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# Increasing the Abundance of Large Bluegills in Lakes with Slow-growing Fish, Using Adult Flathead Catfish and Adult Walleyes.

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*Abstract*.—Three inland lakes with abundant, slow-growing Bluegill *Lepomis macrochirus* populations were stocked with adult Flathead Catfish *Pylodictis olivaris* and Walleyes *Sander vitreus*. All three lakes were located in Newago County, Michigan. These lakes contained few Bluegills larger than six inches and had a long history of management actions focused on increasing the abundance of larger fish for angling. All three lakes were stocked with Flathead Catfish and one with Walleyes ranging from 4.2 to 19.8 lbs/acre. Adult Walleyes were stocked into one of these lakes after five years because the survival of Flathead Catfish was uncertain. Increases in the number of Bluegills 6 inches or larger began within 2 to 5 years after introduction of predator fish and lasted for periods of at least 11 to 19 years. Fishery ranks improved from very poor to good or excellent, with all lakes containing 9-inch Bluegills and two lakes containing 10-inch Bluegills. Growth improved primarily for age-4 and older fish. The number of large Pumpkinseeds *Lepomis gibbosus* and Black Crappies *Pomoxis nigromaculatus* also increased in some lakes. The abundance of small panfish remained high, indicating that maintaining the density of predator fish through stocking will be required to maintain good panfish fisheries with this management procedure. Bullheads *Ameiurus* spp. appeared to be eliminated from one lake by stocking Flathead Catfish at a rate of 16.6 lbs/acre. Stocking adult Flathead Catfish and adult Walleyes could be considered for improving slow-growing panfish populations in lakes where habitat conditions or fish predation prevent survival of juvenile Walleyes.

## Introduction

Bluegills *Lepomis macrochirus* are widely distributed throughout Michigan and are one of the most pursued fish by anglers. Lakes with abundant, slow-growing populations of Bluegills are one of the most common and important management problems in southern Michigan (Scott et al. 1985), because they usually don't provide good fisheries. The minimum acceptable size of Bluegills for harvesting by anglers in Michigan is usually six inches. Slow-growing Bluegill populations contain few individuals larger than six inches.

Populations with slow-growing Bluegills are thought to be caused by two possible reasons (Schneider and Lockwood 1997; Aday et al. 2006). The first is that high recruitment and low mortality of juvenile Bluegills results in high population abundance; slow growth rates of fish occur as the result of competition for the available food supply. The second is that high rates of natural or fishing mortality decrease the abundance of large Bluegills to very low levels, and this decreases the natural mortality rate of small Bluegills caused by cannibalism by larger Bluegills. Among lakes, these influences on Bluegill size structure may be moderated by differences in environmental variables such as temperature, water transparency, and prey availability (Hoxmeier et al. 2009; Rypel 2015).

Since the 1960s, considerable research and management has been conducted to determine effective methods to shift the size structure of slow-growing Bluegill populations to larger fish (Schneider and Lockwood 1997). All of the management techniques originally used involved reducing the abundance of Bluegills to reduce competition for food, with the intention of improving growth rates. These methods included removing the entire fish population with rotenone followed by restocking, partially reducing the fish population with rotenone or antimycin (Antimycin−A, Fintrol concentrate), and partially reducing the panfish population by manual removal with seines or trap nets. With very few exceptions, these methods provided limited benefits, if any, for up to three years. Often these procedures were attempted repeatedly in the same lake.

Schneider and Breck (1997) investigated the potential for predation by Walleyes *Sander vitreus* or Yellow Perch *Perca flavescens* to improve slow-growing Bluegill populations in Michigan using prey consumption studies from 18 inland lakes and experimental ponds. They found that fingerling Walleyes (≥6.2 inches) and adult Yellow Perch (≥7.6 inches) consume age-0 Bluegills and can help increase Bluegill growth rates in lakes with sufficient predator biomass. Schneider (1997) evaluated Walleye predation on Bluegill and Yellow Perch in an experimental fish community in a small Michigan lake. He found that Walleyes reduced the abundance of the Yellow Perch and Bluegill populations, which resulted in higher growth rates and numbers of large fish for these two species.

Schneider and Lockwood (1997) conducted an eight-year study in Michigan lakes evaluating three techniques designed to shift the size structure of slow-growing Bluegill populations to larger fish. The following techniques were tested: (a) treatment with the selective fish toxicant antimycin to reduce the abundance of small Bluegills; (b) stocking large (>6 inches) fingerling Walleyes to reduce the abundance of small Bluegills through predation; and (c) catch-and-release regulations to protect predators and large Bluegills (thereby increasing predation on small Bluegills). They found that lakes treated only with antimycin had immediate, but slight, improvements in the size structure of the Bluegill population that lasted for two to six years, then reverted to slow-growth and smaller fish. For lakes treated with low-density Walleye stocking, Bluegill populations improved considerably by the fifth year and lasted through the sixth year (end of study). Lakes treated with Walleye stocking and antimycin showed a combination of the immediate and delayed responses of the single treatments. The combination antimycin and catch-and-release treatment showed the best response, with the Bluegill population containing many large fish, but slowing growth at the end of the study indicated the improvement in population size structure may decline again. The authors recommended stocking large fingerling Walleyes as a tool for improving stunted Bluegill lakes.

The Michigan fish-rearing system cannot currently produce sufficient numbers of large fingerling Walleyes to stock the many lakes that contain slow-growing Bluegills. Small (1-2 inch) fingerling Walleyes usually exhibit poor survival when stocked into Michigan lakes with abundant Bluegills. Low survival of small Walleye fingerlings is likely the result of predation by the larger Bluegills and competition with the smaller Bluegills. Schneider (1997) found that natural Walleye recruitment in a small Michigan lake began to fail when Bluegill biomass reached 45 lbs/acre. Also, Walleyes are not able to survive in many lakes because they are shallow and do not have suitable water quality conditions.

The Flathead Catfish *Pylodictis olivaris* is another species that may be used to improve Bluegill growth rates and size structure. Flathead Catfish are warmwater fish that are largely piscivorous (Turner and Summerfelt 1971; Minckley and Deacon 1959; Pine et al. 2005). Flathead Catfish from 10 to 16 inches are known to consume Bluegills over a wide range of sizes; a 27-inch Flathead Catfish could consume Bluegills up to about 9 inches (Hackney 1965; Swingle 1967; Slaughter & Jacobson 2008). Adult Flathead Catfish stocked into a 58-acre Minnesota lake had a profound effect on the fish population within a one-year period (Davis 1985). Carp *Cyprinus carpio* and bullheads *Ameiurus* spp. were the most abundant species in the lake and were reduced to 10% of their original population abundance within four years.

This study was conducted to determine if adult Flathead Catfish and adult Walleyes stocked into lakes with slow-growing Bluegills would increase the percentage of larger fish in the population. Three small inland lakes were selected to stock with adult Flathead Catfish. These lakes all had a long history of slow-growing Bluegill populations that contained few fish larger than 6 inches. Anglers rarely fished these lakes because larger fish were seldom caught. Predator fish stocking in these lakes began in 1990 and management level evaluations were conducted intermittently through 2014. Because of concerns with survival of Flathead Catfish in Baptist Lake, predator stocking in this lake shifted to adult Walleyes after five years.

## Methods

### *Study Area and Management History*

Sand, Brush, and Baptist lakes are located in the western portion of the Lower Peninsula of Michigan (Figure 1). All three lakes are located within the Lake Michigan watershed in Newaygo County.

### Sand Lake

Sand Lake (Latitude 43.32665N Longitude -85.90954W) has a surface area of 58 acres and is located in the southwest corner of Newaygo County within the Muskegon River watershed. The lake has no inlet or outlet. A township park on the north side of the lake provides limited public access for launching small boats.

Sand Lake has a maximum depth of 15 feet. All water depths greater than 10 feet deep are found in the western portion of the lake. Bottom materials consist primarily of sand overlain with organic detritus at depths greater than six feet.

Limnological measurements collected in 1949, 1999, 2000, and 2004 indicated that Sand Lake had moderate alkalinity, did not establish a summer thermocline, and had adequate dissolved oxygen for warmwater fish, including Flathead Catfish, from surface to bottom. Nitrogen and phosphorous concentrations measured in 1999 and 2004 indicated the lake had borderline mesotrophic to eutrophic conditions and phosphorous was the limiting nutrient for plant growth. Chlorophyll *a* concentrations in 2004 indicated the lake had borderline oligotrophic to mesotrophic conditions.

The entire lake consists of littoral zone with submerged aquatic vegetation growing over 100% of the lake. Abundant aquatic vegetation was present in the lake since the earliest fisheries survey in 1926. In 1997, aquatic vegetation growing in the middle portion of the lake was predominantly one species of native pondweed *Potamogeton sp.* at moderate densities. Some areas of the lake had more dense vegetation. Eurasian watermilfoil *Myriophyllum spicatum* was found in several portions of the lake. Aggressive plant removal programs using chemicals had been ongoing since about 1960, especially within the five-foot depth contour. Eurasian watermilfoil had been targeted for control since about 1978.

The shoreline of the lake is heavily developed with very little native shoreline vegetation present. Dwelling densities in 2004 were 62/mile and above the 75th percentile for southern Michigan lakes (Wehrly et al. 2015). Visible submerged wood was absent from the lake and shoreline armoring was low at 7%.

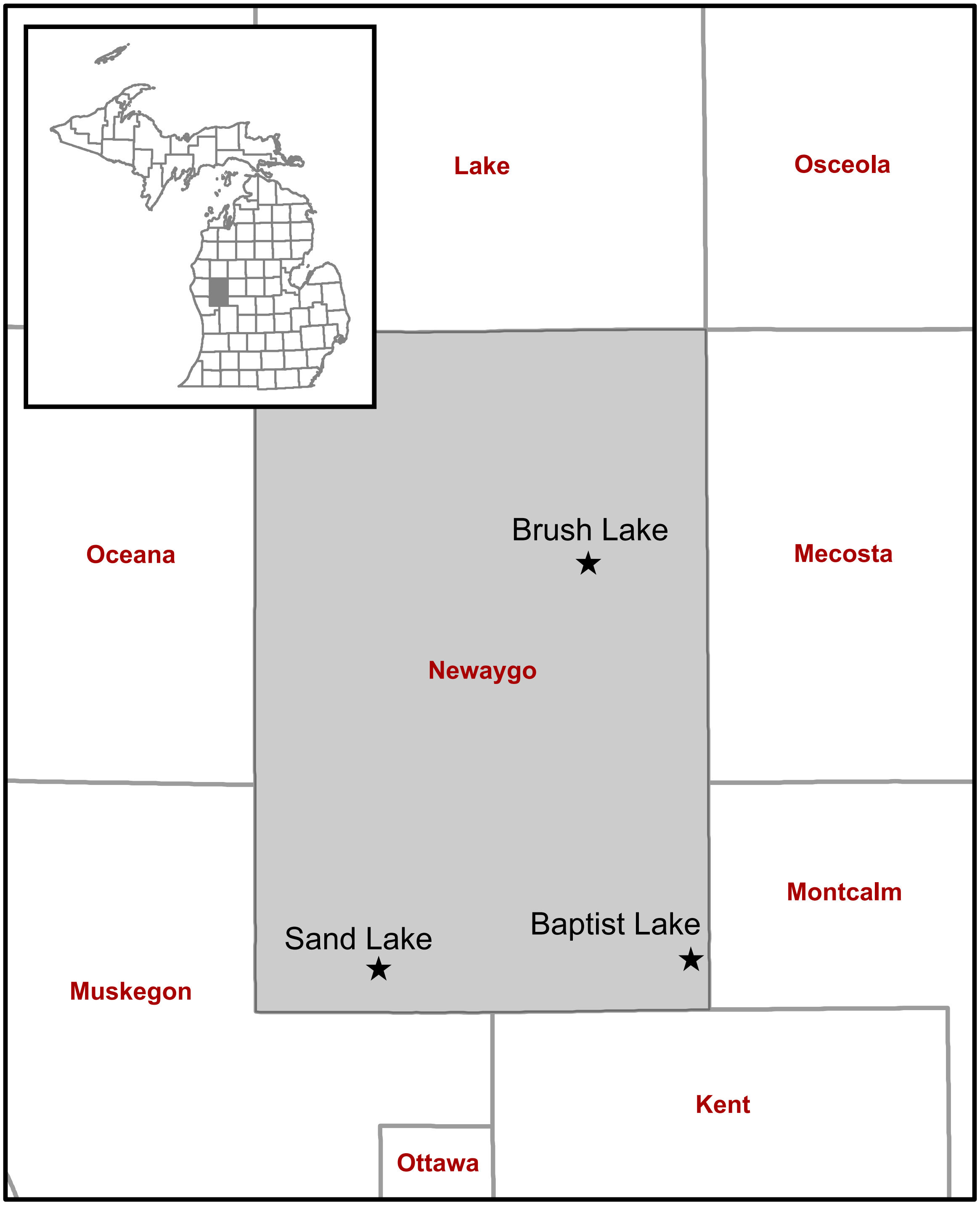


Figure 1.–The locations of Brush, Sand, and Baptist lakes in Newaygo County, Michigan.

Sand lake has a long history of fishery management activities that were directed at increasing the number of large Bluegills and other panfish by reducing panfish abundance. The first fishery survey in 1926 found that large numbers of small Bluegills were present in the lake. In 1949, a rotenone treatment was conducted to remove small Bluegills from the lake, and in 1957, a manual removal by seining was completed for the same purpose. Multiple surveys between 1950 and 1975 found small Bluegills remained abundant in the lake. In 1977, antimycin was applied to the lake to reduce Bluegill abundance, and in 1985 and 1986, manual removals of Bluegills with seines and trap nets were conducted. All of the attempts to reduce the abundance of small Bluegills in Sand Lake with chemical treatments or manual removals failed to improve the size structure of the population for more than a couple of years.

Management of this lake changed to stocking predator fish in 1990 when 65 adult Flathead Catfish with an average weight of 10.9 lbs were introduced (Table 1). In 1992, 23 of these fish (average weight of 11.2 lbs) were removed from the lake due to concerns related to low catch rates of panfish in 1991 and 1992. It was later learned that the 1991 eruption of Mt. Pinatubo in the Philippines caused widespread cooling in the Northern Hemisphere that affected growth and recruitment of several fish species (Schneider and Lockwood 1997; King et al. 1999; Schupp 2002). Based on panfish catch rates collected from 1993 through 1995, the decision was made to stock 25 additional Flathead Catfish in 1995 with an average weight of 10.1 lbs. The length of Flathead Catfish stocked into Sand Lake averaged 27.1 inches (range = 18–41 inches inches). The final weight of Flathead Catfish stocked in 1995 was 961 lbs (16.6 lbs/acre). In 1991, fishing regulations were implemented that prohibited the harvest of all catfish species from Sand Lake. The abundance (± 95% confidence limits) of Flathead Catfish was estimated using trap nets in 1993, 1995, and 1996 using the Chapman modification of the Peterson mark-recapture method (Ricker 1975).

Table 1.–Fish stocked into Sand, Brush, and Baptist lakes 1988–2013. Negative values in parentheses indicate fish that were removed from the lake.

| Year | Species | Life stage | Number stocked | Pounds stocked | Average weight (lbs) |
|---|---|---|---|---|---|
| Sand Lake | | | | | |
| 1990 | Flathead Catfish | Adult | 65 | 708.4 (12.2/acre) | 10.9 |
| 1992 | Flathead Catfish | Adult | (-23) | 257.4 (4.4/acre) | 11.2 |
| 1995 | Flathead Catfish | Adult | 25 | 252.6 (4.4/acre) | 10.1 |
| Brush Lake | | | | | |
| 1995 | Flathead Catfish | Adult | 7 | 105.8 (5.5/acre) | 15.1 |
| Baptist Lake | | | | | |
| 1988 | Walleye | Fingerling | 935 | | |
| 1992 | Walleye | Fingerling | 42,318 | | |
| 1992 | Flathead Catfish | Adult | 23 | 272.4 (3.2/acre) | 11.8 |
| 1993 | Walleye | Fingerling | 9,844 | | |
| 1994 | Walleye | Fingerling | 9,414 | | |
| 1995 | Flathead Catfish | Adult | 24 | 241.6 (2.8/acre) | 10.1 |
| 1996 | Walleye | Fingerling | 8,552 | | |
| 1996 | Flathead Catfish | Adult | (-14) | 154.0 (1.8/acre) | 11.0 |
| 1997 | Walleye | Adult | 419 | 1,054.6 (12.4/acre) | 2.5 |
| 1999 | Walleye | Adult | 88 | 286.0 (3.3/acre) | 3.3 |
| 2002 | Walleye | Adult | 100 | 341.0 (4.0/acre) | 3.4 |
| 2003 | Walleye | Fingerling | 4,444 | | |
| 2005 | Walleye | Fingerling | 8,816 | | |
| 2009 | Walleye | Fingerling | 8,600 | | |
| 2011 | Walleye | Fingerling | 7,124 | | |
| 2013 | Walleye | Fingerling | 10,565 | | |

## *Brush Lake*

Brush Lake (Latitude 43.63749W Longitude -85.68787N) is located in the central portion of Newaygo County within the White River watershed. The lake has a surface area of 19 acres and has a maximum depth of 35 feet. The U.S. Forest Service owns all of the property on the lake and maintains a small campground and boat launch on the north side of the lake that provides public access for boat and shore fishing.

In the habitat survey conducted in 2007, the lake had no dwellings and no hardened shoreline. The number of visible submerged trees (≥3 inch diameter) in 2007 was 70/mile, which was well above 75th percentile for lakes in the Lower Peninsula of Michigan (Wehrly et al. 2015). The entire shoreline of the lake had a good buffer of emergent vegetation and trees except for the small areas occupied by the boat launch and campground.

Nearly the entire lake has sand substrates overlain by organic detritus. The littoral zone of the lake has gently sloping flats from the shoreline into deep water. The littoral zone has moderate growth of submersed aquatic plants with scattered beds of floating-leaved and emergent plants around the entire perimeter of the lake. Eurasian watermilfoil was not present in the lake in 2003.

A survey in 2003 found that a summer thermocline established below 10 feet in Brush Lake and dissolved oxygen was suitable for warmwater fish, including Flathead Catfish, above (≥6.8 mg/l) the thermocline, but not below (≤1 mg/l). Surveys in 2003 and 2007 found the lake had low alkalinity (34−40 mg/l). Total phosphorous and chlorophyll *a* concentrations indicate mesotrophic to oligotrophic productivity conditions in the lake. The nitrogen-phosphorous ratio indicated plant productivity was limited by phosphorous.

A survey of Brush Lake in 1971 found a large number of small Bluegills with only 13% six inches or larger in length. Other species collected in that survey included Pumpkinseed *Lepomis gibbosus*, Black Crappie *Pomoxis nigromaculatus*, bullhead *Ameiurus* spp., and Largemouth Bass *Micropterus salmoides*. The lake was treated with rotenone in 1974 to reduce the number of Bluegills present in the lake and increase the number of large Bluegills. The size structure of the Bluegill population improved through at least 1977 (62% ≥ 6 inches), with some Bluegills reaching 8 inches. A survey conducted in 1994 again indicated abundant small Bluegills in the lake with only 7% six inches or larger in length.

Management of this lake changed to stocking predator fish in 1995 when seven adult Flathead Catfish were stocked into the lake (Table 1). The average length of the stocked fish was 25.4 inches (range = 20–37 inches), with an average weight of 15.1 lbs and a total weight of 105.8 lbs (5.5 lbs/acre). In 1996, fishing regulations were implemented that prohibited the harvest of all catfish species in Brush Lake.

## *Baptist Lake*

Baptist Lake (Latitude 43.33332W Longitude -85.5812N) is located in the southeast corner of Newaygo County within the Muskegon River watershed. The lake has a surface area of 85 acres and has a maximum depth of 65 feet. A county park on the north side of the lake provides public access for boat and shore fishing.

In 2007, the shoreline of the lake had 60 dwellings per mile, which is above the 75th percentile for lakes in the Lower Peninsula of Michigan (Wehrly et al. 2015). The number of visible submerged trees (≥3 inch diameter) in 2007 was 9/mile, which is low but within the 25th and 75th percentiles for lakes in the Lower Peninsula of Michigan (Wehrly et al. 2015). Due to the heavy shoreline development, only a few areas of aquatic and terrestrial vegetative buffers occur along the shoreline. Shoreline armoring was 21% and within the 25th and 75th percentiles for lakes in the Lower Peninsula of Michigan.

The shallow areas of the lake have exposed sand sediments and the deeper areas contain overlying organic sediments. There is one small, shallow bay with primarily organic sediments. The littoral zone of the lake has gently sloping flats followed by sharp drops into deep water. The littoral zone has heavy growth of submersed aquatic plants and a few areas with floating-leaved and emergent plants. Eurasian watermilfoil is present in the lake and chemical treatments for this plant and native plants have occurred since at least 2003.

Seven surveys conducted between 1957 and 2007 found that summer thermoclines develop between 14 and 40 feet, and dissolved oxygen was sufficient for warmwater and coolwater fish, including Flathead Catfish and Walleye, to a depth of at least 25 feet. Surveys in 2003 and 2007 indicated the lake had moderate alkalinity and the nitrogen-phosphorus ratio indicated phosphorous was the limiting nutrient for plant growth. Chlorophyll *a* concentrations, total phosphorous concentrations, and Secchi disk values indicated the condition of the lake was mesotrophic, bordering on oligotrophic.

Surveys in 1957 and 1958 found few Bluegills (<1%) in Baptist Lake 6 inches or larger in length. Other panfish were also small and very few anglers fished the lake. During October 1958, a rotenone treatment was conducted to reduce the number of panfish in the lake. Spring fingerling Rainbow Trout *Oncorhynchus mykiss* were stocked into the lake later in the fall to provide an interim fishery while the fish community recovered. A spring survey in 1959 indicated Black Crappies, Rock Bass *Ambloplites rupestris* and Grass Pickerel *Esox americanus vermiculatus* were absent or at very low abundance in the lake. Species captured in moderate abundance were Bluegill, Pumpkinseed, Northern Pike *Esox lucius*, Green Sunfish *Lepomis cyanellus*, and White Sucker *Catostomus commersonii*. The lake was stocked with adult Bluegills, Largemouth Bass, and Northern Pike in 1959. A survey in June 1960 found large numbers of small Bluegills present, and additional surveys conducted through 1967 had similar findings. Rainbow Trout stocking continued through 1964 and provided a fishery through at least 1961. In 1985 and 1988, Baptist Lake was treated with antimycin along the shoreline and this produced light to moderate mortalities of Bluegills, Pumpkinseeds, and Yellow Perch. Rainbow Trout were stocked from 1989 through 1991, as part of the antimycin treatment program, but a fishery never developed.

Management of Baptist Lake changed to stocking predator fish in 1988 when small fingerling Walleyes were first stocked (Table 1). A total of 47 Flathead Catfish were stocked in 1992 and 1995, with an average length of 29.2 inches (range = 20–38 inches) and an average weight of 11.8 lbs in 1992 and 10.1 lbs in 1995. In 1996, 14 Flathead Catfish (average weight: 11.0 lbs) were removed from the lake because low catches indicated survival was low, and the potential for acquiring more Flathead Catfish was limited. Predator stocking shifted to adult Walleyes in 1997 because small fingerling Walleyes were not surviving and adult fish were available from a nearby river. A total of 607 adult Walleyes were stocked from 1997 through 2002, with an average length of 20.4 inches (range = 15–24 inches) and a total weight of 1,682 lbs (19.8 lbs/acre). In 1996, fishing regulations were implemented that prohibited the harvest of Walleyes and all catfish species in Baptist Lake.

## *Sampling Procedures*

Sampling procedures were similar to a Michigan study designed to evaluate manipulation of overpopulated Bluegill lakes with various methods (Schneider and Lockwood 1997). However, this was a management level study conducted over a 24-year period (1990–2014), and the frequency of sampling and analyses were different. Annual spring sampling (mid-May to early June) was conducted as often as possible but not at regular intervals (Table 2). Sampling in some years may not have occurred during the peak spawning period when nearshore fish movements are the greatest.

Fish were sampled with trap nets, gill nets, and electrofishing gear. Trap nets were used during the spring spawning season to collect fish samples. Trap nets were 3 feet high with hearts of 2.5-inch stretched mesh and pots of 1.5-inch stretched mesh. These nets were effective for measuring abundance of Bluegills and other panfish five inches and larger in length. Trap-net catch per unit of effort was measured as catch per one net lift (overnight set). Juvenile panfish were sampled in shallow water near shore, using a boat equipped with 240-volt DC electrofishing equipment, with front mounted probes and two individuals netting fish. Electrofishing was initially conducted during daylight periods but was changed to after dusk periods in later evaluations for field coordination purposes. Electrofishing catch per unit of effort was measured as fish catch per hour of sampling. Variable-mesh gill nets were used to collect samples of other fish species during some years. Gill nets were used more frequently in Baptist

Table 2.–Trap-net (TN), gill-net (GN), and electrofishing effort expended on Sand, Brush, and Baptist lakes. Water temperatures were collected just below the surface of the water.

| Trap and gill nets | | | | Electrofishing | | | |
|---|---|---|---|---|---|---|---|
| Start date of sample | TN lifts | GN lifts | Water temperature (°F) | Date of sample | Hours sampled | % shoreline sampled | Time of day |
| Sand Lake | | | | | | | |
| 06/12/1984 | 5 | – | 70 | – | – | – | – |
| 05/22/1986 | 8 | – | 61 | – | – | – | – |
| 05/27/1987 | 4 | – | 69 | – | – | – | – |
| 05/20/1988 | 5 | – | 67 | – | – | – | – |
| 05/21/1991 | 8 | – | 67 | 05/29/1991 | 0.44 | 60 | Day |
| 05/20/1992 | 8 | – | 68 | 06/01/1992 | 0.46 | 75 | Day |
| 05/19/1993 | 6 | – | 63 | 05/28/1993 | 0.37 | 50 | Day |
| 05/19/1994 | 8 | – | 62 | 05/19/1994 | 0.39 | 50 | Day |
| 05/16/1995 | 30 | – | 72 | 05/18/1995 | 0.75 | 100 | Day |
| 05/20/1996 | 16 | – | 68 | – | – | – | – |
| 06/10/1997 | 3 | – | 72 | – | – | – | – |
| 07/08/2002 | 8 | – | 82 | 07/17/2002 | 0.95 | 100 | Night |
| 05/15/2007 | 9 | 3 | – | 05/25/2007 | 0.40 | 75 | Night |
| 05/28/2014 | 9 | 3 | – | 06/10/2014 | 0.60 | 75 | Night |
| Brush Lake | | | | | | | |
| 06/04/1994 | 2 | – | – | – | – | – | – |
| 06/22/1999 | 6 | – | 74 | 09/13/1999 | 0.80 | 100 | Day |
| 06/25/2001 | 8 | 2 | 78 | 06/28/2001 | 1.00 | 100 | Night |
| 06/18/2003 | 9 | – | 72 | 06/05/2003 | 0.96 | 100 | Night |
| 05/14/2007 | 9 | 3 | – | 05/24/2007 | 0.62 | 100 | Night |
| 05/27/2014 | 9 | 3 | 72 | 06/09/2014 | 0.84 | 100 | Night |
| Baptist Lake | | | | | | | |
| 06/07/1985 | 4 | 3 | 72 | – | – | – | – |
| 05/19/1987 | 4 | – | 65 | – | – | – | – |
| 06/02/1989 | 2 | 2 | 72 | – | – | – | – |
| 05/18/1994 | 4 | – | 73 | 06/16/1994 | 0.83 | 100 | Day |
| 05/29/1996 | 8 | 2 | 62 | – | – | – | – |
| 05/13/1998 | 12 | – | 66 | – | – | – | – |
| 05/19/1999 | 6 | 2 | 65 | 05/24/1999 | 0.96 | 100 | Night |
| 05/08/2001 | 8 | – | 75 | 05/14/2001 | 2.00 | 100 | Day |
| 06/23/2003 | 6 | 4 | 72 | 07/09/2003 | 0.67 | <100 | Night |
| 06/04/2007 | 9 | 6 | 72 | 06/26/2007 | 0.54 | <100 | Night |
| 06/03/2013 | 9 | 6 | 67 | 06/19/2013 | 0.53 | <100 | Night |

Lake because they were more effective for sampling the fish community in the deeper waters found in this lake.

Fish for ageing were measured for total length to the nearest 0.1 inch, and all fish were categorized within inch groups (e.g., the 1-inch group = 1.0–1.9 inches). Scale samples for ageing were taken from 15 fish per inch group. A minimum of five fish were used to determine average length at age. Average length at age data were compared to state averages (Schneider at al. 2000) to help determine changes in growth rates.

Schneider (1990) described a method for classifying Bluegill populations from lake survey data in Michigan. This procedure uses average length, and percentages of fish larger than 6, 7, and 8 inches to evaluate Bluegill populations and assign a fishery rank. There are seven fishery rank categories: very poor, poor, acceptable, satisfactory, good, excellent, and superior. These classifications were used to evaluate Bluegill population size structure from trap-net samples in the study lakes. Although the classification system was designed for Bluegill, it provides useful information for ranking Pumpkinseed and Black Crappie in some lakes. The total catch of various panfish smaller than 6 inches long in electrofishing samples was used as an indicator of changes in recruitment.

# Results

## *Sand Lake*

Flathead Catfish were collected in all surveys after their introduction in 1990 (Table 3). Catch per unit effort in trap nets varied over the sample period and was highest in 1997. After stocking 65 in 1990 and removing 23 in 1992, the abundance of Flathead Catfish in Sand Lake was estimated at 36 ± 16 (mean ± SD) in 1993 and 18 ± 8 in 1995. Because of this low number, 25 more were stocked in 1995; the abundance was estimated as 51 ± 37 in 1996. Six individual Flathead Catfish were captured in 2014

Table 3.–Trap-net catch per unit effort for Sand Lake. A “P” indicates presence of the species in the 2007 gill-net catch but not in trap nets. Both Black Bullheads and Brown Bullheads were captured.

| Year | Bluegill | Pumpkinseed | Black Crappie | Largemouth Bass | Bullheads | Northern Pike | Yellow Perch | Flathead Catfish |
|---|---|---|---|---|---|---|---|---|
| 1984 | 43.8 | 14.2 | 11.6 | 2.2 | 18.0 | 0.0 | 0.0 | 0.0 |
| 1986 | 44.8 | 37.8 | 9.3 | 1.1 | 5.8 | 0.6 | 0.0 | 0.0 |
| 1987 | 377.0 | 55.8 | 5.5 | 1.5 | 249.5 | 0.8 | 0.8 | 0.0 |
| 1988 | 254.0 | 54.4 | 21.2 | 1.8 | 35.6 | 0.8 | 0.2 | 0.0 |
| 1991 | 21.1 | 18.6 | 9.5 | 5.9 | 2.6 | 0.4 | 0.6 | 1.4 |
| 1992 | 25.4 | 31.1 | 5.4 | 3.4 | 0.1 | 0.5 | 0.0 | 2.8 |
| 1993 | 17.0 | 23.0 | 15.3 | 3.7 | 0.3 | 3.7 | 1.3 | 4.5 |
| 1994 | 12.1 | 17.6 | 6.9 | 6.3 | 0.0 | 0.3 | 0.1 | 0.5 |
| 1995 | 29.1 | 27.7 | 1.9 | 4.0 | 0.0 | 0.1 | 1.0 | 0.7 |
| 1996 | 21.2 | 14.1 | 0.9 | 1.1 | 0.0 | 0.1 | 0.1 | 1.8 |
| 1997 | 77.0 | 8.3 | 0.0 | 1.7 | 0.0 | 0.0 | 0.3 | 9.3 |
| 2002 | 35.1 | 7.2 | 1.7 | 3.0 | 0.0 | 0.0 | 0.0 | 5.2 |
| 2007 | 5.0 | 0.6 | 1.4 | 3.3 | 0.0 | P | P | 1.3 |
| 2014 | 20.3 | 0.4 | 3.8 | 18.4 | 0.0 | 0.3 | 0.3 | 1.1 |

that were from the 67 that were stocked in 1990 and 1995. Juvenile Flathead Catfish were not collected in any survey, indicating natural reproduction did not occur.

Bluegill, Pumpkinseed, and Black Crappie catch per unit effort in 1984 and 1986 was moderate and may have been affected by recent manual removals of panfish (Table 3). Peak catches of these species occurred in 1987–1988, then decreased substantially following the introduction of Flathead Catfish (1990–1995), and remained low throughout the study period.

The Bluegill fishery in Sand Lake was rated very poor to poor from 1984 through 1993 (Table 4). Some 6- and 7-inch Bluegills were found in collections during 1984 and 1986 that may have been related to panfish removal programs during that time period. The percentage of 6-inch and larger Bluegills in the population increased substantially in 1992 following the introduction of Flathead Catfish in 1990. Bluegills 8 inches or larger were first collected in 1993. The fishery was first rated acceptable in 1994 as the number of Bluegills 7 inches or larger increased. Bluegill fishery ratings varied between very poor and acceptable from 1995 through 1997. The Bluegill fishery was rated satisfactory in 2002 and good in 2007 when a large portion of the catch was composed of fish 6 inches or larger and the number of fish 8 inches or larger increased substantially. In 2014, Bluegills 6 inches or larger accounted for 94% of the trap-net catch, and the first 10-inch fish (5%) were collected. The variability in Bluegill size structure and fishery rank between 1994 and 1997 may have been the result of removing 23 Flathead Catfish from the lake in 1992 and then stocking 25 Flathead Catfish in 1995. The average length of Bluegills also decreased during this period, but then increased again in 2002, and reached its highest level in 2014 (Figure 2). The catch rate of Bluegills smaller than 6 inches in electrofishing samples declined after

Table 4.–Sand Lake Bluegill information and fishery rank classifications determined from trap-net collections.

| Year | Number in sample | Minimum length | Maximum length | Average length | % ≥ 6 inches | % ≥ 7 inches | % ≥ 8 inches | Fishery rank |
|---|---|---|---|---|---|---|---|---|
| 1984 | 219 | 3.5 | 7.5 | 4.2 | 7.3 | 1.8 | 0.0 | Very poor |
| 1986 | 153 | 3.5 | 7.5 | 4.6 | 3.3 | 1.3 | 0.0 | Very poor |
| 1987 | 70 | 3.5 | 5.5 | 4.8 | 0.0 | 0.0 | 0.0 | Very poor |
| 1988 | 1,273 | 2.5 | 6.5 | 4.7 | 1.4 | 0.0 | 0.0 | Very poor |
| 1991 | 169 | 3.5 | 6.0 | 4.8 | 1.8 | 0.0 | 0.0 | Very poor |
| 1992 | 204 | 3.5 | 7.1 | 4.9 | 12.7 | 0.5 | 0.0 | Poor |
| 1993 | 101 | 3.5 | 9.0 | 5.1 | 23.8 | 4.0 | 1.0 | Poor |
| 1994 | 97 | 3.7 | 7.8 | 6.0 | 43.3 | 15.5 | 0.0 | Acceptable |
| 1995 | 884 | 2.5 | 7.5 | 5.4 | 28.2 | 5.9 | 0.0 | Poor |
| 1996 | 339 | 3.5 | 7.5 | 5.5 | 35.3 | 7.3 | 0.0 | Acceptable |
| 1997 | 231 | 3.5 | 7.5 | 4.6 | 4.7 | 0.1 | 0.0 | Very poor |
| 2002 | 281 | 3.5 | 8.5 | 5.9 | 39.1 | 10.7 | 1.0 | Satisfactory |
| 2007 | 45 | 4.5 | 8.3 | 6.9 | 84.4 | 55.5 | 8.9 | Good |
| 2014 | 183 | 4.5 | 10.5 | 7.6 | 94.0 | 78.1 | 24.5 | Excellent |

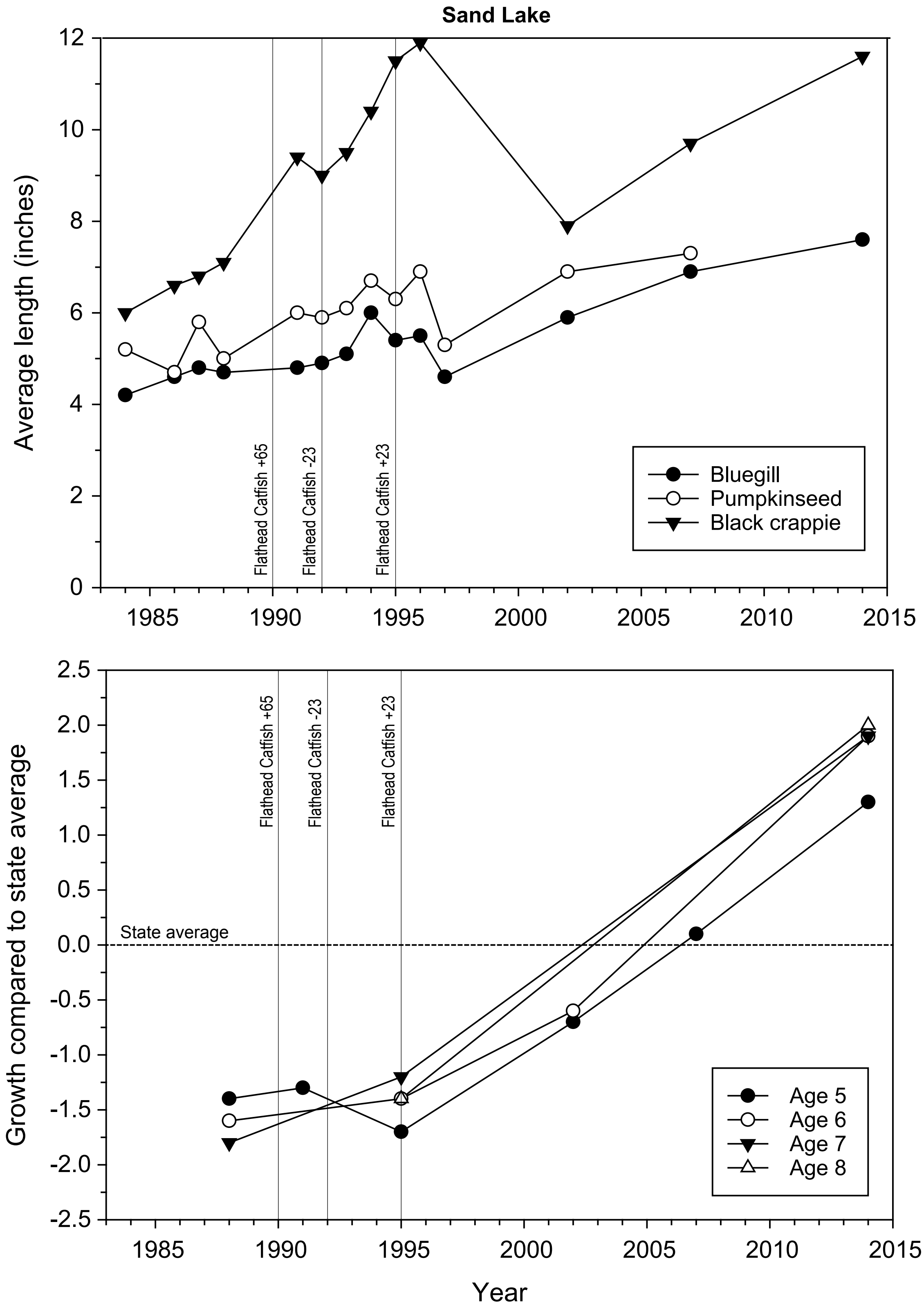


Figure 2.–Average lengths of Bluegills, Pumpkinseeds, and Black Crappies in Sand Lake trap-net samples, 1984–2014 (upper graph). Average deviation from the state average growth index for Bluegills at ages 5–8 (lower graph). Vertical lines indicate years that fish were stocked (+) or removed (-). Growth data were not available in all years.

Table 5.–Sand Lake electrofishing catch per hour and mean lengths for Largemouth Bass of all sizes, and for Bluegill, Pumpkinseed, and Yellow Perch smaller than 6 inches. In 1992, there were two bullheads (10.5 and 11.5 inches) captured and in 2002 there was one Black Crappie (9.5 inches) captured.

| | Bluegill < 6 inches | | Pumpkinseed < 6 inches | | Yellow Perch < 6 inches | | Largemouth Bass | |
|---|---|---|---|---|---|---|---|---|
| Year | Catch per hour | Average length | Catch per hour | Average length | Catch per hour | Average length | Catch per hour | Average length |
| 1991 | 507 | 3.8 | 175 | 2.8 | 0 | – | 2 | 20.0 |
| 1992 | 585 | 3.2 | 106 | 4.2 | 2 | 5.5 | 28 | 9.8 |
| 1993 | 549 | 3.0 | 103 | 3.7 | 0 | – | 46 | 10.8 |
| 1994 | 772 | 2.1 | 46 | 3.2 | 0 | – | 15 | 14.0 |
| 1995 | 253 | 2.7 | 112 | 3.0 | 0 | – | 8 | 13.5 |
| 2002 | 135 | 3.9 | 2 | 5.5 | 73 | 4.1 | 43 | 8.8 |
| 2007 | 285 | 1.9 | 12 | 4.3 | 2 | 3.5 | 247 | 9.1 |
| 2014 | 395 | 3.3 | 7 | 3.3 | 5 | 6.8 | 5.7 | 11.4 |

1994, but substantial numbers of small Bluegills were present in the population through 2014 (Table 5). Average lengths of Bluegills smaller than 6 inches displayed no consistent trends.

The fishery rank of Pumpkinseed increased from poor to acceptable one year after Flathead Catfish were introduced into Sand Lake in 1990 (Table 6). With the exception of 1997, the fishery rank then improved to satisfactory and good through 2002. The fishery rank was not determined for 2007 and 2014, because very few Pumpkinseeds were collected in trap nets. Pumpkinseeds 8 inches or larger first appeared in 1992 and by 1993 more than 50% of Pumpkinseeds collected were 6 inches or larger. Average lengths increased from 4.7–5.8 inches before introduction of Flathead Catfish to 6.9–7.8 inches in 2002–2014 (Table 6; Figure 2). Similar to Bluegill, Pumpkinseed average length and fishery rank dropped significantly in 1997. This may have resulted from the Flathead Catfish removal in 1992 or a sampling anomaly associated with spawning period movements that year. The catch rate of Pumpkinseeds smaller than 6 inches in electrofishing samples declined substantially after 1995 and trends in average lengths were not observed (Table 5). The abundance of small Pumpkinseeds was consistently lower than small Bluegills in electrofishing samples, indicating Bluegills were more abundant in Sand Lake.

The Black Crappie fishery rank was acceptable to excellent prior to introduction of Flathead Catfish in 1990, then increased to superior in all remaining years (Table 7). A large percentage of Black Crappies were 6 inches or larger prior to 1990, but the average length and percentages of fish 7 inches or larger and 8 inches or larger increased substantially after 1990 (Figure 2; Table 7).

Bullhead catch per unit effort was highest from 1984 through 1988 and this may have been partially the result of the antimycin treatment in 1977 and manual removals of panfish in the early to mid-1980s (Table 3). Similar increases in bullhead abundance had been observed in other Michigan lakes treated with antimycin. Bullhead trap-net catch rates decreased sharply after introduction of Flathead Catfish, and none were captured in any sampling gear after 1993.

Sampling to evaluate Largemouth Bass is usually conducted with electrofishing equipment in beds of aquatic vegetation, and gill nets are typically used for Northern Pike and Yellow Perch. The incidental catch of these species in trap nets may not be a good indicator of their abundance. However,

Table 6.–Sand Lake Pumpkinseed information and fishery rank classifications determined from trap-net collections.

| Year | Number in sample | Minimum length | Maximum length | Average length | % ≥ 6 inches | % ≥ 7 inches | % ≥ 8 inches | Fishery rank |
|---|---|---|---|---|---|---|---|---|
| 1984 | 71 | 3.5 | 6.5 | 5.2 | 7.0 | 0.0 | 0.0 | Poor |
| 1986 | 108 | 3.5 | 6.5 | 4.7 | 4.6 | 0.0 | 0.0 | Very poor |
| 1987 | 107 | 3.5 | 6.5 | 5.8 | 46.7 | 0.0 | 0.0 | Poor |
| 1988 | 272 | 2.5 | 7.5 | 5.0 | 20.2 | 1.8 | 0.0 | Poor |
| 1991 | 149 | 3.5 | 7.5 | 6.0 | 45.6 | 15.4 | 0.0 | Acceptable |
| 1992 | 249 | 3.5 | 9.5 | 5.9 | 47.4 | 21.6 | 4.0 | Satisfactory |
| 1993 | 138 | 4.5 | 7.5 | 6.1 | 58.0 | 15.2 | 0.0 | Satisfactory |
| 1994 | 141 | 4.5 | 8.5 | 6.7 | 73.7 | 51.8 | 5.7 | Good |
| 1995 | 829 | 3.5 | 8.8 | 6.3 | 60.5 | 30.3 | 5.5 | Satisfactory |
| 1996 | 225 | 3.5 | 9.5 | 6.9 | 77.8 | 53.3 | 15.1 | Good |
| 1997 | 25 | 3.5 | 7.5 | 5.3 | 20.0 | 16.0 | 0.0 | Poor |
| 2002 | 58 | 5.5 | 9.5 | 6.9 | 84.5 | 44.8 | 6.9 | Good |
| 2007 | 5 | 6.9 | 7.7 | 7.3 | 100 | 80.0 | 0.0 | – |
| 2014 | 4 | 7.5 | 8.5 | 7.8 | 100 | 100 | 25.0 | – |

Table 7.–Sand Lake Black Crappie information and fishery rank classification determined from trap-net collections.

| Year | Number in sample | Minimum length | Maximum length | Average length | % ≥ 6 inches | % ≥ 7 inches | % ≥ 8 inches | Fishery rank |
|---|---|---|---|---|---|---|---|---|
| 1984 | 61 | 5.5 | 11.5 | 6.0 | 24.6 | 4.9 | 4.9 | Acceptable |
| 1986 | 75 | 5.5 | 12.5 | 6.6 | 89.3 | 5.3 | 5.3 | Good |
| 1987 | 22 | 6.5 | 7.5 | 6.8 | 100 | 27.3 | 3 | Excellent |
| 1988 | 106 | 6.5 | 8.5 | 7.1 | 100 | 57.5 | 6.6 | Excellent |
| 1991 | 76 | 5.5 | 11.5 | 9.4 | 98.6 | 93.4 | 78.9 | Superior |
| 1992 | 43 | 5.5 | 12.5 | 9 | 90.7 | 88.4 | 72.1 | Superior |
| 1993 | 89 | 6.5 | 11.5 | 9.5 | 100 | 98.9 | 89.9 | Superior |
| 1994 | 55 | 8.5 | 13.5 | 10.4 | 100 | 100 | 100 | Superior |
| 1995 | 58 | 5.1 | 13.9 | 11.5 | 98.3 | 98.3 | 98.3 | Superior |
| 1996 | 14 | 7.5 | 13.5 | 11.9 | 100 | 100 | 100 | Superior |
| 1997 | 0 | – | – | – | – | – | – | – |
| 2002 | 14 | 6.5 | 8.5 | 7.9 | 100 | 92.9 | 46.1 | Superior |
| 2007 | 13 | 8.6 | 11.6 | 9.7 | 100 | 100 | 100 | Superior |
| 2014 | 34 | 8.5 | 14.5 | 11.6 | 100 | 100 | 100 | Superior |

all three species were collected in Sand Lake throughout the study period, and the highest catch rate for Largemouth Bass occurred in 2014 (Table 3).

Largemouth Bass average lengths in trap-net collections decreased in 2002 and 2007 and then increased again in 2014 (Appendix A). Largemouth Bass 15 inches or larger were collected during all years except 2002. The catch rate of Largemouth Bass in electrofishing samples displayed no trends, with the catch rate in 2007 far exceeding other years (Table 5). Average lengths of Largemouth Bass in electrofishing samples displayed no obvious trends.

Northern Pike were captured throughout the study period and trap-net catch rates were low (Table 3; Appendix A). Three were captured in the 2007 gill-net sample (21–33 inches), and 11 were captured in the 2014 gill-net sample (21−38 inches). Sample sizes were low, and there was no observable trend in Northern Pike average lengths in trap-net samples.

Yellow Perch were captured in trap nets, in low abundance, throughout the study period (Table 3), and one 7-inch fish was captured in the 2007 gill-net sample. Sample sizes were low, but there did not appear to be a consistent trend in Yellow Perch average lengths in trap-net samples (Appendix A). Yellow Perch smaller than 6 inches were found intermittently in electrofishing samples with the highest catch rate observed in 2002 (Table 5).

Average growth of Bluegills and Pumpkinseeds (all ages combined) increased in 2002 and continued to increase for Bluegills through 2014 (Appendix B). Average Black Crappie growth increased by 1993, and increased average growth for Largemouth Bass was indicated in 2014. Sufficient information was not available to evaluate Yellow Perch growth, because information was not available prior to the introduction of Flathead Catfish in 1990.

The Bluegill growth rate increases primarily occurred at age 4 and older, although growth also increased for age-3 fish (Appendix C; Figure 2). In 2014, growth was near the state average for age-4 fish and above the state average for ages 5–8. Age 2–5 growth increased for Pumpkinseeds (Appendix C). Insufficient numbers of Pumpkinseeds were collected to determine ages in 2014. Substantial increases in growth occurred for Black Crappies at ages 3–9, and growth increases occurred as early as 1993 (Appendix C). Largemouth Bass did not display any significant trend in growth, although growth was near or above the state average for age 2–7 fish in 2014 (Appendix C).

## *Brush Lake*

The catch rate of Flathead Catfish in trap-net samples declined slowly during the 19-year period following their introduction into Brush Lake in 1995 (Table 8). Four of the seven Flathead Catfish stocked in 1995 were captured in 2007 and two were caught in 2014. The catch rates of Bluegill,

Table 8.–Catch per unit effort of fish in Brush Lake trap-net collections. Both Yellow Bullhead and Brown Bullhead were present in the catch.

| Year | Bluegill | Pumpkinseed | Black Crappie | Largemouth Bass | Bullheads | Northern Pike | Yellow Perch | Flathead Catfish |
|---|---|---|---|---|---|---|---|---|
| 1994 | 142.0 | 20.5 | 11.0 | 6.0 | 13.0 | 0.0 | 0.0 | 0.0 |
| 1999 | 45.3 | 3.3 | 0.0 | 1.7 | 1.8 | 0.5 | 0.0 | 0.5 |
| 2001 | 29.0 | 0.0 | 0.0 | 1.9 | 0.1 | 0.8 | 0.8 | 0.4 |
| 2003 | 12.0 | 0.8 | 0.1 | 5.1 | 0.1 | 0.8 | 0.8 | 0.2 |
| 2007 | 7.3 | 0.2 | 0.0 | 1.0 | 0.1 | 0.6 | 0.0 | 0.3 |
| 2014 | 11.1 | 2.4 | 4.4 | 2.4 | 1.4 | 2.8 | 0.1 | 0.2 |

Pumpkinseed, Black Crappie, and bullheads declined substantially following introduction of Flathead Catfish.

The Bluegill fishery rated very poor in 1994, improved to good in 1999, then to excellent from 2001 to 2014 (Table 9). The percentage of Bluegills 6 inches and larger in trap-net samples improved substantially within four years after the Flathead Catfish introduction, and by 2001 the percentage of Bluegills 8 inches or larger also increased to high levels. Bluegills 10 inches or larger were collected in 2001, 2003, and 2014. The average lengths of Bluegills in trap-net samples increased after Flathead Catfish introduction (Figure 3). Electrofishing catch rates for Bluegills smaller than 6 inches initially declined following the introduction of Flathead Catfish, and then increased to higher levels in 2007 and

Table 9.–Brush Lake Bluegill information and fishery rank classifications determined from trap-net collections.

| Year | Number in sample | Minimum Length | Maximum length | Average length | % ≥ 6 inches | % ≥ 7 inches | % ≥ 8 inches | Fishery rank |
|---|---|---|---|---|---|---|---|---|
| 1994 | 284 | 3.5 | 7.5 | 5.2 | 7.0 | 0.3 | 0.0 | Very poor |
| 1999 | 272 | 4.5 | 9.5 | 6.7 | 75.7 | 35.7 | 8.8 | Good |
| 2001 | 232 | 4.5 | 10.5 | 7.9 | 93.1 | 75.9 | 46.1 | Excellent |
| 2003 | 108 | 4.5 | 10.5 | 8.1 | 90.7 | 75.9 | 51.8 | Excellent |
| 2007 | 66 | 6.5 | 9.5 | 7.8 | 100 | 93.9 | 33.3 | Excellent |
| 2014 | 100 | 4.5 | 10.5 | 7.6 | 83.0 | 63.0 | 43.0 | Excellent |

Table 10.–Brush Lake electrofishing catch per hour rates and average lengths for Largemouth Bass and bullheads and for Bluegill and Pumpkinseed smaller than 6 inches. There was one Black Crappie (3.5 inches) collected in 1999 and three Yellow Perch (average = 5.5 inches) collected in 2007.

| | Bluegill < 6 inches | | Pumpkinseed < 6 inches | | Largemouth Bass | | Bullheads | |
|---|---|---|---|---|---|---|---|---|
| Year | Catch per hour | Average length | Catch per hour | Average length | Catch per hour | Average length | Catch per hour | Average length |
| 1999 | 63.7 | 2.3 | 20.2 | 2.9 | 16.2 | 11.0 | 5.0 | 5.0 |
| 2001 | 8.7 | 3.4 | 2.9 | 3.8 | 24.3 | 7.4 | 5.8 | 8.3 |
| 2003 | 80.2 | 2.8 | 25.0 | 4.5 | 171.9 | 6.7 | 10.4 | 8.6 |
| 2007 | 337.1 | 2.5 | 51.6 | 4.5 | 137.1 | 8.8 | 8.3 | 9.0 |
| 2014 | 403.6 | 2.3 | 10.7 | 3.4 | 34.5 | 10.5 | 0.0 | – |

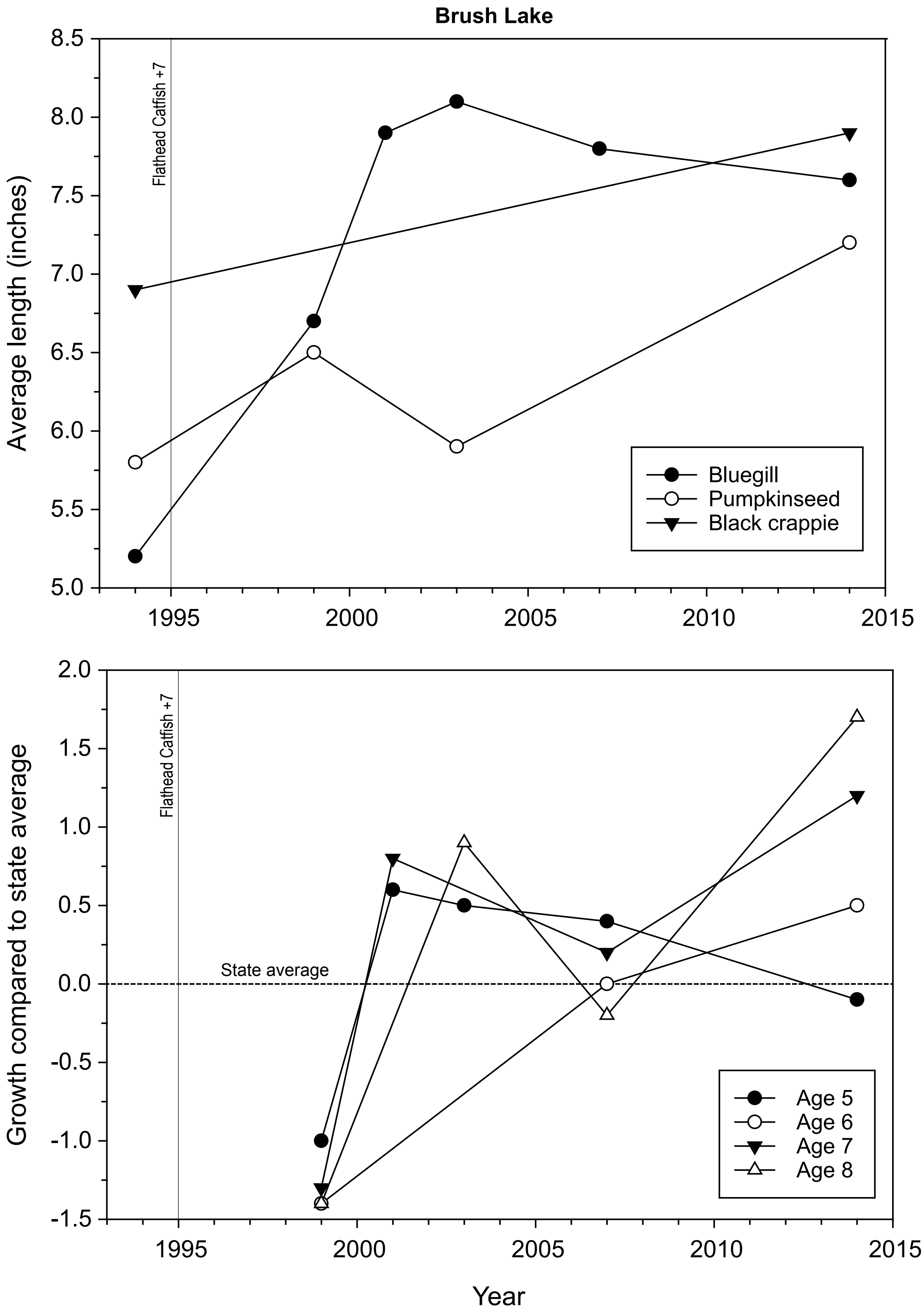


Figure 3.–Average lengths of Bluegills, Pumpkinseeds, and Black Crappies in Brush Lake trap-net samples, 1994–2014 (upper graph). Average deviation from the state average growth index for Bluegills at ages 5–8 (lower graph). Vertical lines indicate years that fish were stocked (+) or removed (-). Growth data were not available in all years.

2014 (Table 10). The average lengths of Bluegills smaller than 6 inches in electrofishing samples did not change substantially.

Pumpkinseeds were less abundant than Bluegills in Brush Lake. The Pumpkinseed fishery improved from acceptable to satisfactory between 1994 and 1999 (Table 11). Very few Pumpkinseeds were collected in trap nets again until 2014. Average lengths in trap nets increased initially, then decreased in 2003, before returning to a higher level in 2014 (Figure 3). Electrofishing catch rates for Pumpkinseed varied throughout the study period (Table 10). Average lengths of Pumpkinseeds in electrofishing samples were somewhat higher after introduction of Flathead Catfish, but declined in 2014 after the two highest years in 2003 and 2007 (Table 10).

Table 11.–Brush Lake Pumpkinseed information and fishery rank classifications determined from trap-net collections.

| Year | Number in sample | Minimum length | Maximum length | Average length | % ≥ 6 inches | % ≥ 7 inches | % ≥ 8 inches | Fishery rank |
|---|---|---|---|---|---|---|---|---|
| 1994 | 41 | 4.5 | 7.5 | 5.8 | 53.6 | 7.3 | 0.0 | Acceptable |
| 1999 | 20 | 6.5 | 7.5 | 6.5 | 85.0 | 10.0 | 0.0 | Satisfactory |
| 2001 | 0 | – | – | – | – | – | – | – |
| 2003 | 7 | 5.5 | 6.5 | 5.9 | 42.9 | 0.0 | 0.0 | Poor |
| 2007 | 2 | 6.5 | 7.5 | 7.0 | – | – | – | – |
| 2014 | 22 | 5.5 | 8.5 | 7.2 | 90.9 | 63.6 | 13.6 | Excellent |

Low numbers of Black Crappies were collected in trap nets in 1994, prior to introduction of Flathead Catfish (Tables 8 and 12). The fishery was ranked acceptable at that time. Only one Black Crappie was collected in trap nets during 2003 and one 6.5-inch fish was collected in the 2007 gill-net sample. In 2014, 40 Black Crappies were collected, averaging one inch greater than before the Flathead Catfish introduction (Figure 3), with a fishery rank of excellent. Black Crappies were not collected in electrofishing samples.

Table 12.–Brush Lake Black Crappie information and fishery rank classifications determined from trap-net collections.

| Year | Number in sample | Minimum length | Maximum length | Average length | % ≥ 6 inches | % ≥ 7 inches | % ≥ 8 inches | Fishery rank |
|---|---|---|---|---|---|---|---|---|
| 1994 | 22 | 5.5 | 11.5 | 6.9 | 59.1 | 45.4 | 22.7 | Acceptable |
| 1999 | 0 | – | – | – | – | – | – | – |
| 2001 | 0 | – | – | – | – | – | – | – |
| 2003 | 1 | – | 9.5 | – | – | – | – | – |
| 2007 | 0 | – | – | – | – | – | – | – |
| 2014 | 40 | 5.5 | 13.5 | 7.9 | 92.5 | 75.0 | 40.0 | Excellent |

Largemouth Bass catch rates in trap nets generally declined after Flathead Catfish introduction (Table 8) and average lengths displayed no trends (Appendix D). Gill-net sampling collected three

Largemouth Bass (8.5–12.5 inches) in 2001 and three (11.5–14.5 inches) in 2007. Largemouth Bass electrofishing catch rates increased after introduction of the Flathead Catfish and then decreased in 2014, and average lengths displayed the reverse pattern (Table 10).

The catch rates of Northern Pike displayed no observable trends in trap nets, although the highest catch rates occurred in 2014 (Table 8). There were no visible trends in average lengths (Appendix D). Three Northern Pike (11.5–22.5 inches) were collected in gill nets during 2001, six (14.5–20.5 inches) in 2007, and two (17.5–20.5 inches) in 2014.

Few Yellow Perch were captured and trends in trap-net catch rates (Table 8) or average lengths were not observed (Appendix D). One Yellow Perch (6.5 inches) was collected in the 2007 gill-net sample. Yellow Perch were only present in the 2007 electrofishing sample, with a catch rate of 6.4/hr and an average length of 5.0 inches.

The catch rate of bullheads in trap nets declined significantly following introduction of Flathead Catfish (Table 8). However, bullhead catch per hour and average lengths in electrofishing samples increased after the 1995 Flathead Catfish introduction until 2014 when none were collected (Table 10). Two 9.5-inch bullheads were captured during 2014 in gill nets.

Average growth of Bluegills (all ages combined) increased in 2001 and remained relatively stable through 2014 (Appendix E). Pumpkinseed average growth did not increase until 2014 and average growth was variable for Largemouth Bass. Northern Pike were growing well below state average in 2014 and average Black Crappie growth was above state average in 2014.

The increases in Bluegill growth rate primarily occurred at age 5 and older, although growth of age-5 fish peaked in 2001 and then declined to near the state average in 2014 (Appendix F; Figure 3). Pumpkinseed growth was above average for age-4 and age-5 fish in 2014, and growth of Largemouth Bass was above average for age 2–4 fish in 2001 and 2014 (Appendix F).

## *Baptist Lake*

Flathead Catfish were captured in trap-net samples during 1996, 1998, and 2007 (Table 13). Some Flathead Catfish from the 47 stocked in 1992 and 1995 (14 removed in 1996) remained in the lake 12 years after they were last stocked. None were captured in the 2013 survey, 18 years after the last stocking, indicating few, if any, remained in the lake. One Walleye (22 inches) was captured in the 1994 survey that may have survived from the 1988 stocking of spring fingerlings. This was the only indication that any survival may have occurred from 10 years of spring fingerling Walleye stocking in this lake. Juvenile Walleyes were not collected in any surveys. Adult Walleyes were captured in trap- or gill-net samples in every survey after adult Walleyes were first stocked in 1997 (Table 13). Although catch rates declined in 2007 and 2013, some Walleyes remained in the lake 11 years after the final stocking in 2002.

Bluegill catch rates in trap nets decreased after introduction of Flathead Catfish in 1992 and 1995 (Table 13). Catch rates then increased to a high level in 2003 then decreased again to low levels in 2007 and 2013. The Bluegill population had a fishery ranking of very poor prior to introduction of Flathead Catfish in 1992 (Table 14). The Bluegill fishery status improved to a poor rating from 1994 through 1998 as the percentage of fish 6 inches or larger and 7 inches or larger increased. Bluegills 8 inches or larger first appeared in samples in 1999, and the fishery was ranked acceptable to satisfactory from 1999 through 2007. In 2013, the Bluegill population had a good fishery ranking and the majority of fish captured were 6 inches or larger and almost half were 7 inches or larger. Average lengths of Bluegills in trap-net samples increased after introduction of Flathead Catfish and Walleyes (Figure 4). The catch rate of Bluegills smaller than 6 inches in electrofishing surveys increased during the study period and

Table 13.–Catch per unit effort of fish in Baptist Lake trap-net and gill-net collections. Both Yellow Bullheads *Ameiurus natalis* and Brown Bullheads *Ameiurus nebulosus* were present in the catch.

| Date of sample | Bluegill | Pumpkinseed | Black Crappie | Largemouth Bass | Bullheads | Northern Pike | Yellow Perch | Flathead Catfish | Walleye | Rock Bass |
|---|---|---|---|---|---|---|---|---|---|---|
| Trap nets | | | | | | | | | | |
| 1987 | 57.7 | 12.7 | 0.0 | 0.2 | 32.5 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 |
| 1989 | 219.0 | 42.0 | 1.5 | 0.0 | 47.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1994 | 104.8 | 3.8 | 0.0 | 0.5 | 0.8 | 0.0 | 0.0 | 0.0 | 0.3 | 1.5 |
| 1996 | 34.3 | 10.2 | 1.2 | 0.4 | 0.5 | 0.2 | 0.1 | 0.9 | 0.0 | 3.4 |
| 1998 | 7.8 | 1.8 | 0.9 | 0.2 | 0.9 | 1.2 | 0.0 | 0.2 | 1.7 | 3.7 |
| 1999 | 58.7 | 4.7 | 3.3 | 1.0 | 2.3 | 0.0 | 0.0 | 0.0 | 9.0 | 9.7 |
| 2001 | 44.1 | 2.9 | 0.8 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 1.5 | 3.4 |
| 2003 | 711.8 | 6.3 | 1.5 | 0.7 | 3.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 |
| 2007 | 14.4 | 1.1 | 2.9 | 0.3 | 2.9 | 0.4 | 0.0 | 0.1 | 0.3 | 1.0 |
| 2013 | 22.9 | 2.3 | 0.7 | 0.3 | 3.1 | 0.8 | 0.0 | 0.0 | 0.0 | 2.4 |
| Gill nets | | | | | | | | | | |
| 1987 | – | – | – | – | – | – | – | – | – | – |
| 1989 | 0.0 | 0.5 | 0.0 | 0.0 | 0.5 | 0.0 | 3.5 | 0.0 | 0.0 | 0.0 |
| 1994 | – | – | – | – | – | – | – | – | – | – |
| 1996 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1998 | – | – | – | – | – | – | – | – | – | – |
| 1999 | 55.0 | 1.2 | 1.0 | 0.5 | 0.0 | 5.0 | 0.5 | 0.0 | 4.0 | 3.5 |
| 2001 | – | – | – | – | – | – | – | – | – | – |
| 2003 | 6.2 | 0.7 | 7.2 | 0.7 | 0.0 | 3.5 | 0.0 | 0.0 | 1.7 | 1.7 |
| 2007 | 9.0 | 0.0 | 0.0 | 0.5 | 0.0 | 4.0 | 0.2 | 0.0 | 0.2 | 0.7 |
| 2013 | 17.2 | 0.0 | 0.3 | 0.7 | 0.7 | 4.8 | 0.5 | 0.0 | 0.5 | 0.3 |

Table 14.–Baptist Lake Bluegill information and fishery rank classifications determined from trap-net collections.

| Year | Number in sample | Minimum length | Maximum length | Average length | % ≥ 6 inches | % ≥ 7 inches | % ≥ 8 inches | Fishery rank |
|---|---|---|---|---|---|---|---|---|
| 1987 | 231 | 3.5 | 7.5 | 4.3 | 7.3 | 0.1 | 0.0 | Very poor |
| 1989 | 438 | 2.5 | 6.5 | 4.8 | 1.1 | 0.0 | 0.0 | Very poor |
| 1994 | 419 | 3.5 | 7.5 | 5.9 | 43.0 | 1.2 | 0.0 | Poor |
| 1996 | 273 | 3.5 | 7.5 | 5.4 | 20.9 | 5.5 | 0.0 | Poor |
| 1998 | 94 | 2.5 | 7.5 | 5.0 | 11.7 | 2.1 | 0.0 | Poor |
| 1999 | 259 | 3.5 | 9.5 | 5.3 | 21.6 | 13.9 | 5.8 | Acceptable |
| 2001 | 353 | 3.5 | 9.5 | 6.1 | 49.0 | 19.3 | 4.5 | Satisfactory |
| 2003 | 4,271 | 3.5 | 9.5 | 5.8 | 28.4 | 3.5 | 1.8 | Acceptable |
| 2007 | 130 | 3.5 | 9.5 | 5.5 | 36.1 | 16.9 | 6.9 | Acceptable |
| 2013 | 206 | 4.5 | 8.5 | 6.7 | 74.3 | 48.5 | 10.2 | Good |

average lengths decreased somewhat (Table 15). Electrofishing catch rates in Baptist Lake may have been affected by the difference in day- and night-sampling periods. The lowest catch rates of Bluegills in electrofishing samples occurred in 1994 and 2001 when samples were collected during the day.

Pumpkinseed catch rates in trap nets decreased following the introduction of the predator fish (Table 13). Pumpkinseeds were less abundant in samples than Bluegills. The Pumpkinseed population was ranked very poor prior to the introduction of Flathead Catfish and adult Walleyes (Table 16). With the exception of 2007 when very few were captured, the Pumpkinseed fishery rank improved to satisfactory during the rest of the study period. Average lengths of Pumpkinseeds in trap-net samples increased after introduction of predator fish (Figure 4). The catch rate decreased moderately and the average length of Pumpkinseeds in electrofishing samples displayed no discernable trends during the study period (Table 15).

Black Crappies and Rock Bass displayed no consistent changes in trap-net catch rates during the study (Table 13). The average length of Black Crappies in net collections decreased after 2001 (Appendix G). The average length of Rock Bass in net samples decreased moderately after 2003 (Appendix G).

Bullhead catch rates in trap nets decreased following the introduction of the predator fish (Table 13). However, catch rates and average lengths of bullheads in electrofishing samples displayed no observable trends (Table 15).

Yellow Perch were collected in low numbers in net collections during the study period (Table 13). Catch rates of Yellow Perch in electrofishing samples decreased during the study period, and the average length was lower in 2013 (Table 15).

There were no discernable trends in the catch rates of Largemouth Bass in nets or electrofishing samples (Tables 13 and 15). There were no obvious trends in average lengths in electrofishing samples. The number of Largemouth Bass in net samples was too low for comparisons of average length but large bass were collected in the 2007 and 2013 samples (Appendix G).

Trends were not apparent in gill-net catch rates for Northern Pike in Baptist Lake (Table 13). There appeared to be no significant trends in average lengths of Northern Pike in net samples and large Northern Pike were captured in all samples (Appendix G).

Average growth of Bluegills, Pumpkinseeds, and Largemouth Bass (all ages combined) did not increase during the study period (Appendix H). Northern Pike growth declined near the end of the study and sufficient data was not available to evaluate growth trends for Yellow Perch and Black Crappie.

Bluegill growth increased at ages 5–8 over the course of the study at varying levels (Figure 4; Appendix I). Age-5 Bluegills displayed less improvement in growth than older fish. More limited

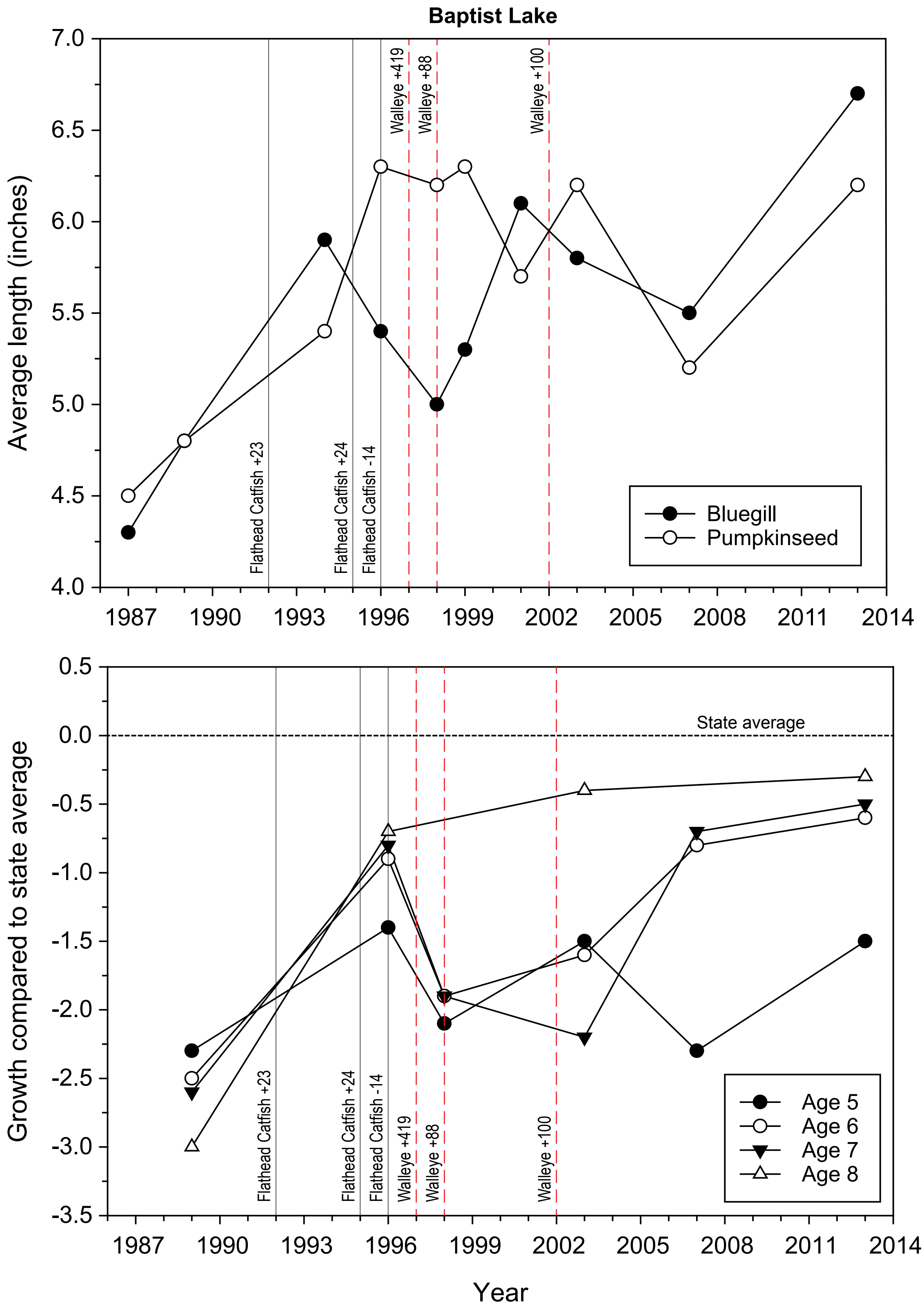


Figure 4.–Average lengths of Bluegills and Pumpkinseeds in Baptist Lake trap-net samples, 1987–2013 (upper graph). Average deviation from the state average growth index for Bluegills at ages 5–8 (lower graph). Vertical lines indicate years that fish were stocked (+) or removed (-). Growth data were not available in all years.

Table 15.–Baptist Lake electrofishing catch per hour rates and mean lengths (inches) for Largemouth Bass and bullheads and for Bluegill, Pumpkinseed, and Yellow Perch smaller than 6 inches.

| | Bluegill < 6 inches | | Pumpkinseed < 6 inches | | Yellow Perch < 6 inches | | Largemouth Bass | | Bullheads | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Catch per hour | Average length | Catch per hour | Average length | Catch per hour | Average length | Catch per hour | Average length | Catch per hour | Average length |
| 1994 | 267.5 | 3.5 | 34.9 | 4.5 | 22.9 | 4.5 | 20.5 | 9.5 | 6.0 | 8.1 |
| 1999 | 283.1 | 3.9 | 7.3 | 4.4 | 18.7 | 4.4 | 76.0 | 11.0 | 1.0 | 10.5 |
| 2001 | 79.0 | 3.2 | 5.0 | 4.9 | 16.0 | 4.0 | 27.5 | 8.3 | 3.5 | 9.9 |
| 2003 | 664.0 | 3.4 | 26.9 | 4.6 | 14.9 | 4.6 | 53.7 | 9.4 | 3.0 | 9.0 |
| 2007 | 512.9 | 3.2 | 24.1 | 4.1 | 13.0 | 4.5 | 74.1 | 9.8 | 7.4 | 9.0 |
| 2013 | 750.0 | 3.0 | 24.4 | 4.7 | 9.4 | 3.7 | 63.7 | 8.5 | 7.5 | 8.0 |

Table 16.–Baptist Lake Pumpkinseed information and fishery rank classifications determined from trap-net collections.

| Year | Number in sample | Minimum length | Maximum length | Average length | % ≥ 6 inches | % ≥ 7 inches | % ≥ 8 inches | Fishery rank |
|---|---|---|---|---|---|---|---|---|
| 1987 | 51 | 3.5 | 6.5 | 4.5 | 17.6 | 0.0 | 0.0 | Very poor |
| 1989 | 84 | 3.5 | 7.5 | 4.8 | 7.1 | 2.3 | 0.0 | Very poor |
| 1994 | 15 | 4.5 | 6.5 | 5.4 | 6.7 | 0.0 | 0.0 | Poor |
| 1996 | 82 | 3.5 | 8.5 | 6.3 | 51.2 | 31.7 | 8.5 | Satisfactory |
| 1998 | 22 | 4.5 | 9.5 | 6.2 | 45.4 | 27.3 | 9.0 | Satisfactory |
| 1999 | 28 | 3.5 | 8.5 | 6.3 | 64.2 | 32.1 | 3.6 | Satisfactory |
| 2001 | 23 | 3.5 | 8.5 | 5.7 | 30.4 | 13.0 | 4.3 | Satisfactory |
| 2003 | 38 | 4.5 | 8.5 | 6.2 | 47.3 | 18.4 | 2.6 | Satisfactory |
| 2007 | 10 | 4.5 | 7.5 | 5.2 | 30.0 | 10.0 | 0.0 | Poor |
| 2013 | 21 | 4.5 | 8.5 | 6.2 | 57.1 | 23.8 | 4.8 | Satisfactory |

information indicated there was improvement in Pumpkinseed growth after 2001 at ages 5–7 when compared to 1989 (Appendix I). Largemouth Bass growth appeared to improve during 2013 at age 4 and age 5 (Appendix I).

## Discussion

The historical methods used in Michigan to reduce panfish abundance with toxicants or manual removals with nets produced variable results and any increases in the numbers of large Bluegills or growth rates of fish were short-term. This study demonstrates that increases in the number of large Bluegills and other panfish, in lakes with slow-growing fish, have the potential to last many years by managing with predator fish. Flathead Catfish age information is limited in Michigan but they were found to achieve an age of 17 years in the St. Joseph River (Daugherty 2004). The maximum age of Flathead Catfish found in other areas of the United States was 28 (Kwak et al. 2006). Sand Lake was stocked with 67 Flathead Catfish, from 1990 through 1995, ranging in size from 18 to 41 inches. In 2014, 19 years after the final stocking in 1995, six individual Flathead Catfish were captured ranging in size from 37 to 52 inches. Brush Lake was stocked with seven Flathead Catfish in 1995, ranging in size from 20 to 37 inches. In 2014, 19 years after stocking, two Flathead Catfish were captured that were 36 and 38 inches long. Baptist Lake was stocked with 47 Flathead Catfish in 1992 and 1995, ranging in size from 20 to 38 inches. Fourteen of these fish were removed from Baptist Lake in 1996. In 2007, one Flathead Catfish was captured that was 42 inches long.

Walleyes are known to reach the age of 18 in Michigan (Hanchin et al. 2007). In 1997, 1999, and 2002, 607 Walleyes were stocked in Baptist Lake, ranging in size from 15 to 24 inches. In 2013, 11 years after the final stocking, three Walleyes were captured that ranged in size from 22 to 23 inches.

Both natural mortality and fishing mortality caused the declines of Flathead Catfish and Walleyes in the two study lakes. Although fishing was closed for all catfish species and Walleyes in the study lakes, some fishing related mortality occurred. Conservation officers found some illegal Walleye harvest in Baptist Lake. In Sand Lake, a number of the Flathead Catfish that were collected in our samples had tags inserted into their dorsal fins that most likely came from anglers who were catching and releasing these fish (reported by other anglers). One was harvested by an angler who was unaware of the regulations.

The only regulations implemented on the study lakes were fishing closures on Walleyes and all catfish species. A statewide regulation implemented in 1993 increased the minimum harvest size for bass from 12 inches to 14 inches, and for Northern Pike from 20 inches to 24 inches. These regulation changes could have affected the fish populations in the study lakes. However, Schneider and Lockwood (1997) found that these regulation changes had no effect on Bluegill population size structure or growth in control lakes in that 8-year study (1988–1996). Some of the sample variability in this study may have been caused by timing of sampling in relation to the spring spawning period of panfish during any particular year, and random variability in annual recruitment. Climatic changes that result in cooler and warmer years have been shown to affect both growth and year-class strength in fish (King et al. 1999; Schupp 2002). Schneider and Lockwood (1997) noted that no strong Bluegill year-classes were produced in sixteen Michigan study lakes during 1992 as a result of the eruption of Mount Pinatubo in June 1991.

Bluegills were the most abundant panfish in the study lakes and the primary species targeted for increasing the percentage of fish 6 inches or larger in length to improve fishing. All three study lakes exhibited substantial increases in the number of Bluegills 6 inches or larger by the end of the study period.

Improvement in the size structure of the Bluegill population in Sand Lake was variable during the study period, especially from 1993 through 1997 (Table 4). A substantial part of the variability possibly resulted from the removal of some Flathead Catfish in 1992, followed by stocking additional catfish in 1995. Increases in the number of Bluegills 6 inches or larger occurred two years after the initial stocking of Flathead Catfish in 1990, and with the exception of one year, the percentage of Bluegills 6 and 7 inches or larger improved in all years. The fishery rank of Bluegills continually improved during the 18-year period from 1997 through 2014, when it was rated excellent. By 2014, nearly 25% of the Bluegills collected in trap-net samples were 8 inches or larger and 10-inch Bluegills were present in the population.

The number of large Bluegills in Brush Lake increased substantially following introduction of Flathead Catfish in 1995 (Table 9). The fishery rank changed from very poor to good within 5 years, then improved to excellent from 2001 through 2014. In 2014, 19 years after the introduction of Flathead Catfish, 83% of Bluegills in trap-net samples were 6 inches or larger and 43% were 8 inches or larger. Ten-inch Bluegills were present in the population by 2001.

The percentage of Bluegills 6 inches or larger increased substantially in Baptist Lake within 4 years after introduction of Flathead Catfish in 1992 (Table 14). The increase in the percentage of larger Bluegills was variable from 1996 through 2007, and this possibly resulted from the removal of Flathead Catfish and subsequent stocking of adult Walleyes during this period. One Flathead Catfish was collected in 2007, but none were collected in 2013. In 2013, 11 years after the final stocking of adult Walleyes, 74% of the Bluegills in trap-net samples were 6 inches or larger and 10% were 8 inches or larger. Schneider and Lockwood (1997) found that stocking 6-inch fingerling Walleyes, alone and with an initial antimycin treatment, increased the number of large Bluegills in five lakes for a period of five to six years, when the study ended. This study demonstrates that adult Walleyes can also be used to increase the number of large Bluegills in Michigan lakes.

The catch rate of Bluegills smaller than 6 inches in electrofishing samples was used to indicate changes in recruitment and abundance of smaller fish. Direct pre-study comparisons of Bluegills smaller than 6 inches could not be made because electrofishing samples were not collected in any of the three study lakes prior to the introduction of Flathead Catfish and adult Walleyes. In Brush Lake and Sand Lake, the lowest catch rate of Bluegills smaller than 6 inches and greatest average sample lengths were achieved within six to seven years after the final stocking of Flathead Catfish in 1995 (Tables 5 and 10). Catch rates in both lakes increased again at the end of the study period. The highest average lengths of Bluegills smaller than 6 inches in electrofishing samples for Baptist Lake occurred within the seven-year period following introduction of Flathead Catfish in 1992 (Table 15). The lowest catch rate of small Bluegills occurred in 2001 after some of the Flathead Catfish were removed in 1991 and adult

Walleyes were stocked in 1997 and 1999. Electrofishing catch rates of Bluegills smaller than 6 inches then increased to higher levels from 2003 through 2013. The drop in catch rates of smaller Bluegills and somewhat greater average lengths indicates that Flathead Catfish decreased the abundance of smaller Bluegills in Baptist Lake. Increasing abundance of smaller Bluegills near the end of the study would be consistent with the lower abundance of Flathead Catfish that was observed. The higher catch rates of Bluegills 6 inches or larger occurring after introduction of adult Walleyes in Baptist Lake suggests adult Walleyes may have been less effective at feeding on juvenile Bluegills than Flathead Catfish, or the density of adult Walleyes was insufficient. Schneider and Lockwood (1997) found that age-0 Bluegill recruitment was undiminished by stocking 6-inch Walleye fingerlings, but the abundance of all other Bluegill age groups declined. Small Bluegills remained abundant in Sand, Brush, and Baptist lakes, and increasing abundance near the end of the study suggests that a return to a Bluegill community dominated by smaller fish may occur without additional introductions of predator fish.

Growth of Bluegills in the three study lakes improved primarily for age-4 and older fish. Growth of age-4 and older Bluegills in Sand Lake increased by 2002 (Appendix C). In 2014, age-4 and older fish were growing at the state average, and age-5 and older fish were growing 1 to 2 inches above the state average. Growth of the older fish increased by more than 3 inches when compared to the pre-study level in 1988. There appeared to be some improvement in age-3 fish growth during 2002 and 2007 in Sand Lake. Pre-study fish growth information was not available for Brush Lake, but age-5 and older Bluegill growth in 1999 was more than 1 inch below the state average (Appendix F). Growth of age-5 and older Bluegills increased in Brush Lake by 2001, and was 1 to 3 inches greater by 2014. Growth of Bluegills in Baptist Lake was more than 2 inches below the state average in 1989, prior to the beginning of predator fish stocking (Appendix I). The growth of age-6 and older Bluegills increased in Baptist Lake by 1996. The older Bluegills were growing just below the state average in 2013, exhibiting an overall increase in the growth rate of about 2 inches. Schneider and Lockwood (1997) found that Bluegill growth increased for all age groups, except age 0, in five Michigan lakes stocked with 6-inch Walleyes. This information suggests that juvenile Walleyes feed more on smaller Bluegills and can improve growth at younger ages. Schneider and Lockwood (1997) used the back-calculation method to evaluate changes in growth, a method that is more sensitive and accurate than making comparisons to state average growth.

The species of fish preyed upon by Flathead Catfish and Walleyes were not specifically evaluated by examining stomach contents in this study. Schneider and Breck (1997) found that a 6.2-inch Walleye was capable of consuming any age-0 Bluegill that might be present in a Michigan lake, based on mouth gape. They also found that 20-inch Walleyes are capable of preying on Bluegills up to approximately 5 inches in length. Consumption of Bluegills by Walleyes from 10 Michigan inland lakes corroborated their findings, with Walleyes from 6 to 20 inches consuming Bluegills from 1 to 2 inches and larger Bluegills were consumed as Walleye length increased. The Flathead Catfish collected in this study often regurgitated their stomach contents after being captured. This occurred in trap nets and when held in cages prior to data collection. Although regurgitated prey were not enumerated or measured, photographs show that multiple species of fish were preyed on. These included fish from about 2 to 14 inches (a Largemouth Bass that was measured) in length. Other prey species observed included Black Crappie, Bluegill, Pumpkinseed, and Yellow Perch. Northern Pike was not an observed prey species. All of these species were relatively abundant in the study lakes. A large snake was regurgitated by a Flathead Catfish during transfer from the river to Sand Lake, indicating the aggressiveness of this predator. Slaughter and Jacobson (2008) found that Flathead Catfish are one of the least gape-limited piscivores and able to consume any size Largemouth Bass, Bluegill or Gizzard Shad *Dorosoma cepedianum*. Pine et al. (2005) found that Flathead Catfish fed on a variety of fish species in two North Carolina coastal rivers where they were introduced. Centrarchids (primarily sunfish), Yellow Perch, darters, and crayfish were primary food items of Flathead Catfish, but a wide variety of other fish was consumed. Their review of the literature also found that Flathead Catfish feed on a wide variety of fish, with important families including Centrarchidae (sunfishes), Ictaluridae (catfish and bullheads), Catostomidae (suckers and redhorses), Clupeidae (shad), and crayfish.

The extirpation of resident fish species is always a concern when introducing new organisms into a lake. All three of the study lakes had received significant manipulation of the fish populations historically, including manual fish removals with nets, treatments with rotenone and antimycin, or both. Fish stocking with game species also occurred in Sand Lake and Baptist Lake. With the exception of bullheads in Sand Lake, all fish species collected prior to introducing Flathead Catfish and Walleyes were present at the end of the study (Tables 3, 8, 13). Bullhead abundance was also significantly reduced in Brush and Baptist lakes. However, Flathead Catfish stocking was at a greater density in Sand Lake (1.2 fish/acre, 16.6 lbs/acre) than in Brush Lake (0.4/acre, 5.5 lbs/acre) or Baptist Lake (0.4/acre, 4.2 lbs/acre). The high-density stocking rate may have resulted in the extirpation of bullheads from Sand Lake. B. Gunderman (MDNR, unpublished data) also reported significant decreases of bullheads in a small Michigan lake following introduction of Flathead Catfish. Bullheads were the preferred forage species of Flathead Catfish in a Minnesota Lake, where their abundance, along with Carp, declined by 90% within 4 years after the introduction of Flathead Catfish (Davis 1985). Pine et al. (2005) reviewed the literature regarding predation effects of Flathead Catfish following their introduction in North Carolina and Georgia rivers. Significant reductions in native catfishes, sunfishes, and suckers were found after Flathead Catfish were introduced and they established spawning populations. Walleyes can strongly affect fish communities and population characteristics of other species through predation (Schneider et al. 2007). Predation by Walleyes on some species, especially Yellow Perch and soft rayed fish, can harm their fisheries.

In 1997, Flathead Catfish were stocked into a 102-acre lake in southern Michigan for the purpose of increasing the size structure of the Bluegill population (B. Gunderman, unpublished data). After 15 years, the fishery rank of Bluegill and Pumpkinseed decreased from good to poor and smaller panfish increased substantially. There was concern that Flathead Catfish reduced the abundance of other predator fish. However, complicating factors that may have contributed to lower numbers of large panfish included the illegal introduction and establishment of Redear Sunfish *Lepomis microlophus* in 2006, and the removal of nearly all aquatic vegetation from the lake in 2008. This information indicates stocked Flathead Catfish may not improve panfish populations in lakes that have average panfish fisheries.

Species that appeared to increase in abundance after introduction of Flathead Catfish and Walleyes were Largemouth Bass in Sand Lake, and Northern Pike in Brush and Baptist lakes. Some additional fish species were captured during the study. These fish were all captured after the study began and were low in abundance or were not captured effectively with our gear. Consequently, changes in the abundance of these species in response to stocking Flathead Catfish and Walleyes could not be ascertained. For Sand Lake, these species included Bowfin *Amia calva*, White Sucker, redhorse *Moxostoma* spp., Johnny Darter *Etheostoma nigrum,* and Brook Silversides *Labidesthes sicculus*; for Brush Lake they included Grass Pickerel, Warmouth *Lepomis gulosus*, Golden Shiner *Notemigonus crysoleucas,* and Spottail Shiner *Notropis hudsonius*; and for Baptist Lake they included Green Sunfish, White Sucker, Grass Pickerel, Golden Shiner, Iowa Darter *Etheostoma exile*, and Sand Shiner *Notropis stramineus*.

The only manipulation of the fishery in this study, other than stocking Flathead Catfish or Walleyes, was to restrict the harvest of all catfish species and Walleyes. These restrictions were implemented to protect the stocked predator species during the study. Because these species are popular game fish, and judging from the known illegal harvest of some of these fish, it is probable that restricting the harvest of stocked predators is necessary for this management method. Using other manipulations in conjunction with predator fish stocking may be beneficial for accelerating improvements in panfish population size structure. Schneider and Lockwood (1997) conducted an initial reduction in the panfish population by using an antimycin treatment prior to stocking large fingerling Walleyes. This method was effective in two of their three treatment lakes. Schneider and Lockwood (1997) also used catch-and-release for all fish (in combination with an initial Antimycin treatment) to successfully increase the percentage of large Bluegills in three lakes. However, increasing abundance of small Bluegills in these lakes near the end of the 8-year study indicated that a reversion to the original conditions might occur. Reduced daily harvest limits of panfish (30 reduced to 10 Bluegills and Pumpkinseeds in Minnesota and 25 reduced to 10 Bluegills, Pumpkinseeds, Yellow Perch, Black Crappies, and White Crappies, *Pomoxis annularis* in Wisconsin) have been shown to increase the mean total length of Bluegill populations in lakes (Jacobson 2005; Rypel 2015). Manual removal of small panfish is another option that might be used in conjunction with stocking adult predators. This method may help accelerate improvements in the panfish population size structure by reducing the initial abundance of small panfish. It may also be used over a longer period of time to increase the longevity of the fishery improvements. Manual removals can also be selective for individual species and can also be conducted cooperatively with partner groups (e.g., angler groups and lake associations). However, manual removals are labor intensive, with the required effort increasing with lake size. Large numbers of small Bluegills would need to be removed to produce a noticeable effect on growth of the remaining fish; the larger the lake, the larger the Bluegill biomass that would need to be removed to have an effect.

The costs and benefits of improving the percentage of large panfish in Michigan lakes by stocking predator fish have not been evaluated. Fisheries managers intuitively know that angler effort is higher in lakes that have good panfish populations with many large fish, and abundant small panfish is one of the most frequent complaints submitted by anglers for inland lakes in Michigan. Panfish (including Bluegill, Pumpkinseed, Black Crappie, Yellow Perch and others) are the most sought after species of fish in Michigan based on the 2011 National Survey of Fishing (U.S. Department of the Interior 2013). Schneider and Lockwood (1997) conducted one stocking of Walleyes 6 inches or larger into six study lakes at 15–18/acre. They found the percentage of larger Bluegills increased throughout the next six years, when the study ended. These results were achieved with relatively low Walleye densities, based on post-stocking survey catch rates. The Michigan Fish Stocking Guidelines recommends stocking 10–30/acre of 3–6 inch Walleye fingerlings to establish a population in warm- and cool-water lakes (Dexter and O'Neal 2004). Typically, fingerlings are stocked every other year to avoid successive year-class suppression. Assuming a stocking rate of 15 fingerlings/acre (≥ 6 inches), with a cost of $1.50 per fingerling, the cost/year of stocking would be $11.25/acre. The value of one angler-day of fishing in Michigan's inland waters was estimated at $29 in 2011 (U.S. Department of the Interior 2013). Increasing effort by less than 0.5 angler-days/acre/year would compensate for the cost of stocking large fingerling Walleyes in a Michigan lake.

The stocking costs for Flathead Catfish and Walleyes in Sand, Brush, and Baptist lakes were not estimated. The adult Walleyes were transferred from an egg-take operation on a river near Baptist Lake. The costs of stocking were very minimal because the fish were already available from the egg-take operation and the lake was very near the river source. Transferring adult Walleyes into Michigan inland lakes to manage panfish populations has not been conducted historically. This option is available to managers as there are several large spawning populations throughout the state. Flathead Catfish stocking costs were more substantial because they were captured from wild populations in several rivers (Grand, Maple, and Kalamazoo) in the western Lower Peninsula and transferred to the lakes. Records were not kept on these operations, so costs could not be estimated. Flathead Catfish were not available from commercial sources. Attempts to spawn Flathead Catfish and rear fingerlings from the gametes were unsuccessful in Michigan (J. Copeland, MDNR, personal communication).

Flathead Catfish are mostly found in the southern half of the Lower Peninsula of Michigan, approximately south of a line between the Manistee River on the west side and Saginaw Bay on the east side (Bailey et al. 2004). Specific studies to determine the full distribution of this species in Michigan have not been conducted. Flathead Catfish have relatively sparse populations in Michigan's warmwater rivers and connected drowned river mouth lakes, and very few are captured in Great Lakes waters (B. Gunderman, J. Baker, M. Tonello, J. Braunscheidel, and M. Thomas, MDNR, personal communication), so obtaining fish from wild populations for managing large numbers of inland lakes would be very limited. There is no indication that naturally-reproducing populations of Flathead Catfish occur in Michigan inland lakes, although they occur in the larger drowned river mouth lakes connected to warmwater rivers. There was no indication of Flathead Catfish natural reproduction in any of the three lakes during this 24-year study. There is the possibility that natural reproduction could occur in a situation where a lake has a warmwater tributary.

## Conclusions and Recommendations

Significant fishery improvements can be achieved by stocking adult Flathead Catfish and adult Walleyes in Michigan lakes that have abundant, slow-growing Bluegill populations. Improvements in the percentage of Bluegills, Pumpkinseeds, and Black Crappies 6 inches or larger in length in the fish populations of three study lakes were achieved. Increases in the percentage of larger Bluegills were observed within 2–5 years after stocking predator fish, and lasted for periods of at least 11–19 years. Stocking of adult Flathead Catfish and adult Walleyes should be considered for improving slow-growing panfish populations in lakes where habitat conditions or fish predation prevent survival of juvenile Walleyes.

Improved growth of Bluegills appears to occur primarily for age-4 and older fish when using adult Flathead Catfish and adult Walleyes as predators. The abundance of small panfish remained high in the study lakes, indicating that maintaining the density of predator fish through stocking will be required to continue good panfish fishing with this management procedure.

Stocking Flathead Catfish and Walleyes can have significant effects on native fish populations. This is an important consideration, especially when threatened, endangered, and species of special concern are present (Derosier et al. 2015). However, small to moderate sized (<500 acres) inland lakes in Michigan typically will not support natural reproduction of these two species. If a problem developed after stocking, both species can be removed from a lake with standard netting procedures. Wild populations of fish can also be affected when population abundance is reduced by removing fish for transfer to other locations. Genetics and disease concerns are also other factors that need to be considered for source and stocked waters (Dexter and O'Neal 2004).

### *Recommendations*

- Stock adult Flathead Catfish at rates from 0.4/acre (4.2 lbs/acre) to 1.2/acre (16.6 lbs/acre). The smallest Flathead Catfish available should be stocked because they may feed on smaller prey, and younger fish will provide benefits for a longer period of time. Some relevant issues with this recommendation are as follows: bullheads are a primary forage species of Flathead Catfish and may be severely reduced or eliminated at high Flathead Catfish stocking densities; stocking Flathead Catfish into lakes with average or better panfish fisheries may cause detrimental effects on the fisheries as described by B. Gunderman (unpublished data); and natural reproduction of Flathead Catfish does not appear to occur in Michigan lakes but may occur in warmwater streams connected to lakes.
- Stock adult Walleyes at a rate of up to 7.1/acre (19.7 lbs/acre). Additional stocking levels of adult Walleyes should be evaluated in other lakes to determine the appropriate stocking rates needed to improve Bluegill growth and size structure in Michigan lakes.
- Fishing closures should be used to protect stocked adult Flathead Catfish and adult Walleyes. The value of stocked predator fish is primarily achieved by improving panfish fishing. Transferring adult fish from one body of water to another to provide fishing is not typically a recommended management practice in Michigan.

- Surveys should be conducted at regular intervals (e.g., 3–5 years) to determine the abundance of stocked predator fish and changes in the fish community.
- Angler surveys should be conducted to help evaluate the benefit of this type of management.
- The costs of stocking adult Flathead Catfish and adult Walleyes should be evaluated so that costs of this method, for a given size of lake, can be estimated in advance and compared with anticipated benefits as well as with other methods.
- Other methods should be tested, in conjunction with predator fish stocking, to determine if fishery improvements in panfish populations could be accelerated or extended. Potential methods that may provide benefits include reducing the abundance of small panfish with manual removals and partial or complete reductions in the angler harvest of large panfish and other predators. Antimycin treatments could be used prior to stocking predator fish.
- Individually tag the adult predator fish that are stocked. This would help provide needed information on growth and survival in lakes as they are recaptured. Tagging would take advantage of the ability to recapture adults of these long-lived species.
- Additional information for interpreting growth and estimating consumption could be obtained by collecting habitat information (e.g., water temperatures, transparency, and aquatic plants) in lakes stocked with predator fish.

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Appendix A.–Sand Lake sample sizes and length (inches) information for Largemouth Bass, Northern Pike, and Yellow Perch from trap-net collections.

| | Largemouth Bass | | Northern Pike | | Yellow Perch | |
|---|---|---|---|---|---|---|
| Year | Number | Average length (range) | Number | Average length (range) | Number | Average length (range) |
| 1984 | 11 | 13.4 (9.5–15.5) | 0 | – | 0 | – |
| 1986 | 9 | 16.5 (13.5–21.5) | 5 | 30.5 (27.5–33.5) | 0 | – |
| 1987 | 6 | 12.8 (6.5–16.5) | 3 | 20.2 (13.5–24.5) | 3 | 7.8 (7.5–8.5) |
| 1988 | 9 | 14.2 (7.5–18.5) | 4 | 22.7 (17.5–27.5) | 1 | 10.5 |
| 1991 | 47 | 11.6 (5.5–18.5) | 3 | 26.8 (25.5–29.5) | 5 | 10.7 (9.5–12.5) |
| 1992 | 27 | 12.1 (9.5–16.5) | 4 | 26 (24.5–27.5) | 0 | – |
| 1993 | 22 | 13.7 10.5–17.5) | 22 | 27.3 (23.5–31.5) | 8 | 8.4 (5.5–10.5) |
| 1994 | 50 | 12.0 (8.5–16.5) | 2 | 27.5 | 1 | 10.5 |
| 1995 | 121 | 12.7 (6.5–17.3) | 2 | 32.5 (32.5–33.5) | 29 | 10.4 (7.5–15.5) |
| 1996 | 18 | 12.3 (7.5–16.5) | 1 | 27.5 | 2 | 11.0 (10.5–11.5) |
| 1997 | 5 | 14.7 (7.5–17.5) | 0 | – | 1 | 8.5 |
| 2002 | 24 | 9.8 (7.5–13.5) | 0 | – | 0 | – |
| 2007 | 30 | 9.2 (5.5–19.5) | 0 | – | 0 | – |
| 2014 | 166 | 14.3 (7.5–16.5) | 3 | 27.2 (24.5–29.5) | 3 | 10.2 (8.5–11.5) |

Appendix B.–Average deviation (inches, all ages combined) from the state average growth index for various fish species in Sand Lake from 1988 through 2014. Growth comparisons were included if at least two ages could be averaged.

| Year | Bluegill | Pumpkinseed | Black Crappie | Largemouth Bass | Yellow Perch |
|---|---|---|---|---|---|
| 1988 | -1.5 | -0.5 | -2.1 | | |
| 1991 | -1.2 | | | | |
| 1992 | -1.0 | | | | |
| 1993 | -1.2 | -0.7 | 1.1 | -0.1 | |
| 1995 | -1.4 | -0.6 | 0.3 | -0.4 | |
| 1996 | | -0.8 | | | |
| 1997 | -2.5 | | | | |
| 2002 | -0.7 | 1.2 | p | 0.0 | -0.2 |
| 2007 | -0.6 | | 0.7 | -0.5 | |
| 2014 | 1.1 | | 2.2 | 0.9 | 0.2 |

Appendix C.–Growth (inches) of Bluegill, Pumpkinseed, and Black Crappie compared to state average growth in Sand Lake from 1988 through 2014. A "p" indicates fewer than five fish were collected.

| | Age | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Bluegill | | | | | | | | | | | | | |
| 1983 | | -0.5 | -0.3 | -0.1 | p | | | | | | | | |
| 1984 | | -0.2 | -0.4 | -0.4 | 0 | | | | | | | | |
| 1986 | | 0.1 | -0.7 | -0.7 | p | p | | | | | | | |
| 1987 | | p | -0.5 | -0.7 | p | p | | | | | | | |
| 1988 | p | 0 | -1.1 | -1.5 | -1.4 | -1.6 | -1.8 | p | | | | | |
| 1991 | p | -1.1 | -1.4 | -1.1 | -1.3 | p | p | p | | | | | |
| 1992 | -0.1 | -1.1 | -1.3 | -1.5 | -1 | -1.2 | | | | | | | |
| 1993 | -0.1 | -1 | -1.7 | -1.6 | -1.5 | -0.6 | -1.4 | | | | p | | |
| 1994 | 0 | | -2.1 | -2 | -1.9 | -1.7 | -1.6 | -1.3 | p | | | | |
| 1995 | -0.2 | -1.3 | -2.1 | -2.1 | -1.7 | -1.4 | -1.2 | -1.4 | -1.2 | | | | |
| 1996 | | p | p | p | p | | | | p | p | | | |
| 1997 | | | | -2.2 | p | -2.5 | -2.6 | p | | p | | | |
| 2002 | -0.3 | -0.9 | -0.7 | -0.6 | -0.7 | -0.6 | p | p | | | | | |
| 2007 | -0.5 | -1.8 | -0.3 | -0.3 | 0.1 | 0 | p | | p | | | | |
| 2014 | | | -0.9 | 0.1 | 1.3 | 1.9 | 1.9 | 2 | p | | | | |
| Pumpkinseed | | | | | | | | | | | | | |
| 1988 | p | -0.3 | -0.8 | -0.6 | -0.6 | -0.5 | 0 | p | | | | | |
| 1993 | | -1.3 | -1.4 | -1.1 | 0.1 | 0.4 | | p | | | | | |
| 1994 | | | | | | | | | | | | | |
| 1995 | | -1.2 | | -1.1 | -0.8 | -0.3 | -0.1 | -0.1 | p | p | | | p |
| 1996 | | | -0.8 | -1 | -1.1 | -0.8 | -0.6 | -0.3 | p | p | p | p | |
| 2002 | | | 1 | 1.4 | 1.1 | | | p | | | | | |
| 2007 | | 0.5 | p | p | p | p | | | | | | | |
| 2014 | | p | | p | p | | | | | | | | |
| Black Crappie | | | | | | | | | | | | | |
| 1988 | | | p | -1.2 | -2.2 | -2.8 | p | | | | | | |
| 1993 | p | p | 1 | 1.1 | 1.3 | p | p | p | p | | | | |
| 1995 | | p | p | | | p | 0.3 | 0.2 | 0.4 | p | p | | |
| 1996 | | | p | p | | | | | p | p | p | p | |
| 2002 | | p | 0 | p | | | | | | | | | |
| 2007 | | | p | 0.8 | 0.5 | p | p | | | | | | |
| 2014 | | | p | 1.6 | p | p | 2.8 | p | | | | | |
| Largemouth Bass | | | | | | | | | | | | | |
| 1984 | | | | p | p | p | p | | | | | | |
| 1986 | p | | p | | p | p | p | p | p | | p | | |
| 1987 | | p | | | p | p | p | | | | | | |
| 1993 | | 0.5 | -0.1 | p | p | -0.9 | 0.2 | p | p | p | | | |
| 1995 | p | p | -1.1 | 0.6 | 0.2 | -0.3 | -0.8 | -1.2 | p | | | p | |
| 1996 | | | p | -1.1 | p | p | p | | p | p | | | |
| 2002 | 0.2 | 0.4 | -0.5 | -0.2 | | p | p | | | | | | |
| 2007 | 1 | 0.6 | -0.7 | -1.3 | -2 | p | | | | p | p | | |
| 2014 | p | 0.9 | p | 2.4 | 0.8 | 0 | -0.5 | p | | | | | |

Appendix D.–Brush Lake sample sizes and length (inches) information for Largemouth Bass, Northern Pike, and Yellow Perch collected in trap nets.

| | Largemouth Bass | | Northern Pike | | Yellow Perch | |
|---|---|---|---|---|---|---|
| Year | Number | Average length | Number | Average length | Number | Average length |
| 1994 | 12 | 11.3 (6.5–16.5) | 0 | – | 0 | – |
| 1999 | 10 | 10.3 (7.5–13.5) | 3 | 21.5 (19.5–24.5) | 0 | – |
| 2001 | 15 | 12.2 (9.5–15.5) | 6 | 15.8 (12.5–17.5) | 6 | 8.8 (7.5–10.5) |
| 2003 | 46 | 10.1 (6.5–14.5) | 7 | 17.2 (14.5–19.5) | 7 | 9.5 (8.5–10.5) |
| 2007 | 9 | 13.6 (7.5–20.5) | 5 | 18.9 (15.5–22.5) | 0 | – |
| 2014 | 22 | 11.8 (7.5–17.5) | 25 | 20.9 (17.5–28.5) | 1 | 13.5 |

Appendix E.–Average growth (inches, all ages combined) of various fish species compared to state average growth in Brush Lake from 1999 through 2014. Growth comparisons were included if at least two ages could be averaged.

| Year | Bluegill | Pumpkinseed | Largemouth Bass | Northern Pike | Black Crappie |
|---|---|---|---|---|---|
| 1999 | -0.9 | -0.6 | | | |
| 2001 | 0.7 | | 0.5 | | |
| 2003 | 0.3 | -1.0 | -1.3 | | |
| 2007 | -0.5 | -0.7 | -0.9 | | |
| 2014 | 0.5 | 0.8 | 0.9 | -2.6 | 0.7 |

Appendix F.–Growth (inches) of Bluegill, Pumpkinseed, and Largemouth Bass compared to state average growth in Brush Lake from 1999 through 2014. A "p" indicates fewer than five fish were collected.

| | Age | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Bluegill | | | | | | | | | | | | | |
| 1999 | 0.2 | p | -0.2 | p | -1 | -1.4 | -1.3 | -1.4 | -1.5 | p | p | p | |
| 2001 | 0.7 | p | 0.6 | 0.7 | 0.6 | p | 0.8 | p | p | p | | | |
| 2003 | -0.1 | -1.3 | 0.6 | 1.1 | 0.5 | p | p | 0.9 | p | p | p | p | p |
| 2007 | p | -1.5 | -1.5 | p | 0.4 | 0 | 0.2 | -0.2 | p | p | | | |
| 2014 | | | p | -0.8 | -0.1 | 0.5 | 1.2 | 1.7 | | | | | |
| Pumpkinseed | | | | | | | | | | | | | |
| 1999 | -0.2 | | | | p | -0.7 | -0.8 | p | | | | | |
| 2001 | p | p | p | p | p | p | p | p | | | | | |
| 2003 | | p | -0.3 | -1.5 | -0.8 | -0.8 | -1.6 | p | | p | | | |
| 2007 | | p | -1 | -0.8 | -0.4 | -0.7 | p | | | | | | |
| 2014 | | | p | 0.7 | 0.9 | p | p | | | | | | |
| Largemouth Bass | | | | | | | | | | | | | |
| 1999 | | | p | -0.2 | p | p | p | | | | | | |
| 2001 | -0.6 | 0.5 | 0.7 | 1.3 | p | p | | p | p | p | | | |
| 2003 | -1.6 | -2 | -0.6 | -1.1 | p | p | p | | | | | | |
| 2007 | p | 0 | -0.3 | -0.9 | -0.8 | -1.7 | p | p | p | | | | p |
| 2014 | | 0.8 | 1.3 | 0.6 | p | p | p | p | | | | | |

Appendix G.–Baptist Lake sample sizes and length (inches) information for Black Crappie, Largemouth Bass, Northern Pike, Rock Bass, and Yellow Perch collected in trap nets and gill nets.

| | Black Crappie | | Largemouth Bass | | Northern Pike | | Rock Bass | | Yellow Perch | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Number | Average length | Number | Average length | Number | Average length | Number | Average length | Number | Average length |
| 1987 | 0 | – | 5 | 6.9 (5.5–7.5) | 4 | 29.5 (25.5–33.5) | 0 | – | 1 | 7.5 |
| 1989 | 3 | 10.2 (9.5–10.5) | 0 | – | 0 | – | 0 | – | 7 | 6.2 (5.5–6.5) |
| 1994 | 0 | – | 2 | 9.5 (9.5–9.5) | 0 | – | 6 | 8.3 (5.5–11.5) | 0 | – |
| 1996 | 10 | 11.6 (9.5–13.5) | 3 | 8.8 (7.5–10.5) | 12 | 23.2 (19.5–28.5) | 27 | 8.8 (4.5–11.5) | 1 | 10.5 |
| 1998 | 11 | 10.9 (6.5–13.5) | 3 | 9.2 (5.5–12.5) | 15 | 24.7 (20.5–28.5) | 44 | 9.2 (4.5–10.5) | 1 | 5.5 |
| 1999 | 22 | 8.9 (5.5–13.5) | 7 | 11.5 (9.5–12.5) | 10 | 22.9 (18.5–27.5) | 65 | 9.7 (4.5–12.5) | 0 | – |
| 2001 | 7 | 10.1 (8.5–11.5) | 0 | – | 7 | 24.1 (17.5–27.5) | 27 | 8.6 (4.5–11.5) | 0 | – |
| 2003 | 38 | 5.8 (4.5–9.5) | 7 | 10.4 (8.5–13.5) | 14 | 20.9 (9.5–27.5) | 17 | 8.4 (4.5–12.5) | 1 | – |
| 2007 | 26 | 7.8 (5.5–11.5) | 6 | 10.0 (6.5–16.5) | 28 | 23.0 (17.5–30.5) | 13 | 7.9 (4.5–11.5) | 1 | 6.5 |
| 2013 | 8 | 8.5 (6.5–10.5) | 6 | 13.3 (9.5–17.5) | 36 | 21.6 (15.5–29.5) | 24 | 7.7 (4.5–11.5) | 3 | 7.5 (6.5–8.5) |

Appendix H.–Average growth (inches, all ages combined) of various fish species compared to state average growth in Baptist Lake from 1985 through 2013. Growth comparisons were included if at least two ages could be averaged.

| Year | Bluegill | Pumpkinseed | Largemouth Bass | Yellow Perch | Black Crappie | Northern Pike |
|---|---|---|---|---|---|---|
| 1985 | -1.7 | | | | | |
| 1987 | -1.3 | -0.9 | | | | |
| 1989 | -2.6 | -1.2 | | | | |
| 1994 | | | | | | |
| 1996 | -1.1 | -0.1 | -2.1 | | | -0.3 |
| 1998 | -2.0 | -0.7 | | | | |
| 1999 | -1.3 | -0.8 | -1.7 | | -0.7 | |
| 2001 | -1.0 | | -1.0 | -2.4 | | |
| 2003 | -1.3 | -0.8 | -1.2 | | | |
| 2007 | -1.3 | -0.7 | -1.9 | | -0.7 | -2.2 |
| 2013 | -1.2 | -0.8 | -1.5 | | | -4.9 |

Appendix I.–Growth (inches) of Bluegill, Pumpkinseed, Black Crappie and Largemouth Bass compared to state average growth in Baptist Lake, from 1985 through 2013. A "p" indicates fewer than five fish were collected.

| | Age | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Bluegill | | | | | | | | | | | | | |
| 1985 | | | -1.6 | -2.6 | -1.6 | -1 | p | | | | | | |
| 1987 | | p | p | -1.1 | -1.4 | p | p | | | | | | |
| 1989 | p | p | p | p | -2.3 | -2.5 | -2.6 | -3 | | | | | |
| 1996 | | | | -1.5 | -1.4 | -0.9 | -0.8 | -0.7 | | | | | |
| 1998 | | p | p | -2 | -2.1 | -1.9 | -1.9 | p | | p | | | |
| 1999 | | -1.3 | -0.9 | -2 | -2.1 | -2.5 | -1.1 | -0.7 | -0.1 | | | | |
| 2001 | -0.2 | -1.3 | -1.1 | -1.3 | -0.9 | -1.2 | -1.1 | -0.7 | p | | | | |
| 2003 | -0.3 | -1.6 | p | -2.3 | -1.5 | -1.6 | -2.2 | -0.4 | -0.4 | p | | | |
| 2007 | -0.3 | -1.5 | p | -2.3 | -2.3 | -0.8 | -0.7 | p | | | p | | |
| 2013 | | -1.4 | -1.9 | -1.8 | -1.5 | -0.6 | -0.5 | -0.3 | p | | | | |
| Pumpkinseed | | | | | | | | | | | | | |
| 1985 | | | p | p | p | | | | | | | | |
| 1987 | | | p | -1 | -0.8 | -0.9 | p | | | | | | |
| 1989 | | -0.8 | -0.9 | -1.3 | -1.2 | -1.6 | -1.8 | | | | | | |
| 1996 | | | | p | -0.9 | 0.3 | 0.4 | p | p | | | | |
| 1998 | | | | p | -1 | -0.4 | p | p | p | | | | |
| 1999 | | | -1.1 | -1 | p | -0.2 | 0 | p | | | | | |
| 2001 | | | p | -0.4 | p | p | p | p | | | | | |
| 2003 | | | -1.1 | -1 | -0.6 | -0.9 | -0.3 | | | | | | |
| 2007 | | p | p | -1.2 | -0.2 | | p | | | | | | |
| 2013 | | p | -0.7 | -0.9 | p | p | p | p | p | | | | |
| Black Crappie | | | | | | | | | | | | | |
| 1996 | | | | | p | | p | p | p | | | | |
| 1998 | | | | | | p | p | p | p | p | p | p | p |
| 1999 | | p | -1.2 | p | 0 | p | -0.1 | | | p | | | |
| 2001 | | | p | p | p | | | | | | | | |
| 2003 | | -1 | p | p | | | | | | | | | |
| 2007 | | -0.6 | -0.7 | p | p | p | | p | | | | | |
| 2013 | | | p | p | p | p | p | | | | | | |
| Largemouth Bass | | | | | | | | | | | | | |
| 1985 | | | p | p | p | p | p | | | | | | |
| 1987 | p | p | p | | | | | | | | | | |
| 1996 | | | p | -1.2 | p | p | -2.3 | -2.9 | p | | | | |
| 1998 | | p | | p | | p | | | | | | | |
| 1999 | | -1.4 | -2.1 | -1.1 | -1.1 | -1.1 | -2.5 | -1.8 | -2.3 | | | | |
| 2001 | p | -1.2 | -1.4 | -0.3 | p | p | | p | | | | | |
| 2003 | 1.4 | -1.8 | p | -1.3 | -2.1 | -2 | p | | | | | | |
| 2007 | p | -2.7 | -1.3 | p | p | -1.7 | p | p | | | | | |
| 2013 | p | -2.6 | -2.7 | -0.6 | -0.2 | p | p | | | | p | | |