characterize fish species composition.

In 2012, we expect to resume standardized reanalysis of acoustic data for the remaining backlog of survey years 1997 and 2004 through 2006. The entire 1997 to 2011 data time series is expected to be thoroughly reported in a separate document with an accompanying description of survey methods and data processing procedures. Upon completion of this overview document, subsequent results will be updated annually in Lake Erie"s FTG Report.

The 2011 Survey

In recent years, the east basin survey has been accomplished as a two-agency endeavour. Acoustic data acquisition to determine fish densities and distribution were measured with a modern scientific echosounder. The current system consists of a Simrad EY60 120 kHz split-beam GPT, with a 7-degree beam transducer mounted on a fixed pole in a down facing orientation approximately 1 m below the water surface on the starboard side of the Ontario Ministry of Natural Resources (OMNR) research vessel, *RV Erie Explorer*. Acoustic data were collected at 300 watts power output, 256 µsec pulse duration, and 2 per second ping rate. Precise navigation of randomly selected acoustic transects was accomplished through an interface of the vessel"s GPS system to a personal computer (PC)-based navigation software program (Nobeltec Navigation Suite ver7) and the ship"s autopilot. The same GPS unit was also connected to a second PC running the Simrad ER60 software that controlled all operations of the echosounder. Geo-referenced raw acoustic data were logged to 10-megabyte size files on the host PC.

The 2011 survey was completed in five nights from July 20 to 28; acoustic sampling was suspended due to poor weather on three nights during this period (Figure 4.1.1). A full complement of twelve acoustic transects were sampled totaling 167 nautical miles. Approximately 864,400 KB of raw acoustic data were recorded including some 58,200 KB of stationary sampling at the ends of some transects to assess target strength (TS) variability of individual fish tracks. A total of 28 water temperature-depth profiles were sampled across all transects in 2011. Companion mid-water trawl collections to obtain representative samples of the pelagic forage fish community for apportioning of acoustic targets did not occur during the 2011 survey due to New York State DEC budget constraints.

Acoustic data were processed using the Myriax Echoview 3.45 software. Acoustic echograms were partitioned into two depth strata, epilimnion and meta-hypolimnion, based on an approximate depth of the 18-Celsius isotherm (from TD profiles) and from a pre-analysis of the relative proportion of age-0 size smelt (-70 to -59 dB) to ALL-size smelt (age-0 + YAO: -70 to -40 dB) by 1-m depth layers for each 800-m transect interval. This pre-analysis of TS distributions was accomplished within a specialized SAS (SAS 2006) program that scanned each 1-m depth layer within a specified depth range in a downward progression and selected the first occurrence where the proportion of age-0 to ALL-size smelt targets was less than 40%. The lower bound of this 1-m depth layer established a preliminary depth for defining the boundary between the two thermal strata (epilimnion and meta-hypolimnion). The SAS-derived Epi-Meta strata boundary was then formatted as a line-definition file and imported into Echoview. This line was then visually examined in the various echogram types (S_v, TS, single target detections) to see how well it spatially delineated age-0 rainbow smelt, located primarily in the epilimnion from deeper YAO smelt, located primarily in the metalimnion and hypolimnion. If necessary, and with knowledge of the thermal structure, the line was adjusted to better delineate the two smelt age (size) groups. The final epi-meta boundary line was then referenced to create the two thermal strata across all intervals of acoustic transects exhibiting thermal stratification. If coldwater habitat was not apparent the interval was considered to be entirely epilimnion.

We applied a -80 dB minimum threshold to the raw ping volume back scattering variable (S_v). Mean S_v data and *in situ* single target detection distributions by analysis cell (thermal strata by 800-m interval) were exported to external text delimited files and then imported into a SAS program for computation of fish densities for age-0 and YAO smelt-size acoustic targets. We used Sawada et al.‟s (1993) N_v index to detect for potential bias from the inclusion of multiple echoes in the *in situ* TS distributions in all analysis cells. If an N_v index for an individual analysis cell exceeded the N_v threshold of 0.1, we replaced the mean backscattering cross section value, sigma (σ_{bs}) for that cell with an average mean sigma calculated from strata cells that had good N_v‟s (<0.1) as recommended in the SOP (Rudstam et al. 2009). Estimates of basin-wide mean fish density and absolute abundance for YAO smelt-size targets was achieved using a one-stage Cluster Analysis in SAS (Proc Surveymeans; SAS 2004).

Acoustic Series Results 2007–2011

Basin-wide acoustic estimates of pelagic YAO rainbow smelt-size density was highest in 2009 (14226/ha) and lowest in 2007 (5015/ha) for the most recent five-year period (Figure 4.1.2). Mean density of YAO-size smelt decreased slightly in 2011 (9398/ha; 9865/ha in 2010) but was still about twice the 2007 density estimate.

Acoustic survey results using the new SOP to describe trends in densities of pelagic forage fish are shown in Table 4.1.1, along with a series of independent bottom trawl measures of YAO rainbow smelt. The synchrony of year-to-year abundance fluctuations between acoustic pelagic fish densities and independent bottom trawl abundance measures for the dominant pelagic forage species (rainbow smelt) in eastern Lake Erie lend support to the veracity of acoustic assessment estimation techniques for pelagic forage fish. It was very constructive to see good agreement of acoustic densities of YAO pelagic forage fish and our independent trawl measures of YAO rainbow smelt abundance.

The spatial distribution of pelagic fish densities for the YAO acoustic size range is shown in Figure 4.1.3. The distribution of sampled acoustic transects through this 2007 to 2011 period shows consistent full spatial coverage of the east basin survey area. Also, this figure demonstrates the spatial distribution of pelagic forage fish densities can markedly differ across years. In 2011, YAO-size smelt densities were greatest in the south-half of the east basin along a band extending from the south shore near the New York-Pennsylvania State border to a point roughly situated near the international boundary north of Dunkirk, NY. This band of high smelt density extended across three transects 58723, 58813, and 58927 (Figures 4.1.1 and 4.1.3). YAO-size smelt density in these three transects combined, averaged 20,440 per hectare with a maximum interval (intervals are 800-m sections of transect) density per transect of 92562, 100480, and 76617 fish/ hectare, respectively.

The mid-basin region between Port Maitland, ON and Dunkirk, NY exhibited high densities in 2009 and 2010 as well. In 2008, YAO-size smelt densities were greatest in a region south of Long Point. In 2007, YAO-size smelt densities were comparatively much lower and evenly distributed throughout the east basin (Forage Task Group 2011). This improved knowledge that the East Basin Lake Erie pelagic fish resource can differ spatially across years reinforces the added value of this broad inter-agency approach to forage fish assessment relative to the unilateral efforts of independent trawling programs conducted by three east basin jurisdictions.

Perspective

A comprehensive analysis of our full series of acoustic survey findings has been planned for several years, but annual constraints on staff time have repeatedly postponed a complete analysis of acoustic data. However, at this time most of the hurdles related to specialized acoustic processing and analysis methodology have been resolved and the east basin investigators are continuing efforts started in 2008 to analyze and report on 15 years of acoustic survey results. Furthermore, upon completion of these new analyses, Forage Task Group acoustic survey investigators currently pursuing somewhat independent efforts in the eastern, central and western basins expect to eventually integrate their analysis and reporting efforts to produce a lake wide July snapshot of pelagic fish density and distribution for Lake Erie.

On another front, the east basin acoustic team is currently seeking to upgrade its license and user agreement for the Echoview software. The version currently being used EV3.45 is outdated and incompatible with Windows 7. This software, last updated in 2005 will soon be replaced by EV5.1, which will provide many improvements in functionality and efficiency and is paramount to maintaining our standard data processing methods, data continuity across survey years and comparability with other acoustic assessments on Lake Erie and the Great Lakes.

4.2 Central Basin Acoustic Survey (J. Deller and P. Kocovsky)

The Ontario Ministry of Natural Resources (OMNR), Ohio Department of Natural Resources (ODNR) and the U.S. Geological Survey (USGS) have collaborated to conduct joint hydroacoustic and midwater trawl surveys in central Lake Erie since 2004. The 2011 central basin acoustic survey was planned according to the protocol and sample design established at the hydroacoustic workshop held in Port Dover, Ontario in December 2003 (Forage Task Group 2005). That survey design calls for eight cross-basin transects on which both hydroacoustic and trawl data are collected. Beginning in 2008 all hydroacoustic data were collected following recommendations in the Standard Operating Procedures for Fisheries Acoustics Surveys in the Great Lakes (GLSOP; Parker-Stetter et al. 2009). The primary purpose of this effort is to estimate densities of rainbow smelt and emerald shiner, which are the primary pelagic forage species in the central basin.

Hydroacoustics

Hydroacoustic data were collected from the USGS *R/V Musky II* and the ODNR-DOW *R/V Grandon*. Acoustic transects corresponding to Loran-C TD lines were sampled from one half hour after sunset (around 2130) to no later than one half hour before sunrise, depending on length of the transect and vessel speed. Sampling started and ended at the 10-m contour. Starting location of sampling alternated from the northern shore to the southern shore on alternating nights.

Hydroacoustics data from both vessels were collected with BioSonics DTX® echosounders and BioSonics Visual Acquisition (release 5.1) software. The *R/V Musky II* were collected using a 120-kHz, 7.1-degree, split-beam transducer and data from the *R/V Grandon* were collected with a 122-kHz, 7.6-degree, split-beam transducer. The transducers on both vessels were mounted to the starboard hull roughly equidistant between the bow and stern with the *R/V Musky II* transducer 1 m below the water surface and the *R/V Grandon* transducer 1.3 meters below the surface. Sound was transmitted at 1 pulse per second (pps) at alternating pulse durations of 0.1 milliseconds (ms), 0.2 ms, 0.3 ms, and 0.4 ms (i.e., each second one pulse lasting 0.1 ms, one pulse lasting 0.2 ms, one pulse lasting 0.3 ms, and one pulse lasting 0.4 ms was transmitted). In past surveys we transmitted sound at 4 pps and 0.4 ms. We altered our protocol in 2010 and 2011 to collect data at shorter pulse durations because shorter pulse durations can better discern individual targets in dense fish layers (Parker-Stetter et al. 2009), which are common near the thermocline in central Lake Erie. Longer pulse durations can result in biased *in situ* TS estimates, which further result in biased density estimates. For this report we use only data collected at 0.4 ms to remain comparable with past practice. We will calculate densities at each pulse duration to determine if shorter pulse durations result in reduced bias in *in situ* target strength estimates and use those results to inform future data collection. Global Positioning Systems (GPS) coordinates from the *R/V Musky II* were collected using a Garmin ® GPSMAP 76Cx, and from the *R/V Grandon,* a Lowrance Ifinder. Both vessels interfaced GPS coordinates with the echosounders to obtain simultaneous latitude and longitude coordinates. Thermal profiles were taken on each transect for calculating the speed of sound in water for use in data analysis. We used the temperature just above the thermocline because the largest proportion of fish occurred nearest this depth in the water column. Because temperature is not uniform from surface to bottom this necessarily results in slight error in estimated depth of fish targets. Selecting temperature nearest the thermocline where fish were densest results in the least cumulative error in depth of fish targets. Prior to data collection we used a standard tungsten-carbide calibration sphere designed specifically for 120 kHz transducers to calculate a calibration offset for calculating target strengths. Background noise was estimated by integrating total sound from passive listening data collected just prior to acoustic sampling from the *R/V Musky II.* Background noise from *R/V Grandon* data was estimated from integrating Sv data in areas where no fish targets were present.

Analysis of hydroacoustic data was conducted following guidelines established in the GLSOP (Parker-Stetter et al. 2009) using EchoView ® version 4.9 software or version 5.1. Proportionate area backscattering coefficient and single targets identified using Single Target Detection Method 2 (Parker-Stetter et al. 2009) were used to generate density estimates for distance intervals. Distance intervals for each transect were either 500-m or 1000-m; longer distances were used when there were fewer single targets. Depth strata were established based on similarity of distributions of single target strength. Settings for pulse length determination level, minimum and maximum normalized pulse length, maximum beam compensation, and maximum standard deviation of major and minor axes followed Parker-Stetter et al. (2009). Minimum target threshold was -75 dB. This value permitted inclusion of all targets at least -69 dB within the half-power beam angle. We used -69 dB as the lowest target of interest based on distribution of *in situ* target strength and theoretical values for rainbow smelt of the lengths captured in midwater trawls (Horppila et al. 1996, Rudstam et al. 2003). The Nv statistic, a measure of the probability of observing more than one fish within the sampling volume (Sawada et al. 1993), which will result in overlapping echoes, was calculated for each interval-by-depth stratum cell to monitor the quality of *in situ* single target data. If Nv for an interval-by-depth stratum cell was >0.1, the mean TS of the entire stratum within a transect where Nv values were <0.1 was used (Rudstam et al. 2009).

Density estimates for age-0 and YAO rainbow smelt and YAO emerald shiner were estimated by multiplying acoustic density estimates within each cell by proportions calculated from trawls. For each cell we used proportions of each species and age group from the trawl sample from the same water stratum and from a similar total water depth that was nearest the cell.

Trawling

The R/V Keenosay, (OMNR) and *R/V Musky II* (USGS) conducted midwater trawling concurrent with acoustic data collection. The *R/V Musky II* conducted four 10-minute trawls in Ohio waters on one transect, while the *R/V Keenosay* conducted up to eight 20-minute trawls per transect in Ontario waters. Both vessels used trawls of the same design for all trawling. Whenever possible, trawl vessels attempted to distribute trawl effort above and below the thermocline to adequately assess species composition throughout the water column. Catch was sorted by species and age group and relative proportions of each species and age group were calculated for each trawl. Age group was determined based on age-length keys and length distributions. Age group classifications consisted of young-of-year (age-0) for all species and yearling-and-older (age-1+) for forage species and age-2-or-older (2+) for predator species. Total lengths were measured from a subsample of individuals from each species and age group.

Results

Four cross-lake transects were sampled between 5 July and 8 July 2011 (Figure 4.2.1). Mechanical problems with the R/V Grandon prevented completion of the three eastern most transects. Acoustic data collection on the western most transect was canceled due to weather conditions. Trawling was completed by OMNR on all four prescribed transects. ODNR was able to trawl two transects and USGS was able to trawl on one transect (Figure 4.2.1). Crew shortages prevented additional trawling aboard the Musky II.

Trawl catches were dominated by rainbow smelt and emerald shiner (Table 4.2.1). Both species" distributions were more segregated by depth this year compared to 2010. Species other than rainbow smelt and emerald shiner included unidentified cyprinidae, white perch, white bass, walleye, round goby, steelhead, gizzard shad and freshwater drum.

Emerald shiner, age-0 rainbow smelt and YAO rainbow smelt segregated into distinct layers of the water column, with age-0 rainbow smelt and emerald shiner in the epilimnion and YAO rainbow smelt in the thermocline and hypolimnion. Most trawl catches were composed of either YAO rainbow smelt or both age-0 rainbow smelt and emerald shiner (Table 4.2.1).

Acoustic TS distributions by depth showed distinct differences in TS distributions across depth strata. The depth of the break varied considerably, from as shallow as 11 m to as deep as 18 m. Hence there is no absolute depth separating fish layers and the layers do not necessarily correspond to the epi- and hypolimnia. We refer instead to upper and lower fish layers.

Similar to previous years, upper layers were dominated by age-0 rainbow smelt and YAO emerald shiner (Table 4.2.2). Lower layers were dominated by YAO rainbow smelt (Table 4.2.2). Age-0 rainbow smelt densities were highest in Ohio waters on transects 57725 and 57850, east and west of Fairport Harbor, OH (Figure 4.2.2). Yearling-and-older rainbow smelt densities were higher in Canadian waters on the eastern transects relative to the western transects (Figure 4.2.3). Overall, densities were highest for emerald shiner (Figure 4.2.4).

Discussion

The 2011 hydroacoustics results were similar to most years in terms of depth distributions of the two primary species. Hydroacoustic target size increased with depth and there was usually a distinct break in target density around the thermocline. Typical to central basin surveys, age-0 rainbow smelt and emerald shiners were caught above the thermocline, while YAO rainbow smelt were caught below the thermocline. Midwater trawl catches in 2010 showed a much less distinct species distribution with age-0 rainbow smelt and emerald shiners being caught in large proportions throughout the water column

Acoustic density estimates also did not suffer from the potential of biased *in situ* target strength estimates as in past years. Since 2004 up to 85% of in situ target strength estimates have been biased in dense fish layers, which typically were near the thermocline. In 2010 fewer than 14% of analytic cells were biased and in 2011, fewer than 2% of analytic cells were biased. Low bias of *in situ* estimates of target strength were likely a result of lower overall fish densities and fish being more widely distributed by depth. Bottom trawl surveys suggest the overall forage population is below average in the central basin in 2011. Hydroacoustic data showed 2011 densities up to 40,000 fish per hectare, an increase from 2010, but still well below densities of over 100,000 fish per hectare in 2008. Dissolved oxygen profiles found no evidence of hypoxia, which could cause fish to congregate tightly around the thermocline.

Hydroacoustic data have been collected at pulse durations less than 0.4 ms in 2010 and 2011. We report only those density estimates from data collected at 0.4 ms pulse duration so data are comparable to past years. The data we collected at shorter pulse durations will be analyzed to determine if bias of target strength estimates can be further reduced. We will also assess how density estimates are affected by collecting data at different pulse durations.

4.3 West Basin Acoustic Survey (E. Weimer)

Introduction

A standardized inter-agency fishery acoustics program has been used to assess forage community abundance and distribution in the eastern basin of Lake Erie since 1993. The acoustic survey was expanded to the central basin in 2000 (Forage Task Group 2004). In 1997, a pilot program was conducted by Sandusky Fisheries Research Unit staff adjacent to Sheldon‟s Marsh in July to assess the feasibility of using acoustic technology in the shallow waters of the western basin. The pilot study showed much promise and results indicated an offshore to nearshore gradient in forage-sized fish abundance. As charged by the LEC, since 2004 a pilot western basin acoustic survey has been initiated to explore the utility of using down-looking sonar for assessing pelagic forage fish abundance in the west basin. These data have been used in conjunction with current survey data to develop a standardized acoustic sampling program for the west basin of Lake Erie that will complement the ongoing acoustic surveys in the central and eastern basins and facilitate an annual lake snapshot of pelagic forage fish abundance and biomass.

Methods

Following a one year hiatus caused by equipment malfunctions, the western basin hydroacoustic survey was conducted again in 2011. Of the three proposed cross-basin transects, all were completed July 19-27th except the northern half of Transect 3(eastern transect; Figure 4.3.1), which was lost due to equipment failure. Data was collected using a BioSonics DTX echosounder employing a single, downward-facing, 6.8-degree, 201-kHz split-beam transducer, a Garmin global positioning system, and a Panasonic CF-30 laptop computer. The acoustic system was calibrated before the survey with a tungsten carbide reference sphere of known acoustic target strength. The mobile survey, conducted aboard the ODNR‟s *R/V Almar*, was initiated 0.5 h after sunset and completed by 0.5 h prior to sunrise. Transects were navigated with waypoints programmed in a Lowrance GPS, and speed was maintained at 8-9 kph using the GPS. The transducer was mounted on a fixed pole located on the port side of the boat amidships. The transducer was mounted 1 m below the surface. Data were collected using BioSonics Visual Acquisition 5.0.4 software. Data were collected at a ping rate of 10 pings/second, a pulse length of 0.2 ms, and a minimum threshold of -70 dB. Water temperature and dissolved oxygen level was recorded at the surface, 2-m depth, and bottom of the water column at the beginning of each transect; 2-m water temperature was included in data settings in Visual Acquisition to calculate sound speed and absorption coefficients. Data were written to file and named by the date and time the file was collected. Files were automatically collected every 30 minutes. Latitude and longitude coordinates were written to the file as the data were collected to identify sample location.

Data were analyzed using the Myriax software Echoview 4.5. Only targets with acoustic returns larger than -60 dB were included in analysis. Total length was estimated from target strength using Love‟s dorsal aspect equation (Love 1971):

Total length = 10 ^ ((Target Strength + 26.1)/19.1) * 1000

Biomass estimates were based on average target length as determined by the above equation.

Results

One hundred ten kilometers were surveyed during 2011, with 3.196 GB of data collected. Mean western basin fish density and biomass estimates in the western basin were 1,158 fish per hectare and 5.8 kg per hectare, respectively. Densities were lowest in Transect 3, but larger-bodied fish compared to the other transects lead to similar biomass levels (Figure 4.3.2). Compared with previous years with when similar surveys were completed, 2011 fish densities were the lowest of the series. Biomass estimates for all three transects were similar to the 2008 survey, but generally lower than 2006 and 2007. Fifty-seven percent of fish surveyed were estimated to be 30-59 mm TL, lower than previous years; 91% were between 30-109 mm.

Table 4.1.1. Indices of relative abundance of pelagic forage fish species in eastern Lake Erie from a basin-wide acoustic survey from 2007 to 2011, compared with bottom trawl survey results for rainbow smelt conducted by Ontario, New York and Pennsylvania during the same period. Indices are reported as arithmetic mean number caught per hectare (NPHa) for the yearling-and-older (YAO) age group.

		Number per hectare				
Sampling Method	**East Basin Index Stratum**	**2011**	**2010**	**2009**	**2008**	**2007**
Btm. Trawl YAO Smelt	**ON-DW**	**277**	**223**	**1654**	**77**	**233**
Btm. Trawl YAO Smelt	**NY-Fa**	**640**	**998**	**3017**	**546**	**177**
Btm. Trawl YAO Smelt	**PA-Fa**			**407**	**2**	**1006**
Btm. Trawl YAO Smelt	**basin trawl avg. (area weighted)**	**359**	**438**	**1939**	**214**	**301**
Acoustic YAO-smelt size fish	**East Basin (all thermal strata)**	**9398**	**9865**	**14226**	**12430**	**5015**

Ontario Ministry of Natural Resources Trawl Survey

ON-DW	Trawling is conducted weekly during Oct. at 4 fixed stations in offshore waters of Outer Long Point Bay using a 10-m trawl.

New York State Department of Environmental Conservation Trawl Survey

NY-Fa	Trawling is conducted at 30 nearshore (15-30 m) stations during Oct. using a 10-m trawl

Pennsylvania Fish and Boat Commission Trawl Survey

PA-Fa	Trawling is conducted at nearshore (<22 m) and offshore (>22 m) stations during Oct. using a 10-m trawl.

Inter-agency East Basin Acoustic Survey

East Basin Acoustic	Acoustic survey encompassing Ontario, Pennsylvania and New York waters with cross-basin transects > 15-m depth contour (Figure 4.1.2).

Table 4.2.1. Percent composition of fish captured in trawl samples collected by the *R/V Keenosay, R/V Musky II* and *R/V Grandon* in the central basin Lake Erie in July, 2011. *R/V Keenosay* trawl ID numbers are 1001-4005. *R/V Musky II* trawl ID numbers are 201-204. *R/V Grandon* trawl ID numbers are 730-735. Layer was determined from distribution of acoustic target size to depth along each transect. Upper layer refers to target sizes similar to AGE-0 rainbow smelt. Lower layer refers to target sizes similar to YAO rainbow smelt. Layer was assigned to trawl data based on the depth and transect where the trawl was fished. Species composition from trawl data was applied to acoustic data based on layer and transect.

Transect	Trawl ID	Trawl depth (m)	LAT	LONG	Layer	Emerald shiner All	Freshwater drum YAO	Round goby ALL	Rainbow smelt AGE-0	Rainbow smelt YAO	White perch YAO	Yellow perch AGE-0
58100	1001	15	42.3927	-80.9165	Lower	0	0	0	0	1.000	0	0
58100	1002	15	42.3867	-80.9218	Lower	0.014	0	0	0	0.986	0	0
58100	1003	11	42.3870	-80.9215	Upper	0.953	0	0	0	0.023	0.023	0
58100	1004	5	42.4173	-80.9248	Upper	1.000	0	0	0	0	0	0
58100	1005	9	42.5675	-80.9847	Upper	0.894	0	0.001	0	0.102	0	0
58100	1006	7	42.5688	-80.9810	Upper	0.992	0	0.002	0	0.001	0.002	0.001
58100	1007	5	42.5627	-80.9892	Upper	0.993	0	0	0	0	0	0
58100	1008	7	42.6108	-81.0090	Upper	0.346	0	0	0.004	0.643	0	0
58100	1009	5	42.6117	-81.0127	Upper	0.682	0	0.006	0	0.263	0.028	0
57850	2001	5	42.5670	-81.4733	Upper	0.037	0	0	0	0.955	0.003	0
57850	2002	8	42.5503	-81.4663	Upper	0.270	0	0	0	0.724	0.003	0
57850	2003	13	42.4903	-81.4397	Lower	0.056	0	0	0	0.889	0	0
57850	2004	11	42.4750	-81.4332	Upper	0.786	0	0	0.143	0	0	0
57850	2005	5	42.4862	-81.4453	Upper	0.912	0	0	0.059	0	0.029	0
57850	2006	16	42.3373	-81.3730	Lower	0	0	0	0	1.000	0	0
57850	2007	13	42.3137	-81.3660	*	0.357	0	0	0.357	0.286	0	0
57850	2008	10	42.3250	-81.3680	Upper	0.889	0.056	0	0	0	0.056	0
57850	2009	5	42.3037	-81.3562	Upper	1.000	0	0	0	0	0	0
57600	3001	7	42.2580	-81.8297	Upper	0.122	0	0	0	0.874	0.002	0
57600	3002	5	42.2410	-81.8252	Upper	0.995	0	0	0	0.004	0.001	0
57600	3003	5	42.2223	-81.8117	Upper	0.996	0	0	0	0	0.002	0.002
57600	3004	8	42.2092	-81.8042	Upper	0.986	0.004	0	0.007	0.004	0	0
57600	3005	7	42.2223	-81.8072	Upper	0.985	0.002	0	0.010	0	0.001	0.001
57475	4001	15	41.9108	-82.1393	Lower	0.908	0	0	0	0.092	0	0
57475	4002	5	41.9088	-82.1397	Upper	0.992	0	0	0.004	0	0	0
57475	4003	14	42.0525	-82.2148	Lower	0.636	0.030	0	0.182	0.121	0	0.030
57475	4004	5	42.0587	-82.2177	Upper	0.960	0	0	0	0	0.040	0
57475	4005	6	42.1538	-82.2600	Upper	0.996	0.001	0	0	0.002	0.001	0
57850	201	3	42.4858	-81.4391	Upper	0.097	0	0	0.903	0	0	0
57850	202	11	42.4118	-81.4051	Upper	0.095	0	0	0.524	0.381	0	0
57850	203	16	42.1444	-81.2923	Lower	0	0	0	0	1.000	0	0
57850	204	11	42.0726	-81.2610	Upper	0	0	0	0.917	0	0	0.083
57725	730	15	42.0737	-81.5067	Lower	0	0	0	0	0.999	0	0.001
57725	731	17	41.9663	-81.4548	Lower	0.002	0	0	0	0.996	0	0.001
57725	732	8	41.8825	-81.4177	Upper	0	0	0	0	1.000	0	0
57975	733	9	41.9208	-80.9703	Upper	0	0.587	0	0	0.187	0	0.20
57975	734	17	42.0228	-81.0177	Lower	0	0.001	0	0	.998	0	0.001
57975	735	14	42.0810	-81.0473	Lower	0	0.002	0	0	0.998	0	0

*Trawl depth was the same as layer separation depth

Table 4.2.2. Mean acoustic density (fish/hectare) by species and age class for hydroacoustic transects in central Lake Erie, July 2011.

Upper layer		LORAN TD line				
Species	Life stage	57475	57600	57725	57850	57975
Emerald shiner	All	24264	11849	2783	9466	0
Rainbow smelt	AGE-0	68	87	1549	13576	3904
	YAO	23289	10312	717	1321	0
Yellow perch	AGE-0	0	534	140	1071	355
Other[1]		376	56	12	381	0

Lower layer		LORAN TD line				
Species	Life stage	57475	57600	57725	57850	57975
Emerald shiner	All	1613	17	9	9	0
Rainbow smelt	AGE-0	183	0	0	0	0
	YAO	231	891	1223	1595	611
Yellow perch	AGE-0	30	0	0	0	0
Other[1]		30	2	9	9	0

[1] Other species include: YAO freshwater drum, YAO yellow perch, round goby, walleye, white perch, white bass, steelhead, whitefish and gizzard shad.

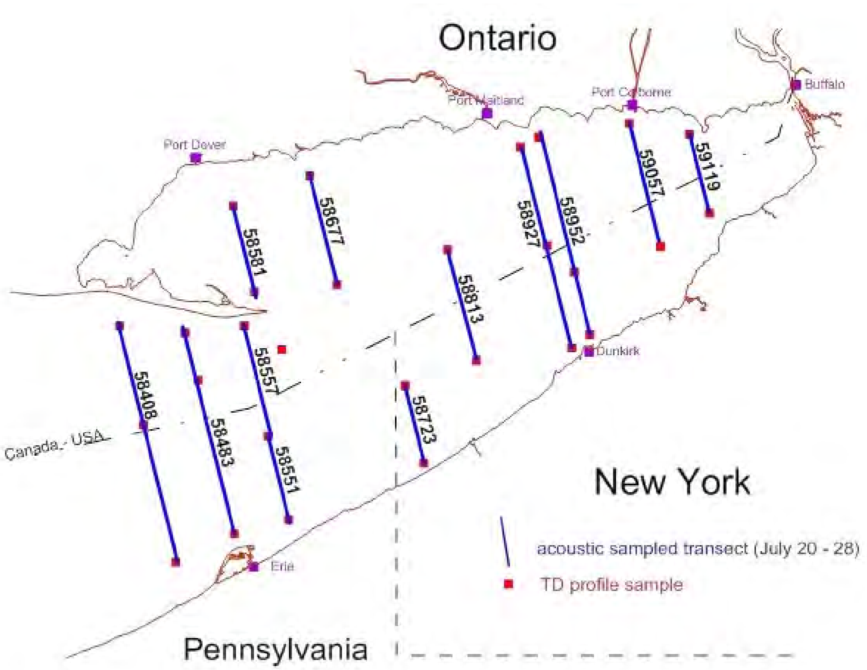

Figure 4.1.1. July 2011 eastern basin Lake Erie inter-agency acoustic survey transects, mid-water trawl and temperature profile sites sampled by the Ontario Ministry of Natural Resources (OMNR) research vessel, *RV Erie Explorer* .

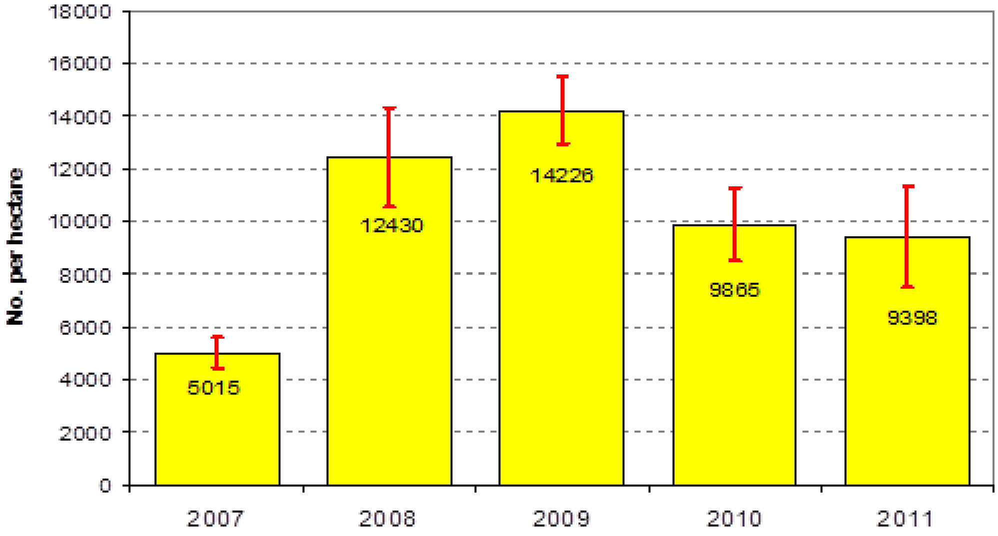

Figure 4.1.2. Mean density (Number per hectare) estimates of pelagic YAO rainbow smelt-sized forage fish sampled with a 120-kHz split-beam echosounder during July fisheries hydroacoustic assessments of eastern Lake Erie, 2007 - 2011. Density estimates were derived from a spatially stratified cluster analysis of acoustic transects comprised of 800-m length sample units. Standard error (of mean) bars shown.

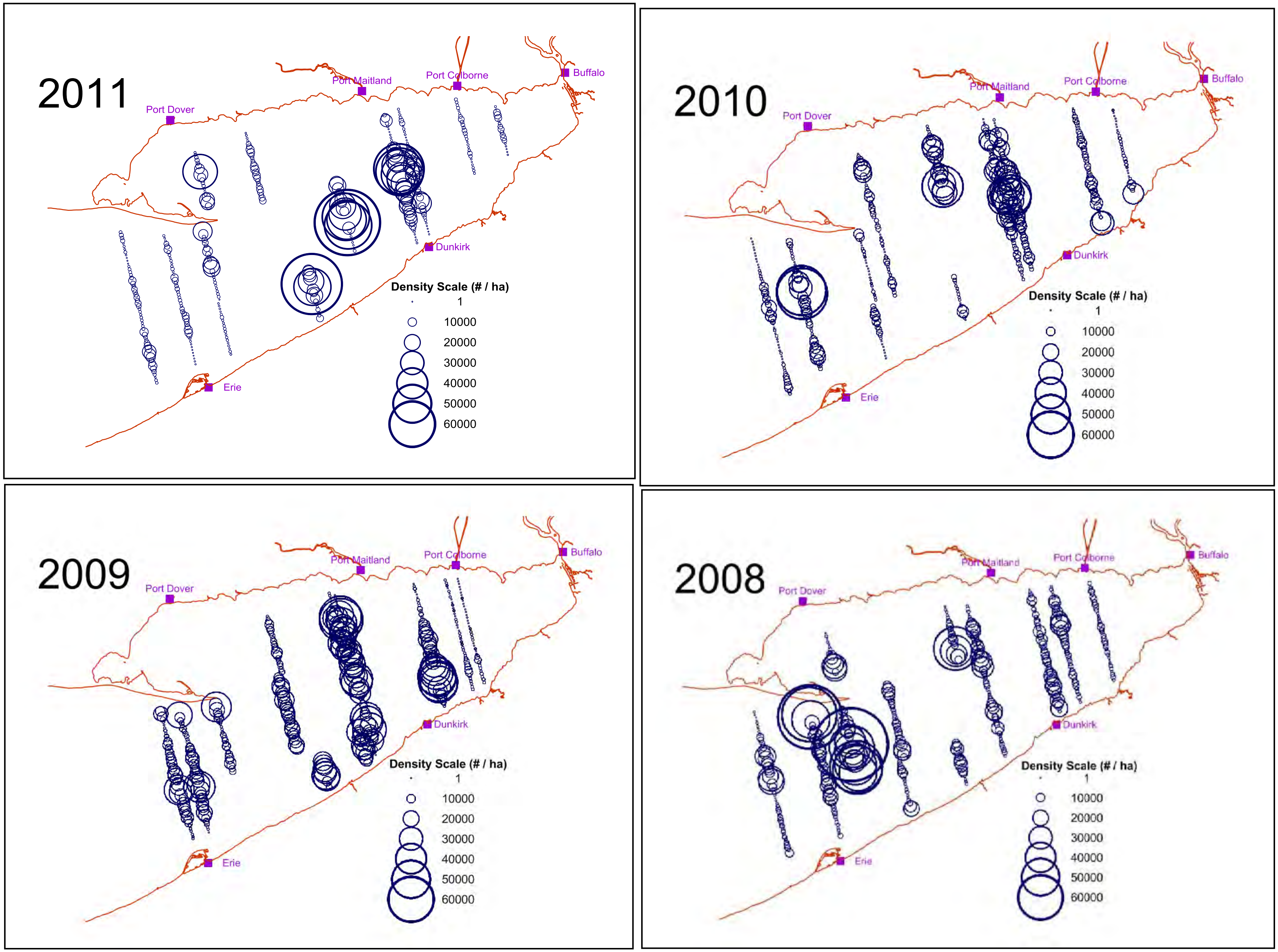

Figure 4.1.3. Relative density (No. fish / ha) of pelagic, YAO rainbow smelt-sized forage fish per 800-m interval along transects sampled with a 120-kHz split-beam echosounder during July fisheries acoustic surveys in eastern Lake Erie, 2008 to 2011.

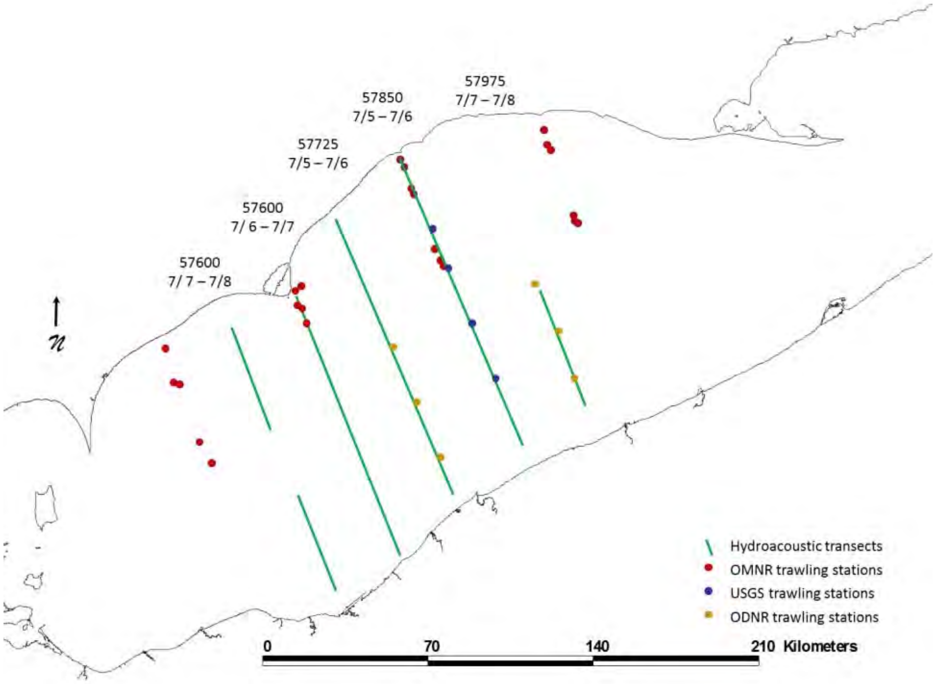

Figure 4.2.1 Hydroacoustic transects and midwater trawling stations in the central basin, Lake Erie, July 5-8, 2011. Transect numbers are Loran-TD lines.

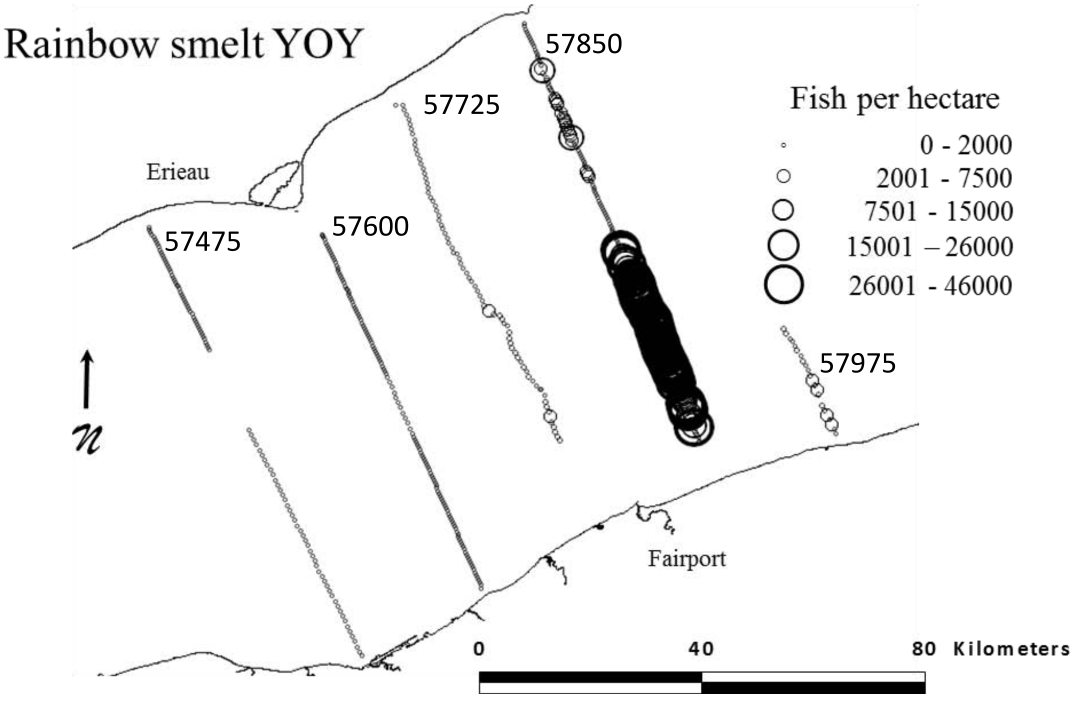

Figure 4.2.2. Density estimates of age-0 rainbow smelt (fish * ha^{-1}) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 500-m or 1000-m segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2011.

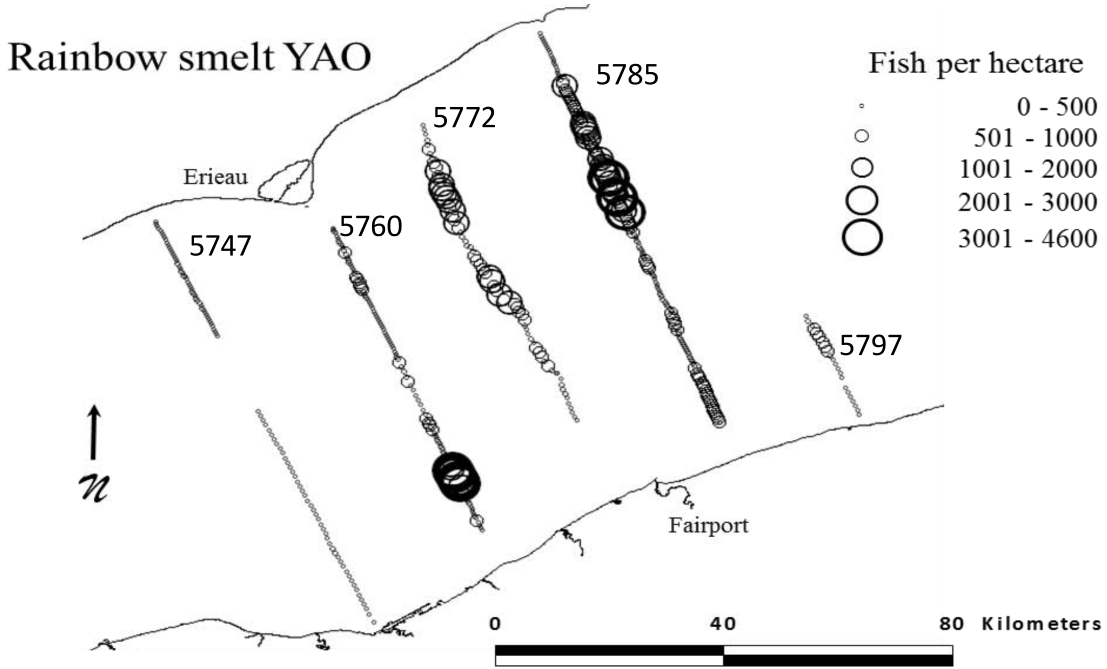

Figure 4.2.3 Density estimates of YAO rainbow smelt (fish * ha^{-1}) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 500-m or 1000-m segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2011.

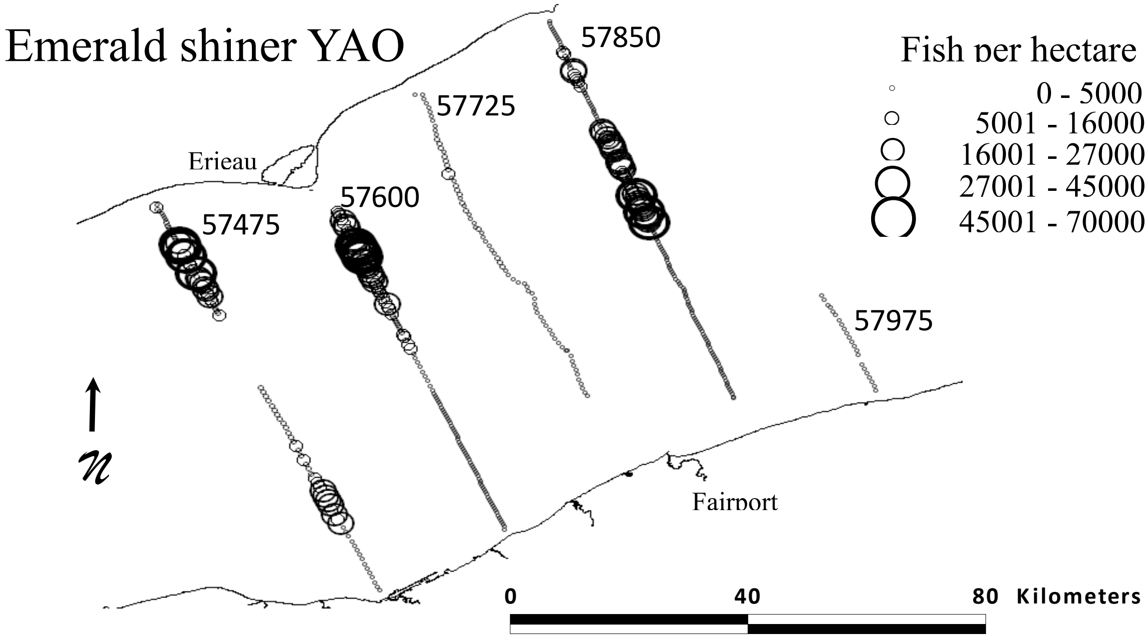

Figure 4.2.4 Density estimates of YAO emerald shiner (fish * ha^{-1}) per distance interval along hydroacoustic transects in the central basin, Lake Erie. Distance intervals were 500-m or 1000-m segments to ensure adequate numbers of single targets for *in-situ* analysis. Transects are Loran-TD lines sampled in 2011.

Figure 4.3.1. Spatial abundance of forage fish along three western basin hydroacoustic transects, July 2011. Equipment failure ended the survey midway through the eastern transect. Legend densities are in fish per hectare.

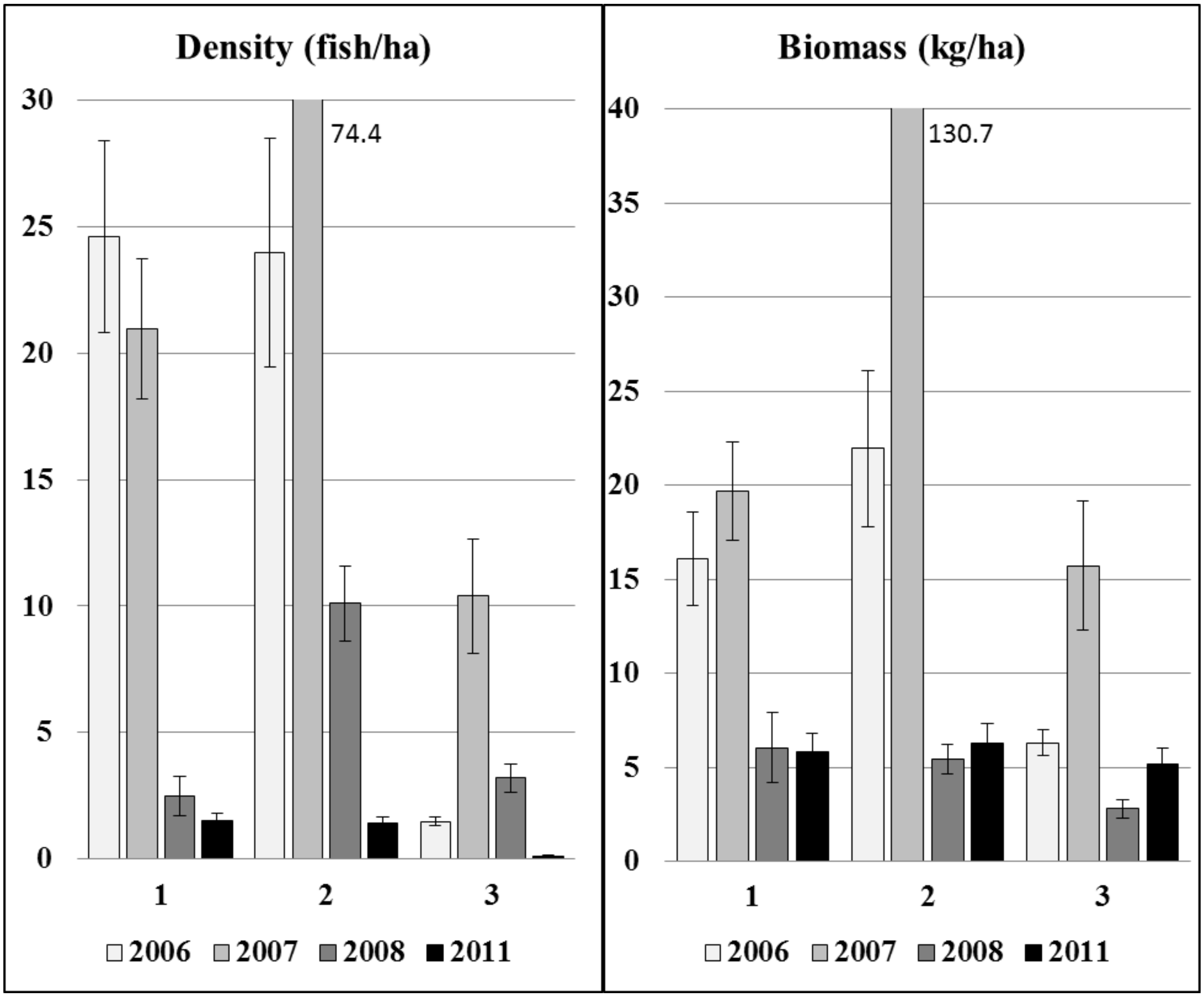

Figure 4.3.2. Mean fish density (#/ha; A) and biomass (kg/ha; B) along three western basin transects during the annual hydroacoustic survey, 2006-2011. Results from 2009 and 2010 are not represented due to insufficient data. Error bars are standard errors.

5.0 Interagency Lower Trophic Level Monitoring Program, 1999-2011

(B. Trometer, and J. Markham)

In 1999, the FTG initiated a Lower Trophic Level Assessment program (LTLA) within Lake Erie and Lake St. Clair (Figure 5.0.1). Nine key variables, as identified by a panel of lower trophic level experts, were measured to characterize ecosystem change. These variables included profiles of temperature, dissolved oxygen and light (PAR), water transparency (Secchi), nutrients (total phosphorus), chlorophyll *a*, phytoplankton, zooplankton, and benthos. The protocol called for each station to be visited every two weeks from May through September, totaling 12 sampling events, with benthos collected on two dates, once in the spring and once in the fall. For this report, we will summarize the last 13 years of data for summer surface temperature, summer bottom dissolved oxygen, chlorophyll *a* concentrations, zooplanktivory, water transparency and total phosphorus. Stations were only included in the analysis if there were at least 3 years of data, each containing 6 or more sampling dates. Stations included in this analysis are stations 3, 4, 5 and 6 from the western basin, stations 7, 8, 9, 10, 11, 12, 13 and 14 from the central basin, and stations 15, 16, 17, 18, 19, 20 and 25 from the eastern basin (Figure 5.0.1). Station 25 (located off Sturgeon Point in 19.5 meters of water) was added in 2009.

The fish community objectives (FCO) for the lower trophic level ecosystem in Lake Erie are to maintain mesotrophic conditions that favor percids in the western, central and nearshore waters of the eastern basin, and oligotrophic conditions that favor salmonids in the offshore waters of the eastern basin (Ryan *et al.* 2003). Associated with these trophic classes are target ranges for total phosphorus, water transparency, and chlorophyll *a* (Table 5.0.1). For mesotrophic conditions, the total phosphorus range is 9-18 µg/L, summer (June-August) water transparency is 3-6 meters, and chlorophyll *a* concentrations range between 2.5-5.0 µg/L (Leach *et al.* 1977). For the offshore waters of the eastern basin, the target ranges for total phosphorus are <9 µg/L, summer water transparency of >6 m, and chlorophyll *a* concentrations of <2.5 µg/L.

Mean Summer Surface Water Temperature

Summer surface water temperature represents the temperature of the water measured at one meter or less below the surface for offshore stations only. This index should provide a good measure of relative system production and growth rate potential for fishes, assuming prey resources are not limiting. Mean summer surface temperatures across all years are warmer in the western basin (22.7 C) and progressively get cooler in the central (21.9 C) and eastern basins (20.6 C; Figure 5.0.2). Mean surface temperatures range from 21.2 C in 2004 to 24.3 C in 2010 in the western basin, 20.1 C in 2003 to 23.8 C in 2005 in the central basin, and 18.9 C (2004) to 22.5 C (2005) in the eastern basin. Above average temperatures were evident across all basins in 2005, 2006, 2010, and 2011; below average temperatures occurred in 2000, 2003, 2004, 2008, and 2009. Although warmer temperatures are more prevalent in the latter half of the time series, the trends are not significant. In 2011, the mean summer surface water temperature was higher than the long-term average in all three basins (west 23.5 C, central 22.8 C, and east 21.8 C).

Hypolimnetic Dissolved Oxygen

Dissolved oxygen (DO) levels less than 2 mg/L are deemed stressful to fish and other aquatic biota (Craig 2012; Eby and Crowder 2002). Hypolimnetic DO can become low when the water column becomes stratified, which can begin in early June and continue through September in the central and eastern basins. In the western basin, shallow depths allow wind mixing to penetrate to the bottom, generally preventing thermal stratification. As a result, there are relatively few summer observations of low hypolimnetic DO concentrations in the time series (Figure 5.0.3). In 2011, DO was below the 2 mg/L threshold on two occasions in the west basin; at station 3 on 7/27/2011 (1.9 mg/L) and at station 6 on 8/9/2011 (1.8 mg/L).

Low dissolved oxygen is more of an issue in the central basin. It happens almost annually at the offshore stations (8, 10, 11 and 13) and occasionally at inshore stations as well. Dissolved oxygen of less than 2 mg/L has been observed as early as mid-June and can persist until late September before fall turnover remixes the water column. In 2011, bottom DO was below 2 mg/L threshold in the central basin on only two occasions at station 8 (7/26/2011, 0.8 mg/L; 8/8/2011, 0.6 mg/L) (Figure 5.0.3).

DO is rarely limiting in the eastern basin due to greater water depths, a large hypolimnion and cooler water temperatures. The only occasion when DO was below 2 mg/L threshold was in 2010 at the new station 25 on July 14 and again on August 13 (Figure 5.0.3). No DO concentrations of less than 8 mg/L were recorded in the east basin in 2011.

Chlorophyll *a*

Chlorophyll *a* concentrations indicate biomass of the phytoplankton resource, ultimately representing production at the lowest level. For mesotrophic status in the west, central, and nearshore eastern basins, chlorophyll *a* concentrations should range between 2.5-5.0 µg/L. Chlorophyll *a* concentrations should be less than 2.5 µg/L in the offshore eastern basin to be classified as oligotrophic (Leach *et al.* 1977). In the west basin, mean chlorophyll *a* concentrations have mainly been above targeted levels in the 13 year time series, falling into eutrophic status rather than mesotrophic status (Figure 5.0.4). Annual variability is also the highest in the west basin. Chlorophyll *a* concentrations in 2011 were 7.9 µg/L in the west basin and have been increasing for the past three years.

In the central basin, chlorophyll *a* concentrations have been within the targeted mesotrophic range for the entire time series, and that trend continued in 2011 (3.3 µg/L) (Figure 5.0.4). In the eastern basin, chlorophyll a concentrations in the nearshore waters have been below the targeted mesotrophic level for the entire time series (Figure 5.0.4). This may be due to high levels of grazing by dreissenids (Nicholls and Hopkins 1993) in the nearshore eastern basin waters where biomass of quagga mussels, *Dreissena bugensis,* remains high (Patterson *et al.* 2005). Conversely, chlorophyll *a* levels in the offshore waters of the eastern basin remain in, or slightly above, the targeted oligotrophic range. In 2011, chlorophyll *a* concentrations were 1.9 µg/L in the nearshore waters of the eastern basin and 2.4 µg/L in the offshore waters.

Total Phosphorus

Total phosphorus levels in the western basin have exceeded FCO targets since the beginning of this monitoring program (Figure 5.0.5). Total phosphorus concentrations in the west basin dramatically increased in 2011 to 113.0 µg/L, a time-series high. In four of the last five years, total phosphorus levels in the west basin have been in the hyper-eutrophic range.

In the central basin, total phosphorus levels have been on the increase and have exceeded FCO targets since 2006 (Figure 5.0.5). Similar to the west basin, the central basin experienced a dramatic increase in total phosphorus in 2011 to a time series high of 47.6 µg/L. In the nearshore waters of the eastern basin, total phosphorus levels have remained stable and within the targeted mesotrophic range for the entire time series (Figure 5.0.5). However, a gradual increasing trend is evident since 2006. Total phosphorus levels stable in the offshore waters of the eastern basin show a similar trend to nearshore waters, and have recently risen above the targeted oligotrophic range into the mesotrophic range. In 2011, total phosphorus concentrations in the eastern basin decreased in both nearshore waters (11.8 µg/L) and offshore waters (8.9 µg/L) and were within their targeted trophic levels.

Water Transparency

Similar to other fish community ecosystem targets (i.e. chlorophyll *a*, total phosphorus) water transparency has been in the eutrophic range, which is below the FCO target in the western basin for the entire time series (Figure 5.0.6). Mean summer Secchi depth readings in the western basin were 2.0 m in 2011. In contrast, water transparency in the central basin has remained within the targeted mesotrophic range for the entire series, including 2011 (4.4 m; Figure 5.0.6). Transparency was in the oligotrophic range, which is above FCO target range for the nearshore waters of the eastern basin from 1999 through 2007, but has been stable and within the FCO targets for the last four years (Figure 5.0.6). In the offshore waters of the eastern basin, water transparency was within the oligotrophic target range from 1999 through 2007, but fell into the mesotrophic range in both 2008 and 2010. In 2011, mean summer Secchi depth readings was 4.8 m in the nearshore waters of the eastern basin, which was within the targeted mesotrophic range, and 5.5 m in the offshore waters, which was below the targeted oligotrophic range.

Zooplanktivory Index

Fish are size-selective predators of zooplankton, removing larger prey with a resultant decrease in the overall size of the prey community that reflects feeding intensity (Mills *et al.* 1987). Johannsson *et al.* (1999) estimated that a mean zooplankton length of 0.57 mm or less sampled with a 63-µm net reflects a high level of predation by fish. For 1999-2004, zooplankton predation was high in Lake Erie, as the average size of the community was generally less than this critical 0.57 mm size (Figure 5.0.7). Since 2005 in the western basin and 2006 in the central basin, the mean size of the zooplankton community has been below the critical size, indicating low feeding intensity, for all years except 2007.

The trend of low feeding intensity continued in 2011 in both the western and central basins. In the eastern basin, the zooplanktivory index has been the most stable and is generally at the critical size level.

Distribution of New Zooplankters

For this review data from stations 3, 4, 5, 6, 9, 10, 11, 12, 15, 16, 17, 18, 19 and 20 were included. *Bythotrephes longimanus* was first collected in Lake Erie in October 1985 (Bur et al. 1986). It is consistently present at central and eastern basin stations, but is very rare at western basin stations. Densities ranged from 0.001 to 510/m^3 and were generally higher from July through September.

Cercopagis pengoi was first collected in Lake Ontario in 1998, and by 2001 was collected in western basin of Lake Erie (Therriault et al. 2002). They first appeared in west basin samples at station 5 in July 2001 and station 9 in September 2001. In subsequent years it has also been found at stations 5, 6, 9, 10, 15, 16, 17, 18 and 19. Except for the year 2002, when it was collected at 8 stations, *Cercopagis* is seen less frequently around the lake than *Bythotrephes*. Densities ranged from 0.03 to 876/m^3.

The first record of *Daphnia lumholtzi* in the Great Lakes was in the western basin of Lake Erie in August 1999 (Muzinic 2000). It was first identified in this sampling effort in August 2001 at stations 5 and 6, and at station 9 by September 2001. It was collected at stations 5 and 6 in 2002, and at stations 5, 6, 8 and 9 in 2004. Data is not available for these stations from 2005 through 2008. In 2007 it was found at station 18, the first record for the eastern basin. Densities were relatively low ranging from 0.002 to 61/m^3.

Fish Community Ecosystem Targets

Measures of lower trophic indicators (total phosphorus, transparency, chlorophyll *a*) in 2011 indicate that the western basin is eutrophic to hyper-eutrophic. Current conditions favor a centrarchid (bass, sunfish) and cyprinid (carp, minnows) fish community instead of the desired percid (walleye, yellow perch) fish community (Table 5.0.2). In the central and nearshore eastern basin, the lower trophic measures in 2011 mainly fell within the targeted mesotrophic range preferred by percids. However, it is worth noting that total phosphorus concentrations in the central basin were high in the eutrophic range in 2011. In the offshore waters of the eastern basin, 2011 total phosphorus and chlorophyll *a* measures indicate an oligotrophic class that favors salmonids while transparency indicates a shift towards a mesotrophic class that favors percids.

Microcystis blooms in western Lake Erie (E. Weimer and J. Chaffin)

Following decades of eutrophication and annual blooms of cyanobacteria, the passage of the Great Lakes Water Quality Agreement in 1972, and the pollution control measures that lead to substantially reduced phosphorus and phytoplankton levels in Lake Erie and limited cyanobacteria biomass. However, the past decade has witnessed increases in total phytoplankton and the return of cyanobacteria blooms in the western basin. Unlike previous blooms, which were dominated by nitrogen-fixing species like *Anabaena* spp. and *Aphanizomenon* spp., current blooms consist of

Microcystis spp., a non-nitrogen fixer. While bloom intensity since the mid-1990s has varied, the annual occurrence of *Microcystis* blooms has created concern among managers that Lake Erie is once again becoming eutrophic.

Causes of *Microcystis* blooms and eutrophication in western Lake Erie have been linked to several potential sources. Watershed practices have increased the amount of biologically available phosphorus flowing into the western basin, and small tributaries are providing a potential source of *Microcystis* to the lake. Turbidity, particularly suspended sediments in and around Maumee Bay, provides ideal growth conditions for *Microcystis*, because it can float near the surface while other phytoplankton sink out of the sunlight. Invasive *Dreissenid* mussels selectively avoid cyanobacteria during feeding, and excreted nutrients, particularly forms of nitrogen and phosphorus, are readily available for uptake by *Microcystis*. Internal lake processes also increase the availability of nutrients.

Researchers are examining factors that influence the presence and intensity of *Microcystis* blooms in Lake Erie, and are searching for management levers that can be used to halt or reverse this trend. The University of Toledo has been monitoring *Microcystis* in Maumee Bay and western Lake Erie since 2002, looking at conditions that promote blooms and the cellular „health‟ of the cyanobacteria in an attempt to identify deficiencies that limit growth. Researchers from Ohio State University and collaborators at Ohio State University‟s, F. Stone Laboratory are looking at the timing and intensity of blooms in the Maumee and Sandusky systems. Researchers from Heidelberg University are examining nutrient loading in tributaries and in Lake Erie, and investigating the effects of toxic microcystins on larval mayflies in the Lake Erie benthos. Researchers at the USGS are developing genetic approaches to rapidly assay *Microcystis* biomass and potential toxicity. NOAA has developed an experimental forecast bulletin for harmful algal blooms in western Lake Erie. These represent just a few of the efforts being made to address this issue.

The Lake Erie lower trophic program has been collecting bi-weekly total phosphorus and phytoplankton samples from May through September in Lake Erie since 1998. These samples coincide with the *Microcystis* increase, and may be valuable in identifying lake wide trends and conditions that favor these increases. As reported in the Lower Trophic section of this report, total phosphorus has shown an increasing trend in the west and central basins (Figure 5.0.5). Most of the phytoplankton data are not available as many samples remain archived due to the financial constraints of processing. Currently, the FTG has a total of 775 phytoplankton samples archived at The Ohio State University‟s Museum of Biological Diversity. Some phytoplankton samples from Ohio waters of the western and central basins have been processed, but are not currently organized in a useable format. The FTG will organize these data in the upcoming year for use in the 2012 report, and will pursue opportunities to process the archived samples as funding allows.

Table 5.0.1. Ranges of lower trophic indicators for each trophic class and associated fish community (Leach *et al.* 1977; Ryder and Keer 1978).

Trophic Class	Phosphorus (µg/L)	Chlorophyll a (µg/L)	Transparency (m)	Harmonic Fish Community
Oligotrophic	<9	<2.5	>6	Salmonids
Mesotrophic	9 - 18	2.5 - 5.0	3 - 6	Percids
Eutrophic	18 - 50	5.0 - 15	1 - 3	Centrarchids
Hyper-eutrophic	>50	>15	<1	Cyprinids

Table 5.0.2. Measures of key lower trophic indicators and current trophic class, by basin, from Lake Erie, 2011. The east basin is separated into nearshore and offshore.

Basin	Phosphorus (µg/L)	Chlorophyll a (µg/L)	Transparency (m)	Trophic Class
West	113	7.9	2.0	Eutrophic/Hyper
Central	48	3.3	4.4	Mesotrophic
East - Nearshore	12	1.9	4.8	Mesotrophic
East - Offshore	9	2.4	5.5	Oligotrophic/Mes

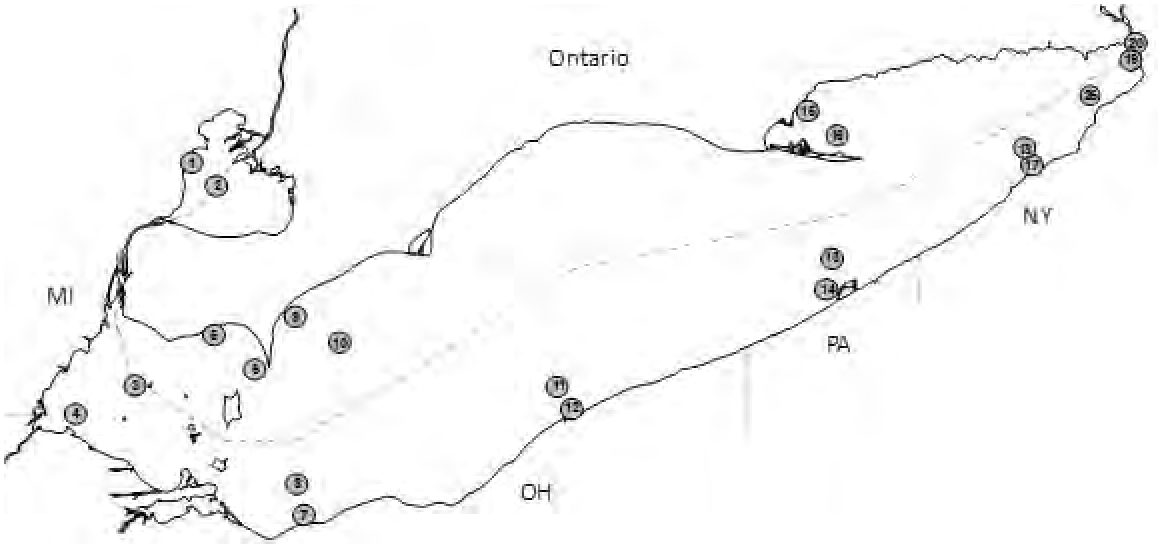

Figure 5.0.1. Lower trophic level sampling stations in Lakes Erie and St. Clair. Station 25 was added in 2009.

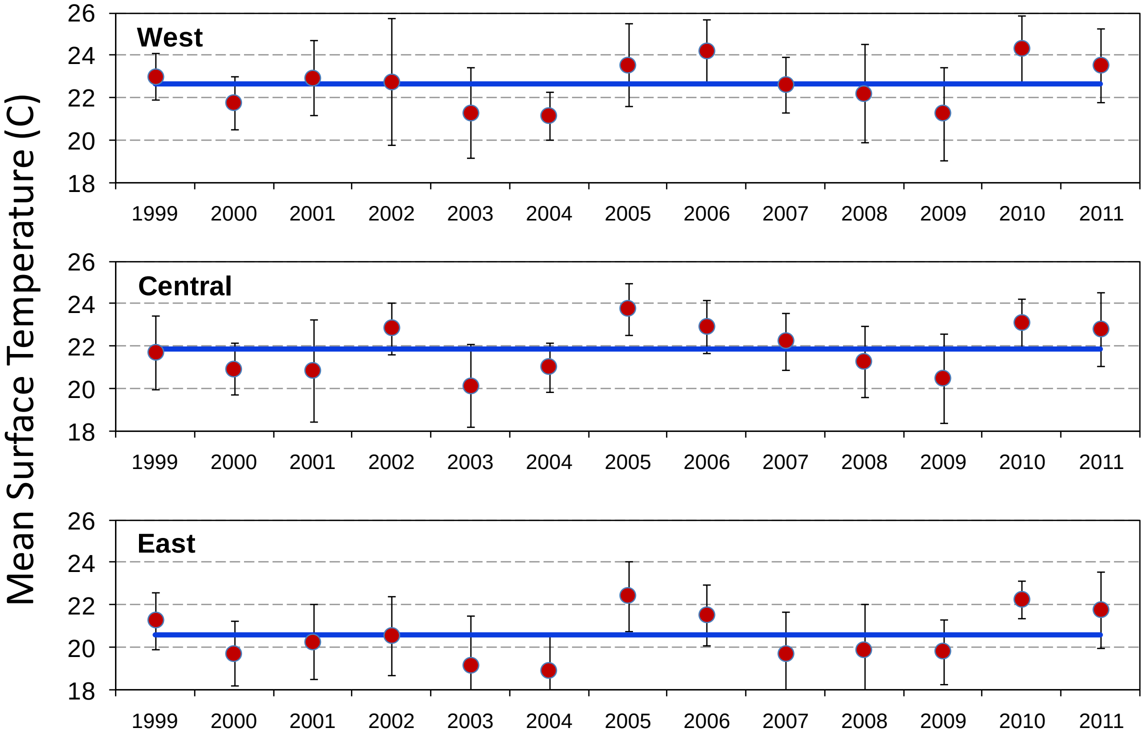

Figure 5.0.2. Mean summer (June-August) surface water temperature (C) at offshore stations, weighted by month, with 95% confidence limits (2 SE‟s) by basin in Lake Erie, 1999-2011. Dark blue lines represent time series average water temperature. Data included in this analysis by basin and station: West - 3, 6; Central – 8, 10, 11, 13; East – 16, 18, 19, 25.

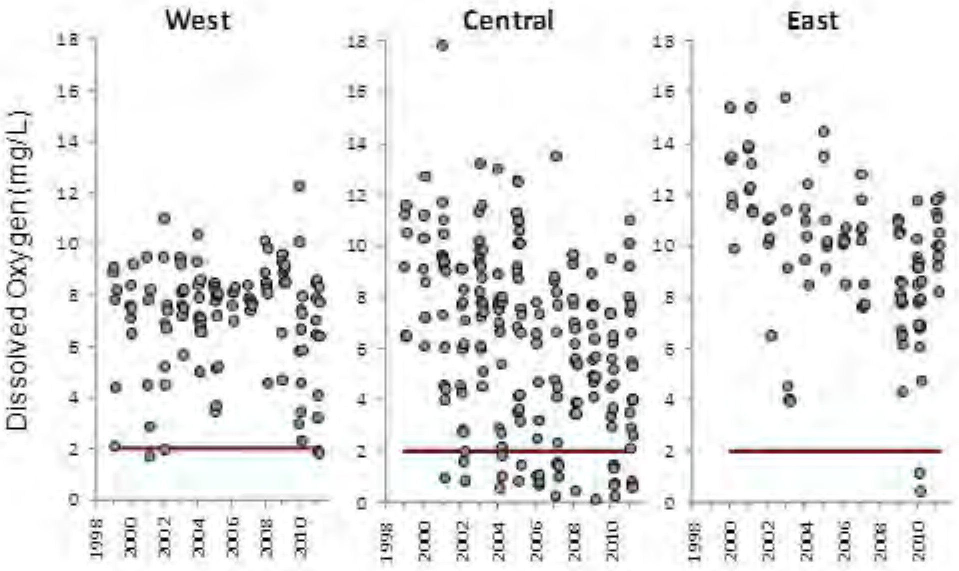

Figure 5.0.3. Summer (June-August) bottom dissolved oxygen (mg/L) concentrations for offshore sites by basin in Lake Erie, 1999-2011. The red horizontal line represents 2 mg/L, a level below which oxygen becomes limiting to the distribution of many temperate freshwater fishes. Data included in this analysis by basin and station: West - 3, 6; Central – 8, 10, 11, 13; East – 16, 18, 19, 25.

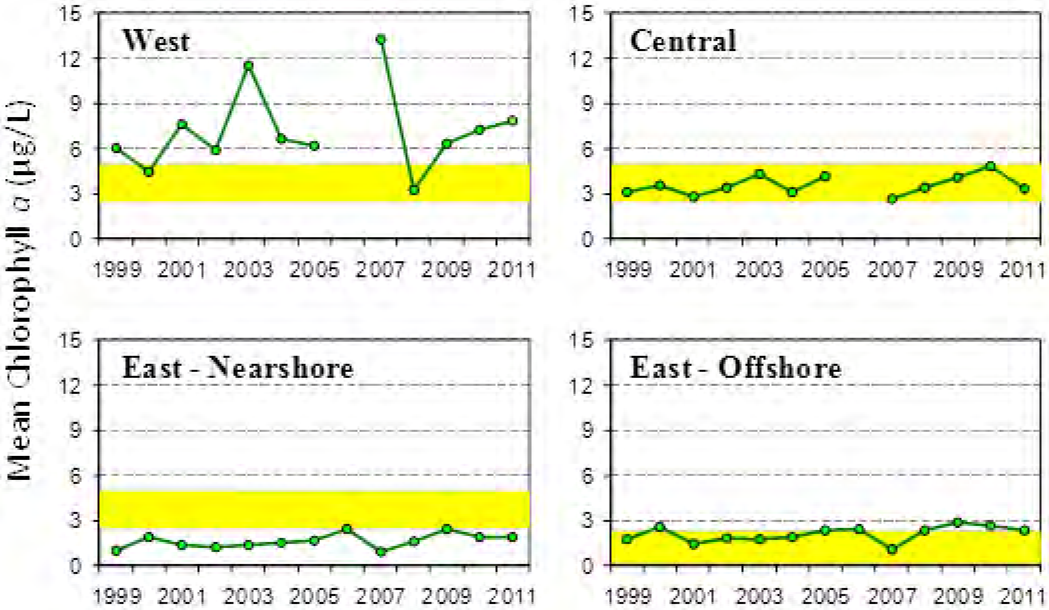

Figure 5.0.4. Mean chlorophyll *a* concentration (ug/L), weighted by month, by basin in Lake Erie, 1999-2011. The east basin is separated into nearshore and offshore. Yellow bars represent targeted trophic class range. For this analysis data from stations 3 through 20 and 25 were included.

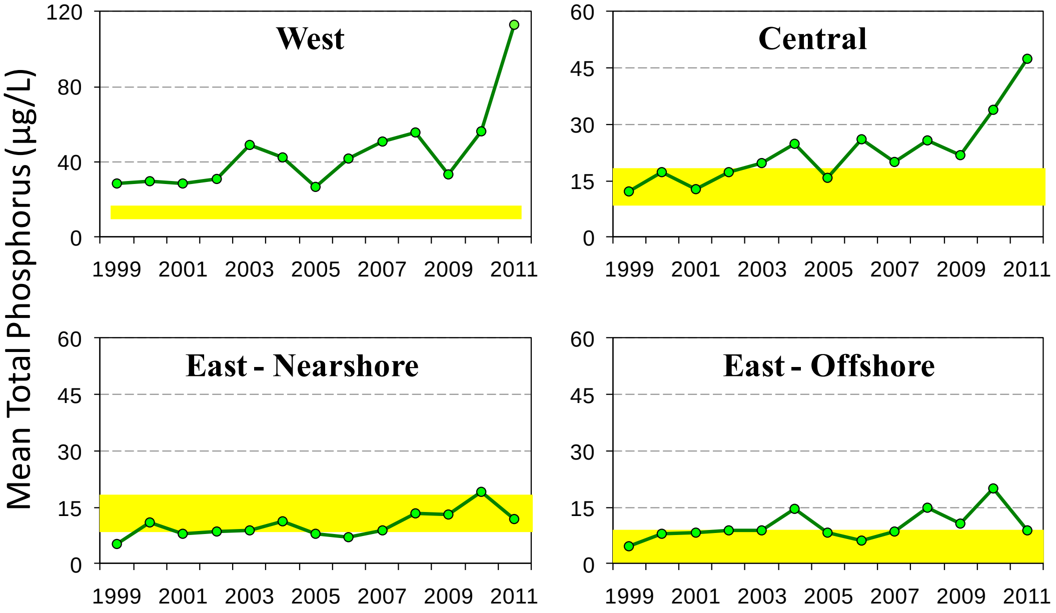

Figure 5.0.5. Mean total phosphorus (µg/L), weighted by month, for offshore sites by basin in Lake Erie, 1999-2011. The east basin is separated into nearshore and offshore. Yellow shaded areas represent the targeted trophic class range. For this analysis data from stations 3 through 20 and 25 were included.

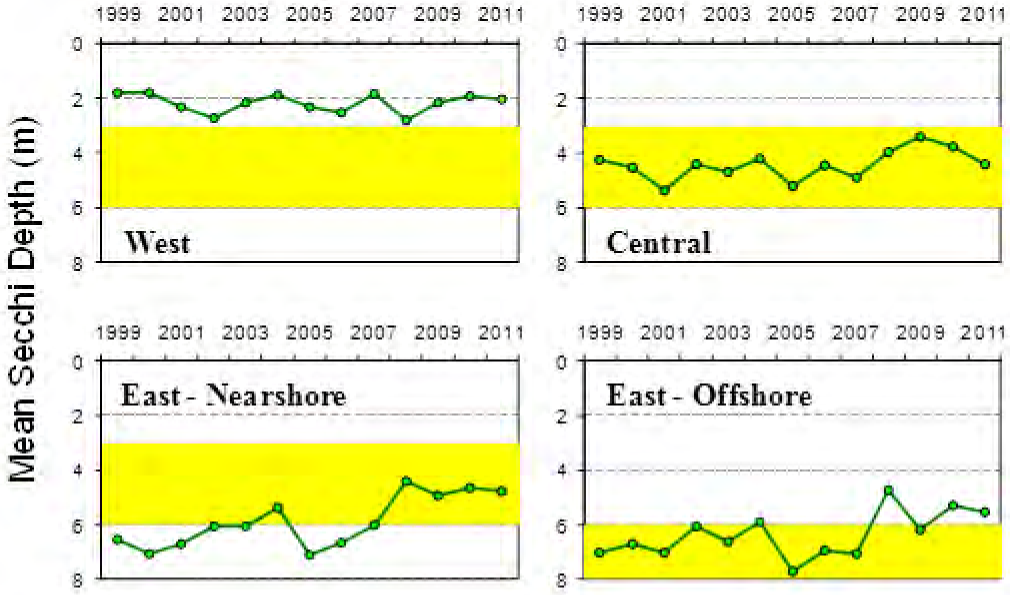

Figure 5.0.6. Mean summer (June-August) Secchi depth (m), weighted by month, by basin in Lake Erie, 1999-2011. The east basin is separated into inshore and offshore. Yellow shaded areas represent the targeted trophic class range. For this analysis data from stations 3 through 20 and 25 were included.

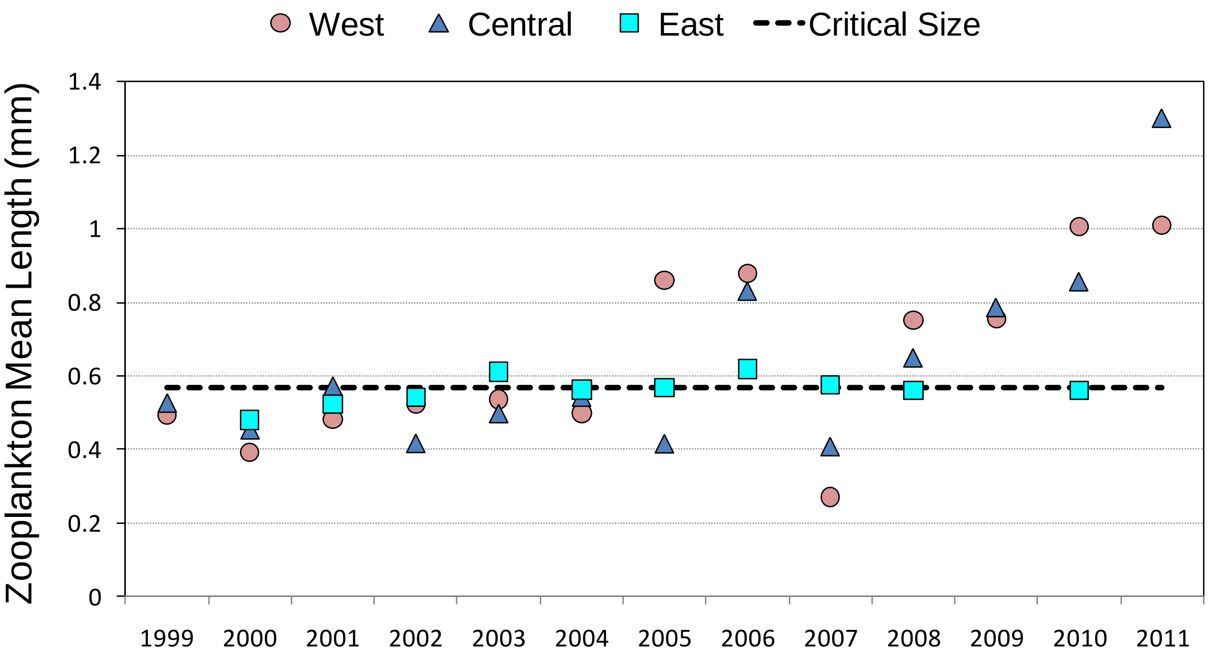

Figure 5.0.7. Mean length of the zooplankton community sampled with a 63 µm plankton net hauled through the epilimnion of each basin of Lake Erie, 1999-2011. The horizontal dashed line depicts 0.57 mm; if the mean size of the zooplankton community is 0.57 mm or less, predation by fish is considered to be intense (Mills *et al*. 1987, Johannsson *et al*. 1999). For this analysis data from stations 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 were included.

6.0 Lakewide Round Goby Distribution

Round goby (*Neogobius melanostomus*), were first discovered in the St. Clair River in 1990, and became established in the central basin of Lake Erie in 1994. In the past, the Forage Task Group has provided annual maps chronicling the spread of round goby throughout Lake Erie. Round goby have become established in all areas of Lake Erie. They are routinely caught in bottom trawl surveys and are common items in predator diet samples. Round goby are now treated as a regular forage species and abundance information is reported in section 2.0, *Status and Trends of Forage Species.* Please refer to previous Forage Task Group reports for information on the yearly spread and distribution of round goby in Lake Erie prior to 2006.

7.0 *Hemimysis anomala* (T. MacDougal and J. Markham)

Hemimysis anomala, commonly called the bloody-red shrimp, is a small shrimp-like mysid crustacean native to European waters, primarily the Black Sea, the Azov Sea, and the Caspian Sea. It was first detected in the Great Lakes in 2006, likely as a result of introduction via ballast water from oceangoing ships. Confirmed observations of *Hemimysis anomala* from disparate geographic locations in 2006 (near Muskegon, MI, along the northeast shoreline of Lake Erie and in Lake Ontario near Oswego, New York) suggest that HA was established and broadly distributed within the Great Lakes at this point. (NOAA- GLERL; *Hemimysis* fact sheet, February 2007).

Occurrence in Fish Diets

Hemimysis anomala have been observed in the diets of a limited number of Lake Erie fish species. First observed in white perch in 2006 in Long Point Bay, they had also been observed in the stomachs of rock bass and, less frequently, yellow perch in the western basin waters by 2009 (Figure 7.0.1). In 2010 they were found for the first time in white bass and walleye (the walleye also contained a rainbow smelt offering a secondary possible source). Because they are rarely observed other than in fish stomachs, documentation of *H. anomala* occurrence in fish diets has provided the most reliable method for tracking expansion of this invasive species in Lake Erie. Although there is no spatially comprehensive, lake-wide analysis of fish diets, at least three surveys allow for the consideration of the consumption of hemimysis by fish in all three basins (Figure 7.0.1). It should be noted that not all fish species are examined in all three surveys and that the number of individual fish examined varies between surveys and years. However, this data gives us a general picture of spatial difference and trend over time (within surveys).

Diet analysis from a gillnet index fishing program in Long Point Bay on the north shore of the eastern basin provides some idea of changes in species use since 2006. To date, the primary and most consistent consumer of *H. anomala* is white perch, which has proportionally increased from 3% in 2006 to 14% in 2009. In 2011, white perch continued to be the primary consumer of *H. anomala* in this survey, occurring in 6% of white perch examined (Figure 7.0.2). Rock bass are the second most consistent consumer, being found in 1-3% of examined individuals in 2007-2011 (but not in 2006 or 2010). *H. anomala* have not been observed in any yellow perch from Long Point Bay over the same time period, during which 2764 stomachs were examined.

Conversely, yellow perch were the first known consumers of *Hemimysis anomala* reported in the central basin (5 fish from ODNR surveys of Ohio waters). In 2010 one yellow perch from the western basin (USGS trawl surveys) was observed to have consumed *H. anomala*. *Hemimysis anomala* has also been found in the stomach of a white perch taken from east of Pelee Island in the western basin in 2009 (USGS surveys), and is the first observation from offshore waters. This suggests that the islands of the western basin likely also harbor this mysid. In 2011, hemimysis was observed in four yellow perch and one white perch in the western basin at locations including Michigan waters, the most western reports to date. Occurrences of *H. anomala* in white perch have been observed in all three basins, with proportions of fish consuming *H. anomala* increasing from west (0.40%) to central (0.99%) to east (5.86%). Occurrences of H. anomala in yellow perch are confined to the central and west where they have been found, respectively in 0.23% and 0.53% of the stomachs examined.

By way of comparison, *H. anomala* in Lake Ontario have been shown to be utilized by rock bass (August) and yellow perch (October) to some degree (33% and 2%; respectively) but are predominantly utilized by alewives (69%-100%) in August, September, and October (Lantry *et al.* 2010). No Lake Ontario white perch consumed *H. anomala*, although the number examined was small (n=4).

Occurrence in Other Surveys

Outside of fish diets, *H. anomala* can be difficult to locate because the species is nocturnal, preferring to hide in rocky cracks and crevices near the bottom along the shoreline during daylight. It sometimes exhibits swarming behavior, especially in late summer, forming small dense reddish-tinged clouds containing thousands of individuals concentrated in one location and visible just below the surface of the water in a shallow zone (NOAA- GLERL; Hemimysis fact sheet, February 2007). Their preference for rocky substrate is also apparent from catches in survey gill nets from Long Point Bay (Figure 7.0.3).

In 2007, one free-swimming individual was detected in waters associated with the NRG Energy Steam Station in Dunkirk, NY and underwater video of the lakebed near Hoover Point, Ontario revealed multiple swarms of what appear to be *H. anomala* in 7m depths associated with rocky areas. In November 2008, lake trout egg traps captured 58 individuals on Brocton Shoal, a historic lake trout spawning area just west of Dunkirk. These samples were collected at depths of 13.7-18.9 m. *Hemimysis anomala* were also collected in egg traps in this same area during 2009 but in lesser numbers. Targeted sampling for *H. anomala*, conducted by the Canadian Department of Fisheries and Oceans (DFO-GLLFAS), along the north shore during 2007 and 2008, regularly found *H. anomala* in large numbers in all three lake basins (K. Bowen, Dept. of Fisheries and Oceans, GLLFAS, pers. comm.). In 2010 these same traps were deployed in association with a subset of the Long Point Bay index gillnets in an attempt to better understand relationships between *H. anomala* abundance, substrate type, presence of fish and consumption by fish. Unfortunately, although *H. anomala* consuming fish were caught, few (n=2) free-swimming *Hemimysis anomala* were trapped. In April of 2011, a single individual *H. anomala* was caught in a zooplankton net in School House Bay, Middle Bass Island (Darren Bade, Kent State University, pers. comm.) (Figure 7.0.1).

The impact of this species on Lake Erie and the other Great Lakes is still unknown, but based on its history of invasion across Europe, significant impacts are possible. If integrated into the current lake ecosystem, this species has the potential to alter foodwebs by serving as both a food source and as a consumer of zooplankton resources. In its native waters, its main prey item is zooplankton, primarily cladocerans, rotifers, and ostracods. Laboratory studies using *Daphnia* have shown that HA consumes preferentially small and medium-size zooplankton (0.7-1.5 mm), although it can attack larger prey, and also consumes small amounts of algae (Pérez-Fuentetaja personal observation). This species has the ability to reduce zooplankton biomass where it is abundant. Due to its lipid content, *H. anomala* is considered a high-energy food source and has the potential to increase the growth of planktivores (Kipp and Ricciardi 2007).

The Forage Task Group will continue to monitor and document the progression of this species and consider its impact on the Lake Erie ecosystem.

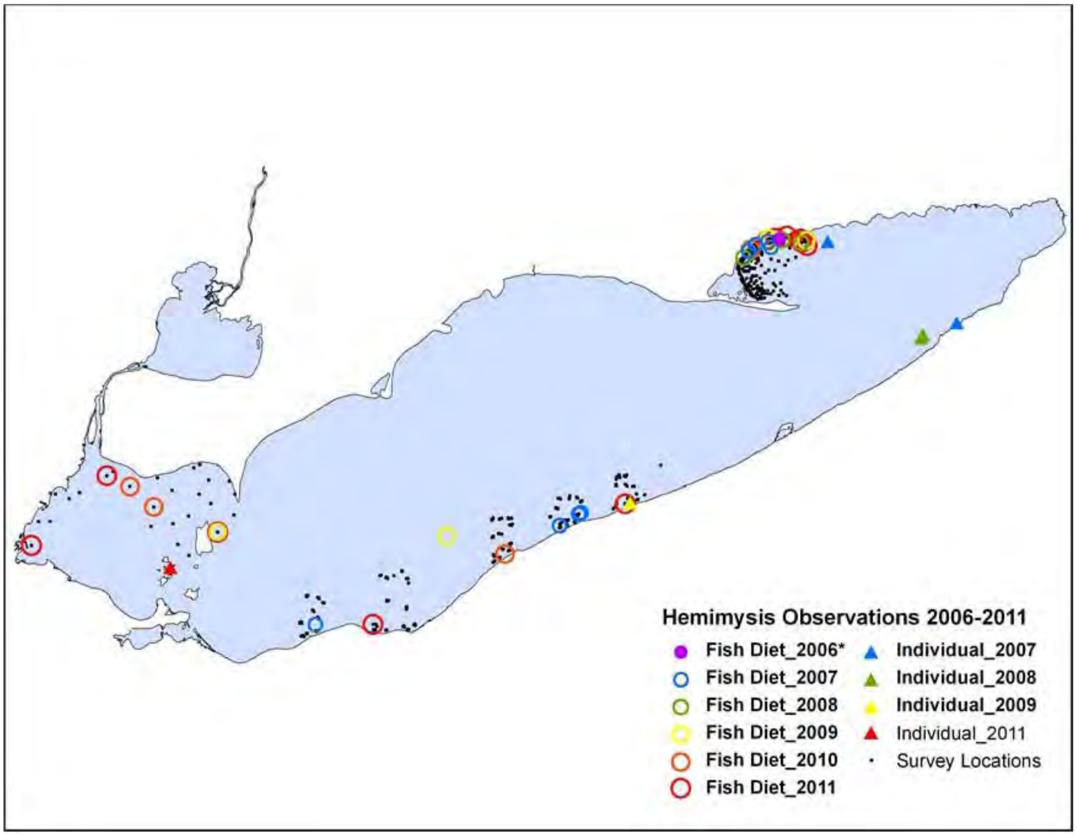

Figure 7.0.1. Distribution of *Hemimysis anomala* observations in Lake Erie, 2006-2011. Survey locations indicate where diet analysis occurs.

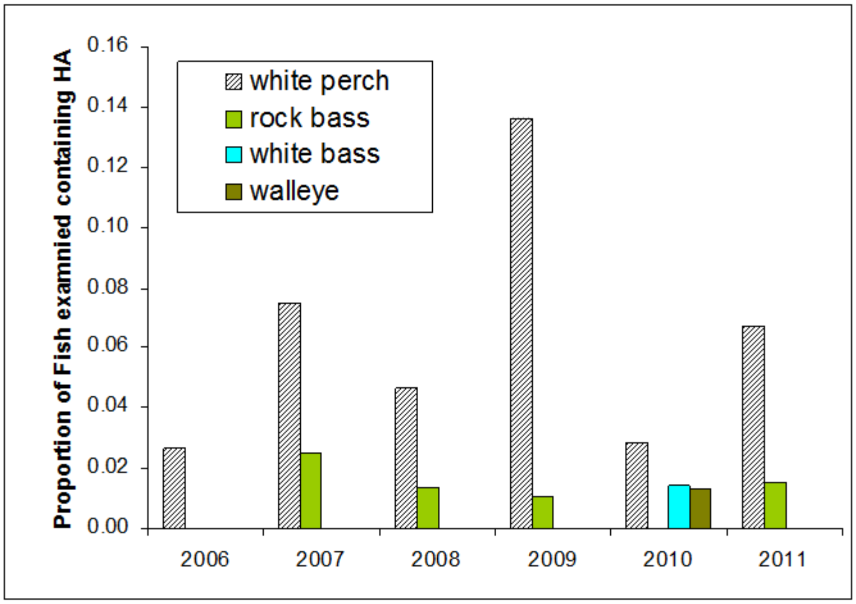

Figure 7.0.2 Occurrence of *Hemimysis anomala* in the diets of four fish species (proportion of fish stomachs examined) captured in by gillnet in Long Point Bay, Ontario,2006 – 2011.

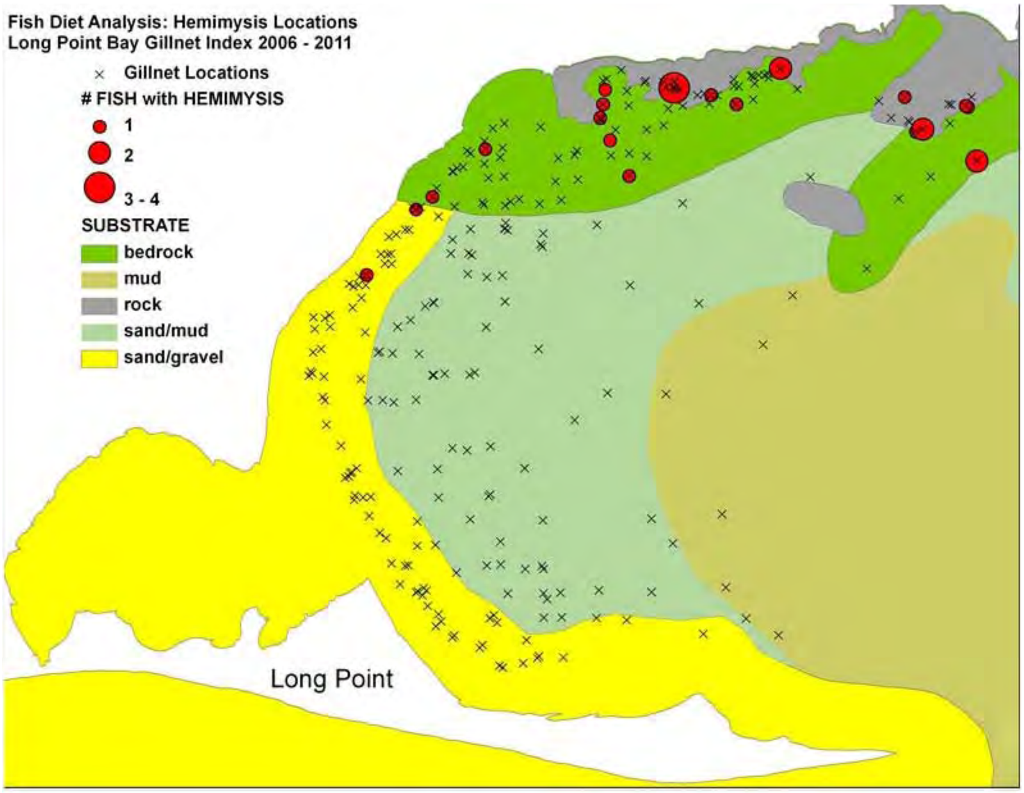

Figure 7.0.3. Distribution and occurrence of *Hemimysis anomala* observed in fish diets in a gillnet survey in Long Point Bay, Lake Erie, 2006 – 2011.

8.0 Protocol for Use of Forage Task Group Data and Reports

- The Forage Task Group (FTG) has standardized methods, equipment, and protocols as much as possible; however, data are not identical across agencies, management units, or basins. The data are based on surveys that have limitations due to gear, depth, time and weather constraints that vary from year to year. Any results, conclusions, or abundance information must be treated with respect to these limitations. Caution should be exercised by outside researchers not familiar with each agency‟s collection and analysis methods to avoid misinterpretation.

- The FTG strongly encourages outside researchers to contact and involve the FTG in the use of any specific data contained in this report. Coordination with the FTG can only enhance the final output or publication and benefit all parties involved.

- Any data intended for publication should be reviewed by the FTG and written permission obtained from the agency responsible for the data collection.

Acknowledgments

The Forage Task Group would like to thank Dr. Richard Kraus for contributions to section 2.4; Dr. Lars Rudstam (Cornell University), Dr. Dave Warner (USGS) and Don Einhouse for their continued support of hydroacoustic surveys, section 4.0; Justin Chaffin (University of Toledo) for contributions to *Microcystis* blooms in Lake Erie, section 5.0; and Nick Agins (Ohio State University) and Andy Cook (OMNR) for contributions to multiple sections of this report.

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