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Growth, Movement, and Contribution of Stocked and Wild Fish to the Lower St. Joseph River Walleye Population

Brian J. Gunderman

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Abstract.–Walleyes *Sander vitreus* are native to the St. Joseph River but abundance of this species was reduced in the late 19th and early 20th centuries by habitat degradation and dam construction. Water quality in the river began to improve in the 1970s, and the Michigan Department of Natural Resources initiated a Walleye stocking program in 1980 to augment the existing population and enhance fishing opportunities. Age-frequency data from creel surveys conducted on the river during the 1990s suggested substantial natural recruitment of Walleyes in this system. As part of an effort to more accurately quantify the relative contributions of stocked and wild fish to the lower St. Joseph River Walleye population, oxytetracycline-marked spring fingerlings were stocked at various locations downstream of the Niles, Buchanan, and Berrien Springs dams during 2005–2011. Fall electrofishing surveys were conducted annually at six sites between the Niles Dam and Benton Harbor during 2005–2012. Sagittal otoliths were removed from each Walleye and examined for oxytetracycline marks, and ages of captured Walleyes were ascertained from dorsal fin ray samples. The total catch for all sampling efforts was 431 Walleyes from the 2005–2012 year classes. Marked fish represented 47% of the catch. The percentage of marked fish varied among sampling sites and cohorts. Significant positive correlations were observed between capture rates for unmarked and marked young-of-year Walleyes and between capture rates for unmarked and marked age 0–2 Walleyes. Upstream movement of Walleyes through the Berrien Springs fish ladder was limited. However, downstream movement of stocked Walleyes past one or more dams was common. Catch-per-effort of unmarked young-of-year Walleyes was highest in the stream reaches immediately downstream of dams. No significant correlations were observed between mean April discharge during the year of hatching and subsequent electrofishing catch rates for unmarked juvenile Walleyes. Mean lengths at age for Walleyes in the lower St. Joseph River exceeded statewide averages. General linear model results indicated that marginal mean lengths at age were significantly greater for Walleyes collected downstream of the Berrien Springs Dam compared to fish captured upstream of the dam. Conversely, marginal mean lengths at age for unmarked and marked fish were not statistically different. Stocked fish strongly contribute to the Walleye population in this system, and biennial stocking of spring fingerling Walleyes is recommended to maintain the existing fishery.

Introduction

The St. Joseph River basin, located in southwest Michigan and north-central Indiana, is the third largest river basin in Michigan. The river begins at Baw Beese Lake in Hillsdale County and flows in a northerly arc before turning south and entering Indiana. The river flows west through the cities of Elkhart and Mishawaka, then makes an abrupt turn to the north at the city of South Bend. It re-enters

Michigan in southeastern Berrien County and flows northwest to its confluence with Lake Michigan at the twin cities of St. Joseph and Benton Harbor. The St. Joseph River main stem is 210 miles long, and its tributaries total an additional 1,641 miles (Wesley and Duffy 1999). The watershed encompasses 4,685 square miles: 3,000 square miles in Michigan and 1,685 square miles in Indiana. The average discharge at the mouth is 4,598 cubic feet per second (Dexter and Ledet 1994). Agriculture (70%) and forests (17%) are the predominant land uses within the watershed (DeGraves 2005).

The lower St. Joseph River supports a diverse fish community that changes seasonally. Numerous warmwater species live in the river year-round. Fish ladders at the Berrien Springs (river mile [RM] 23), Buchanan (RM 33), Niles (RM 42), South Bend (RM 56), and Mishawaka (RM 60) dams allow steelhead *Oncorhynchus mykiss*, Chinook Salmon *O. tshawytscha*, Coho Salmon *O. kisutch* and Brown Trout *Salmo trutta* from Lake Michigan to ascend the river as far as the Twin Branch Dam (RM 63; Figure 1). Some warmwater species (e.g., Walleye *Sander vitreus*, Smallmouth Bass *Micropterus dolomieu*, and White Suckers *Catostomus commersonii*) also use the fish ladders, but movement of these species through the ladders is limited. Approximately 99% of the fish moving through the Berrien Springs and Niles fish ladders are salmonids.

Walleyes are native to the St. Joseph River. Archaeological evidence and anecdotal information suggest that abundance of this species was reduced in the late 19th and early 20th centuries by habitat degradation and dam construction (Wesley and Duffy 1999). Water quality in the river began to improve in the 1970s, and the Michigan Department of Natural Resources (MDNR) initiated a Walleye stocking program in 1980 to augment the existing population and enhance fishing opportunities (Table 1).

Creel surveys were conducted annually from the Niles Dam to Benton Harbor during 1992–2004. The primary purpose of these surveys was to collect information regarding fishing effort and harvest of salmonids. However, creek clerks also collected data on harvest of Walleyes and other native species. The mean annual fishing effort during this period was 224,285 angler hours. Targeted effort estimates (which only are available for 1997–2004) indicated that 59% of the fishing effort was directed toward salmonids, 16% was directed toward Walleyes, and the remaining 25% was directed toward other species or no particular species. Walleyes were 16% of the total harvest in the lower St. Joseph River (range = 8% between the Buchanan and Berrien Springs dams to 29% between the Jasper Dairy boat launch and Carronde Park) during 1992–2004 (Figure 1; Table 2). The estimated total Walleye harvest between the Niles Dam and Benton Harbor for this period was 51,673 fish (Gunderman 2017). Walleye harvest/angler hour (HPH) averaged 0.0177 fish/hr. This HPH is close to the median of HPH values recorded for Michigan rivers and similar to Walleye HPHs in the Grand and Kalamazoo rivers (Z. Su, MDNR – Fisheries Division, unpublished). Within the lower St. Joseph River, Walleye HPH varied by stream reach from 0.0087 fish/hr between the Buchanan and Berrien Springs dams to 0.0348 fish/hr between the Jasper Dairy boat launch and Carronde Park.

The abundance of forage fish and variable habitat types in the St. Joseph River facilitate rapid growth of Walleyes. Walleyes harvested in the river downstream of the Berrien Springs Dam during 1994–2003 were growing above state average growth rates (mean growth index = +2.5; Schneider et al. 2000). The minimum size limit for Walleyes is 15 inches and the daily possession limit is five fish. Creel data collected below Berrien Springs Dam from 1994 to 2003 showed that Walleyes were recruiting to the fishery at age 2, and this age class averaged 16.3 inches. Walleyes harvested during this period primarily were ages 2–4. Beginning in April 1999, anglers were prohibited from harvesting more than one Walleye 23 inches or larger per day between the Berrien Springs Dam and the mouth of the river. No changes in the age structure of the population were observed after the regulation change, so this regulation was rescinded in April 2010.

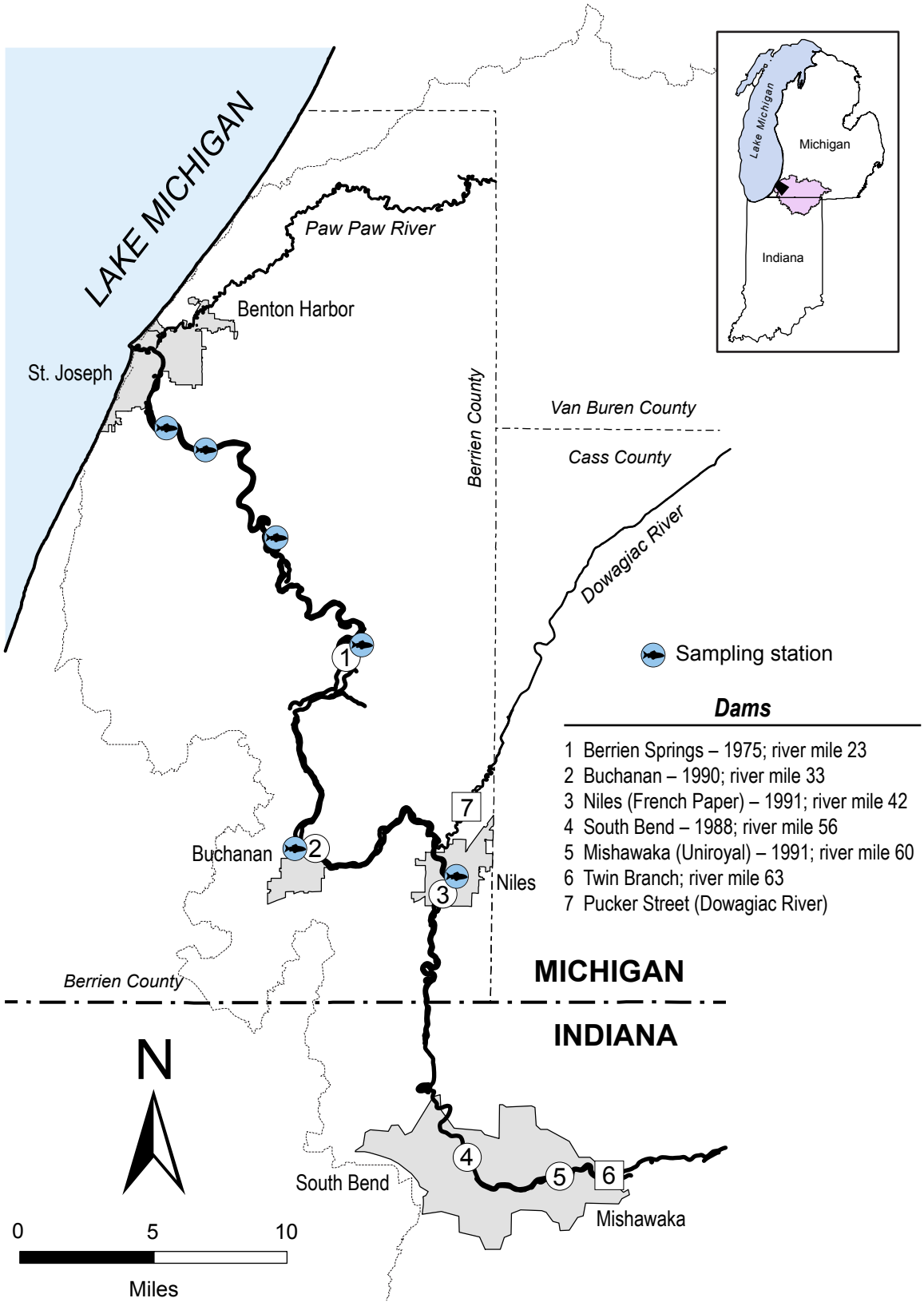

Figure 1.–Major dams and cities in the lower St. Joseph River watershed. Circles indicate dams with fish ladders and squares indicate dams that are impassable barriers. The year of fish ladder construction is listed for dams with fish passage. Sampling locations for the annual electrofishing surveys on the lower St. Joseph River, 2005–2012. See Table 2 for station descriptions.

Table 1.–Walleye stocking in the St. Joseph River between the Niles Dam and Lake Michigan, 1980–2004.

Year	Fry	Spring fingerlings	Fall fingerlings
1980	1,090,000	216	
1981	2,190,000	91	
1982	4,600,000	51,667	
1983		21,698	
1984	3,030,000	92,621	
1985	3,000,000	161,564	
1986	1,137,500	159,676	
1987	1,843,000	106,124	
1988	3,600,000	148,242	
1989	3,000,000	112,403	
1990			
1991		121,518	5,500
1992		86,002	
1993		103,402	
1994		72,591	
1995		91,764	
1996		53,248	
1997		110,233	
1998		56,195	
1999		227,561	
2000		127,355	
2001		151,644	
2002			
2003		101,732	
2004			

Table 2.–Sampling locations for the annual electrofishing surveys on the lower St. Joseph River, 2005–2012. Mean widths were measured with a rangefinder during the 2005 survey. Mean depths were estimated with an electronic depth sounder in 2011. The station boundaries at sites 3 and 4 were adjusted in 2006 to avoid areas that were too deep for efficient sampling.

Site	General description	Upstream end	Downstream end	Station length (mi)	Mean width (ft)	Mean depth (ft)
1	Niles boat launch to stormwater outlet below railroad crossing	N 41.82626º W 86.25769º	N 41.83654º W 86.25971º	0.8	228	5.5
2	Buchanan access site (lower) to Bachelor Island	N 41.83998º W 86.35596º	N 41.84804º W 86.36626º	0.8	297	5.0
3	Power line to downstream end of large island below Shamrock Park	N 41.95632º W 86.33032º	N 41.96316º (2005) W 86.32093º	0.8	291	5.0
		N 41.95000º W 86.33660º	N 41.95626º (2006-12) W 86.32911º			
4	Jasper Dairy launch to first major bend downstream	N 42.01303º W 86.39144º	N 42.02284º (2005) W 86.39230º	1.0	243	6.5
		N 42.00898º W 86.38986º	N 42.02258º (2006-12) W 86.39052º			
5	Irrigation pipe to I-94 East	N 42.06026º W 86.43152º	N 42.06188º W 86.44880º	1.0	324	5.0
6	Carronde Park to Eagle Point Harbor	N 42.06994º W 86.46970º	N 42.07931º W 86.47487º	0.8	339	6.5

Suitable Walleye spawning and nursery habitat exists in the St. Joseph River, providing the possibility for natural reproduction. During alternate years from 1990 to 1998, no spring fingerling Walleyes were stocked in the St. Joseph River below the Berrien Springs Dam. Walleye recruitment to the creel during this period was estimated at 55% from non-stocked years. These results suggested substantial natural recruitment in this system. However, because stocked fish were not marked, it was not possible to quantify the contribution of stocked fish to the population. This information is necessary to evaluate the cost-effectiveness and importance of the stocking program for maintaining the Walleye fishery in the lower St. Joseph River.

Methods

In 2005, MDNR began a more rigorous evaluation of the relative contributions of stocked and wild fish to the St. Joseph River Walleye population. Spring fingerling Walleyes were stocked below the Niles, Buchanan, and Berrien Springs dams in 2005 (Table 3). These fish were marked with oxytetracycline (OTC) during the fry stage according to the procedures outlined by Fielder (2002). Fish stocked below Berrien Springs Dam received a single OTC mark. Fish stocked below the Buchanan and Niles dams were double-marked: once as fry and once as spring fingerlings. This marking protocol was used to facilitate detection of upstream and downstream movement of Walleyes past the Berrien Springs Dam. No Walleye stocking occurred in the study area in 2006. However, the Indiana Department of Natural Resources (IDNR) stocked approximately 70,000 double OTC-marked spring fingerling Walleyes in the St. Joseph River upstream of Twin Branch Dam (Figure 1). In 2007, MDNR's Walleye rearing program was disrupted by the discovery of viral hemorrhagic septicemia (VHS) virus in the Great Lakes. The broodstock populations that provide eggs for MDNR's Walleye program have access to the Great Lakes and potentially could have been infected with the virus. All Walleye rearing operations were suspended while research was completed regarding the distribution and transmission of the VHS virus. In 2008 and 2009, MDNR stocked single-marked (i.e., fry-marked) Walleyes below Berrien Springs Dam. Stocking was prohibited upstream of the Berrien Springs Dam during these years due to continued concerns regarding the potential spread of the VHS virus. These restrictions were lifted the following year, and double-marked Walleyes were stocked below the Niles and Buchanan dams in 2010. In 2011, double-marked Walleyes were stocked below the Niles, Buchanan, and Berrien Springs dams. (In contrast to the stocking procedures in 2005, 2008, and 2009, the fish stocked below Berrien Springs Dam in 2011 were double-marked to facilitate an evaluation of immigration of single-marked Walleyes from other systems [e.g., the Muskegon River] into the lower St. Joseph River.) IDNR stocked a total of 38,993 fall fingerling Walleyes in the Twin Branch Impoundment in 2008, 2009, and 2011. The fish stocked in 2008 were marked with a left pectoral fin clip and the fish stocked in 2009 and 2011 were unmarked.

Fall electrofishing surveys were conducted annually at six sites (below Niles Dam, below Buchanan Dam, and four sites below Berrien Springs Dam) during 2005–2012 (Figure 1; Tables 2 and 4). Electrofishing began at the upstream boundary of the sampling reach and proceeded in a downstream direction. In general, sampling was conducted across the entire width of the river channel by making a total of seven passes (three passes on both sides of mid-river and one pass down the middle of the river). In 2012, only five passes were completed at site 3 due to low water levels. At site 4, only three passes were made along a 0.2 mile portion of the site during 2006–2012 because the outside bend of the river was too deep for efficient sampling.

Sampling crews collected Walleyes that appeared to be from the 2005–2012 year classes and thus potentially could have OTC marks. In 2005, only Walleyes that appeared to be young-of-year (YOY) fish were collected. By 2012, all Walleyes of any size were collected. Total length was recorded for all Walleyes captured.

Table 3.–Spring fingerling Walleye stocking in the Berrien County portion of the St. Joseph River, 2005–2012. All Walleyes were marked with oxytetracycline (OTC) as fry. Fish listed as double-marked also were marked as spring fingerlings.

Year	Stream reach	Stocking location	Number of fish	OTC mark
2005	Niles Dam to Buchanan Dam	Niles City Park	25,760	Double
	Buchanan Dam to Berrien Springs Dam	Buchanan City Launch	24,852	Double
	Berrien Springs Dam to mouth	Shamrock Park	18,201	Single
2008	Berrien Springs Dam to mouth	Shamrock Park	14,245	Single
		Berrien Co. Sportsmen's Club	23,995	Single
		Benton Township Launch	16,106	Single
2009	Berrien Springs Dam to mouth	Shamrock Park	15,000	Single
		Berrien Co. Sportsmen's Club	24,569	Single
		Benton Township Launch	22,537	Single
2010	Niles Dam to Buchanan Dam	Niles City Park	25,090	Double
	Buchanan Dam to Berrien Springs Dam	Buchanan Dam Access Site	25,090	Double
2011	Niles Dam to Buchanan Dam	Niles City Park	24,756	Double
	Buchanan Dam to Berrien Springs Dam	Buchanan City Launch	24,756	Double
	Berrien Springs Dam to mouth	Shamrock Park	15,015	Double
		Berrien Co. Sportsmen's Club	20,047	Double
		Benton Township Launch	15,015	Double

Table 4.–Start and end dates for electrofishing surveys conducted on the lower St. Joseph River during 2005–2012.

Year	First survey completed	Last survey completed
2005	October 13	November 3
2006	October 17	November 1
2007	October 23	November 7
2008	October 14	November 6
2009	October 13	November 17
2010	October 11	November 22
2011	November 1	December 1
2012	October 29	November 20

Dorsal spine samples were collected from each fish for age determination. Spine samples were sectioned using a table-mounted high-speed rotary cutting tool. Sections approximately 0.5 mm thick were cut as close to the proximal end of the spine as possible. Cross-sections were cleaned with water or glycerin and examined at 40x–80x with transmitted light. Age determinations typically were performed by one technician, but questionable samples were reviewed by two technicians. Sagittal otoliths were removed from each Walleye and examined for OTC fry- and fingerling-marks according to the procedures described by Fielder (2002). Due to a miscommunication between the field office and the laboratory, otoliths from the 2010 survey were identified as marked or unmarked but were not further identified as single- or double-marked.

After the dorsal fin rays and otoliths were examined, captured Walleyes were divided into cohorts (i.e., year classes). Data from the 2005–2012 surveys were pooled to calculate percentage contributions of marked and unmarked fish to each cohort. Percentages of marked and unmarked fish were calculated for the lower St. Joseph River (all sites) and individual sites. Spearman's rank correlation test was used to evaluate potential correlations between the number of spring fingerling Walleyes stocked and subsequent capture rates for unmarked and marked fish of each year class in fall electrofishing surveys. This test also was used to assess the relationship between electrofishing catch rates of unmarked and marked Walleyes in the lower St. Joseph River.

Mion et al. (1998) found that survival of larval Walleyes in Lake Erie tributaries was inversely related to stream discharge. It was hypothesized that flow conditions also influenced survival of naturally produced Walleyes in the St. Joseph River. Spearman's rank correlation test was used to evaluate correlations between mean April discharge at the United States Geological Survey (USGS) gauge site at Niles during the year of larval emergence and subsequent catch-per-effort (CPE) of unmarked juvenile (age 0–2) Walleyes.

A general linear model was used to assess whether variation in length at age of age-0 to age-7 Walleyes could be explained by origin (hatchery vs. wild), location (upstream vs. downstream of Berrien Springs Dam), or sampling year. In this analysis, origin was a fixed effect, while location and sampling year were treated as categorical blocking variables. Marginal (least squares) mean lengths at age of hatchery and wild fish were computed to account for unequal sample sizes across blocks.

Results

The total catch for all sampling efforts was 431 Walleyes from the 2005–2012 year classes. Marked fish (n = 201) were 47% of the catch (Table 5). The percentage of marked fish at individual sampling sites ranged from 33% at site 1 to 53% at site 6 (Figure 2).

The percentage of marked fish varied among cohorts (Figure 3; Tables 6–11). Only 4% of the Walleyes from the 2009 cohort had OTC marks, whereas marked fish were 89% of the 2011 cohort. No Walleyes were stocked in the St. Joseph River in 2007. Twelve unmarked fish from that year class were captured during this study. Eleven (92%) of these fish were collected downstream of the Berrien Springs Dam. No young-of-year Walleyes were captured in 2012. Across cohorts, there were no consistent increases or decreases in the percentage contribution of marked fish with increasing age (Figure 4).

Significant positive correlations were observed between spring fingerling Walleye stocking numbers and subsequent capture rates for marked YOY Walleyes, and unmarked age 0–2 Walleyes (Figures 5–6; Table 12). Significant positive correlations also were observed between capture rates for unmarked and marked YOY Walleyes and between capture rates for unmarked and marked age 0–2 Walleyes. No significant correlation was detected between spring fingerling Walleye stocking numbers and subsequent capture rates for marked 0–2 Walleyes.

Upstream movement of stocked Walleyes was limited. During 2005–2012, 36 marked fish from the 2005 year class were captured at sites 1 and 2. Thirty-five of these fish had double OTC marks indicating that they had been stocked upstream of the Berrien Springs Dam. One fish with a single OTC mark was captured at site 1 in 2008. This fish apparently moved upstream through the Berrien Springs and Buchanan fish ladders.

Downstream movement of stocked fish past one or more dams was common. Fifty-three marked fish from the 2005 year class were captured at sites 3–6 during 2005–2012. Two fish collected in the 2010 surveys were identified as marked but were not further identified as single or double-marked. Of the remaining 51 individuals, 30 (59%) were double-marked fish that had moved downstream from the Niles or Buchanan stocking sites. Similarly, 10 double-marked fish that IDNR stocked upstream of Twin Branch Dam in 2006 were collected during this study. These fish had moved downstream past four or more dams.

Three single-marked Walleyes from the 2006 year class were captured at sites 5 and 6. These fish presumably were stocked in Muskegon Lake and moved along the coastline of Lake Michigan before ascending the St. Joseph River. Single-marked Walleyes also were stocked in Muskegon Lake in 2010 and 2012, but none of these fish were collected during the present study.

For each year class, the Walleye CPE varied with age and typically was greatest for juvenile fish. Thus, CPE of age 0–2 fish provides a rough index of year class strength. Relatively strong year classes of wild fish were produced in 2005 and 2008 (Figures 5–6). The CPE for marked Walleyes also was high for the 2005 and 2008 year classes. Less data were available to assess the strength of the 2011 and 2012 year classes. Natural recruitment apparently was poor in those years, but many marked fish from the 2011 year class were collected in 2012 (Table 11). There were no significant correlations between mean April discharge at the USGS gauge site in Niles during the year of hatching and subsequent electrofishing catch rates for unmarked juvenile Walleyes (Figure 7).

Forty-four unmarked YOY Walleyes were collected during the 2005–2012 electrofishing surveys. Catch rates for unmarked YOYs were greatest at the upper sampling stations. Ninety-one percent of the unmarked YOYs were collected at sites 1–3 (Figure 8). Site 2 had the highest total catch for marked YOYs. Eighteen marked YOYs were collected at site 2 in 2005, whereas zero marked YOYs were captured at this site during 2006–2012. No YOYs were collected at site 6.

Table 5.–Numbers of unmarked (U) and oxytetracyline-marked (M) Walleyes captured per year at each sampling station on the St. Joseph River during 2005–2012. Only Walleyes from the 2005–2012 year classes were included in this analysis. See Figure 1 for site locations.

	2005		2006		2007		2008		2009		2010		2011		2012		Total	
Site	U	M	U	M	U	M	U	M	U	M	U	M	U	M	U	M	U	M
1	10	5	3	1	7	2	1	3	1	0	8	0	2	3	1	2	33	16
2	5	18	2	3	1	1	14	4	0	0	7	0	2	1	1	0	32	27
3	0	1	1	6	0	1	8	4	5	1	14	3	17	7	5	10	50	33
4	1	1	2	5	3	3	0	2	3	4	4	1	3	3	6	4	22	23
5	0	4	6	3	7	2	2	1	3	6	5	6	4	3	1	4	28	29
6	0	0	14	16	5	3	10	2	5	5	16	10	3	2	12	34	65	72
All	16	29	28	34	23	13	35	16	17	16	54	20	31	19	26	54	230	201

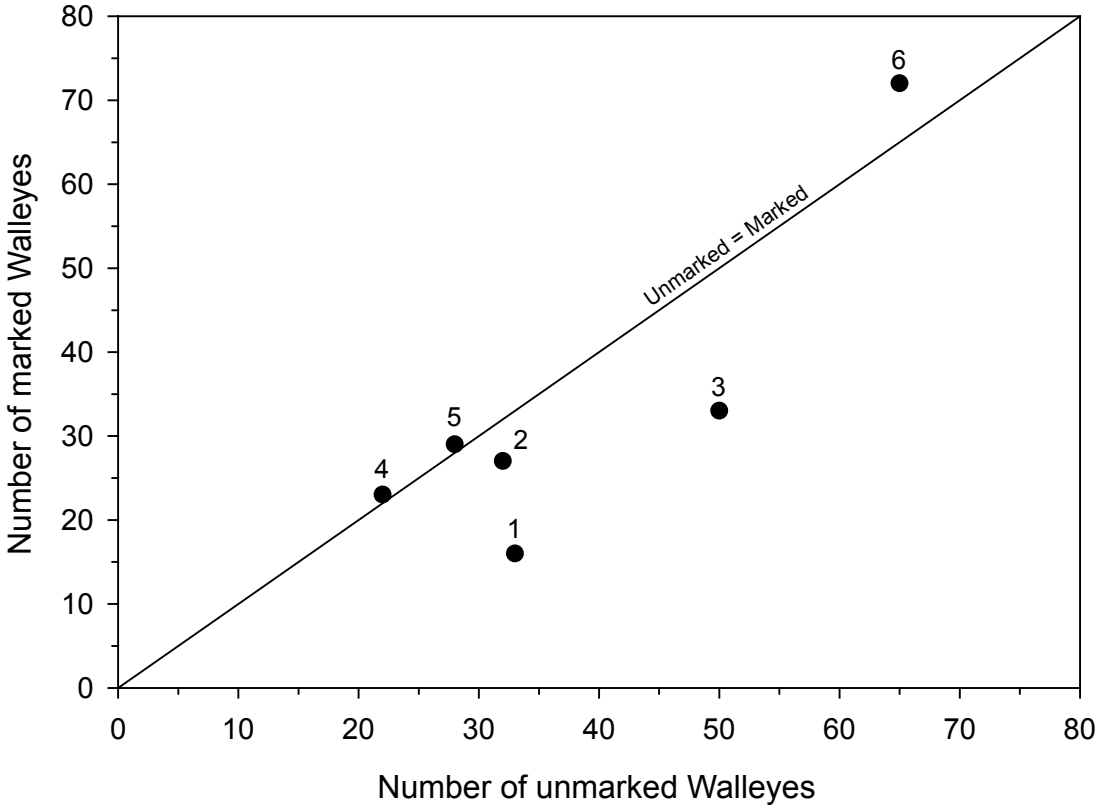

Figure 2.–Numbers of unmarked and oxytetracycline-marked Walleyes captured at each site (labels = site numbers) in the St. Joseph River during fall electrofishing surveys, 2005–2012. See Figure 1 for site locations.

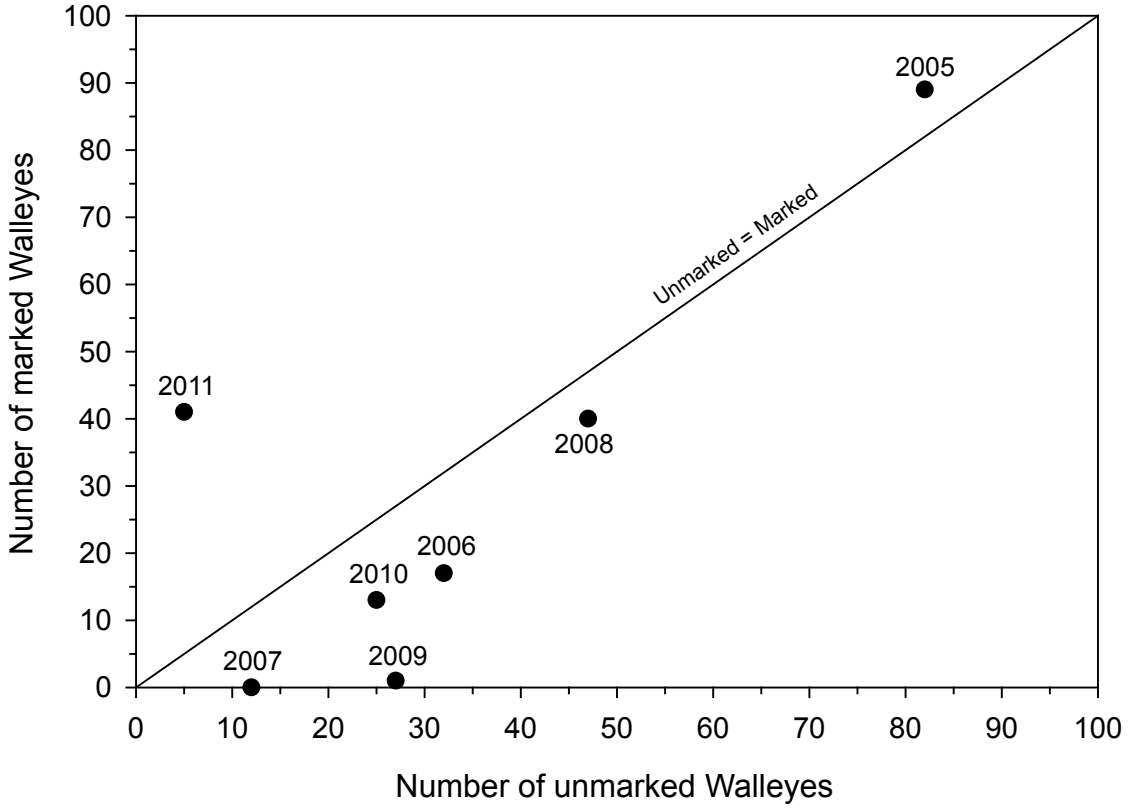

Figure 3.–Numbers of unmarked and oxytetracycline-marked Walleyes from each year class captured in the St. Joseph River during fall electrofishing surveys, 2005–2012. No fish from the 2012 year class were collected.

Table 6.–Numbers of unmarked and oxytetracycline-marked Walleyes from the 2005 year class collected at each sampling site during the 2005–2012 fall electrofishing surveys on the lower St. Joseph River. See Figure 1 for site locations.

Site	Unmarked	Marked	Total Catch	% Marked
1	21	11	32	34.4
2	11	25	36	69.4
3	4	9	13	69.2
4	8	11	19	57.9
5	13	10	23	43.5
6	25	23	48	47.9
Total	82	89	171	52.0

Table 7.–Numbers of unmarked and oxytetracycline-marked Walleyes from the 2006 year class collected at each sampling site during the 2006–2012 fall electrofishing surveys on the lower St. Joseph River. See Figure 1 for site locations.

Site	Unmarked	Marked	Total Catch	% Marked
1	3	3	6	50.0
2	2	2	4	50.0
3	5	2	7	28.6
4	2	2	4	50.0
5	7	3	10	30.0
6	13	5	18	27.8
Total	32	17	49	34.7

Table 8.–Numbers of unmarked and oxytetracycline-marked Walleyes from the 2008 year class collected at each sampling site during the 2008–2012 fall electrofishing surveys on the lower St. Joseph River. See Figure 1 for site locations.

Site	Unmarked	Marked	Total Catch	% Marked
1	1	0	1	0.0
2	15	0	15	0.0
3	17	9	26	34.6
4	4	6	10	60.0
5	0	10	10	100.0
6	10	15	25	60.0
Total	47	40	87	46.0

Table 9.–Numbers of unmarked and oxytetracycline-marked Walleyes from the 2009 year class collected at each sampling site during the 2009–2012 fall electrofishing surveys on the lower St. Joseph River. See Figure 1 for site locations.

Site	Unmarked	Marked	Total Catch	% Marked
1	3	0	3	0.0
2	3	0	3	0.0
3	8	0	8	0.0
4	3	0	3	0.0
5	4	0	4	0.0
6	6	1	7	14.3
Total	27	1	28	3.6

Table 10.–Numbers of unmarked and oxytetracycline-marked Walleyes from the 2010 year class collected at each sampling site during the 2010–2012 fall electrofishing surveys on the lower St. Joseph River. See Figure 1 for site locations.

Site	Unmarked	Marked	Total Catch	% Marked
1	5	1	6	16.7
2	0	1	1	100.0
3	8	5	13	38.5
4	3	0	3	0.0
5	1	2	3	66.7
6	8	4	12	33.3
Total	25	13	38	34.2

Table 11.–Numbers of unmarked and oxytetracycline-marked Walleyes from the 2011 year class collected at each sampling site during the 2011–2012 fall electrofishing surveys on the lower St. Joseph River. See Figure 1 for site locations.

Site	Unmarked	Marked	Total Catch	% Marked
1	0	1	1	100.0
2	0	0	0	–
3	4	8	12	66.7
4	0	4	4	100.0
5	0	4	4	100.0
6	1	24	25	96.0
Total	5	41	46	89.1

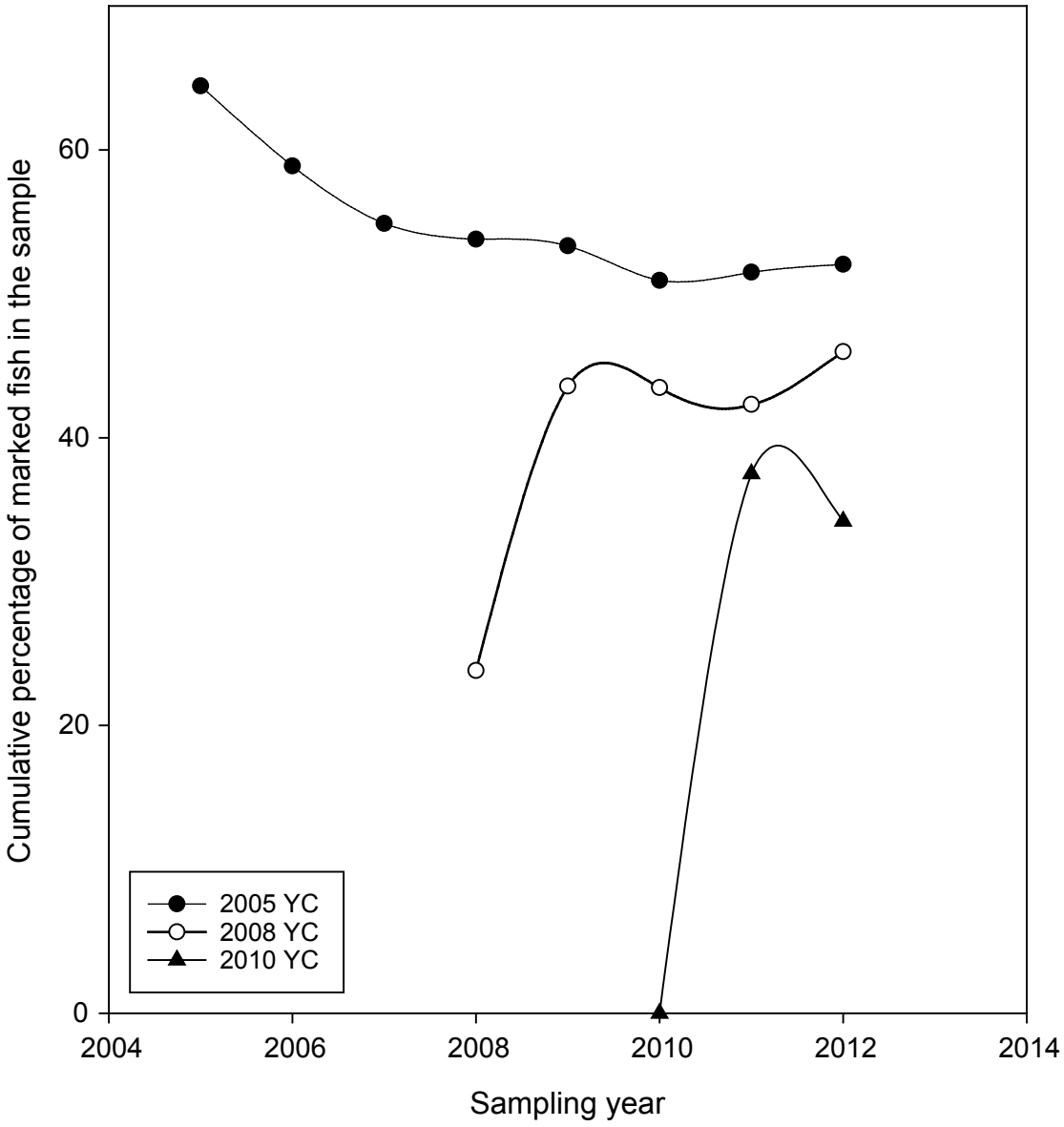

Figure 4.–Cumulative percentages of oxytetracycline-marked fish in the catch for each Walleye cohort. Walleyes were captured during fall electrofishing surveys in the lower St. Joseph River, 2005–2012. Percentages plotted for a given sampling year include fish captured during that year and all preceding years. YC = year class.

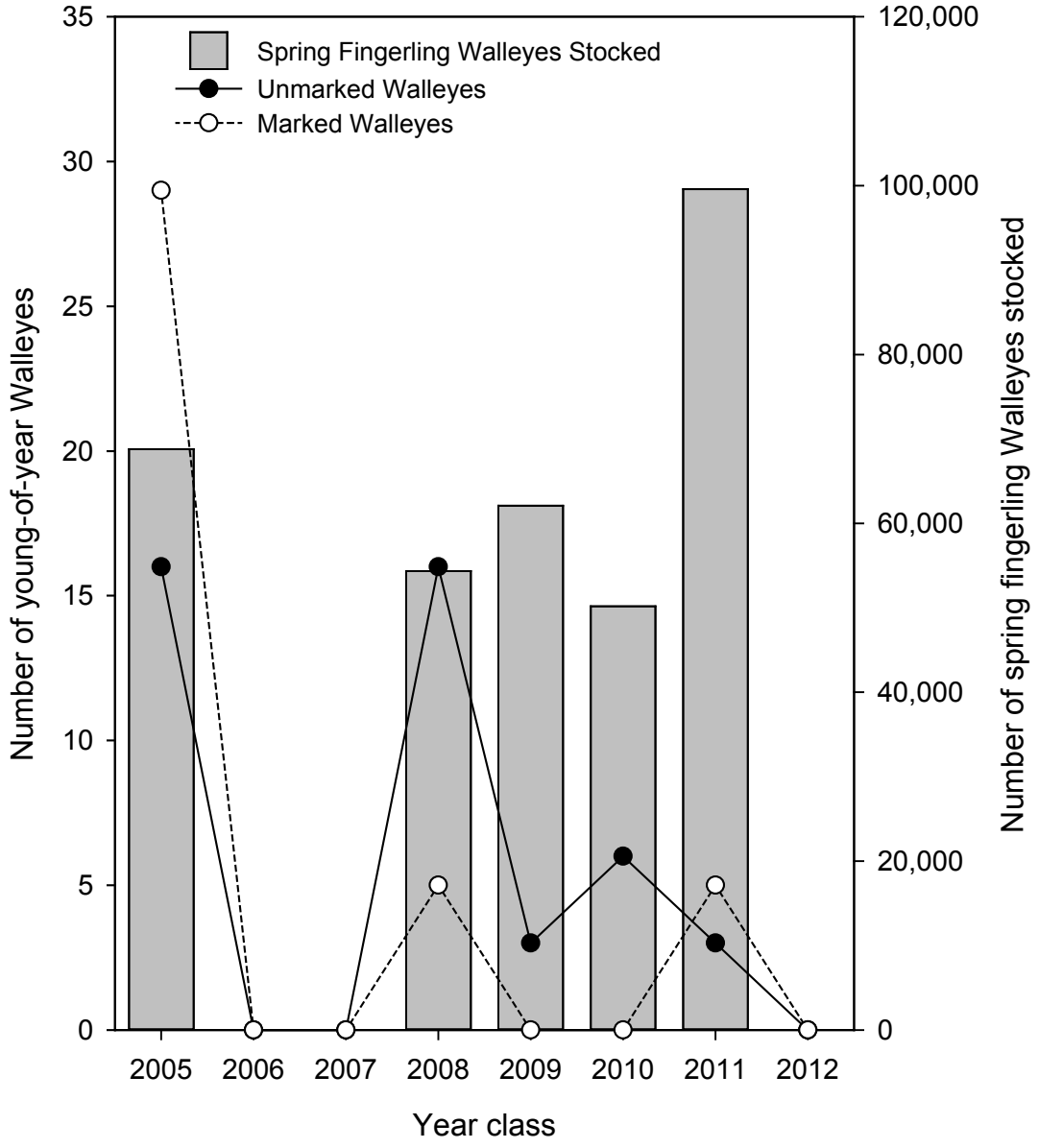

Figure 5.–Numbers of unmarked and oxytetracycline(OTC)-marked young-of-year Walleyes captured in the St. Joseph River during fall electrofishing surveys (2005–2012) and numbers of spring fingerling Walleyes stocked between Niles Dam and Benton Harbor each year. All stocked fish were marked with OTC.

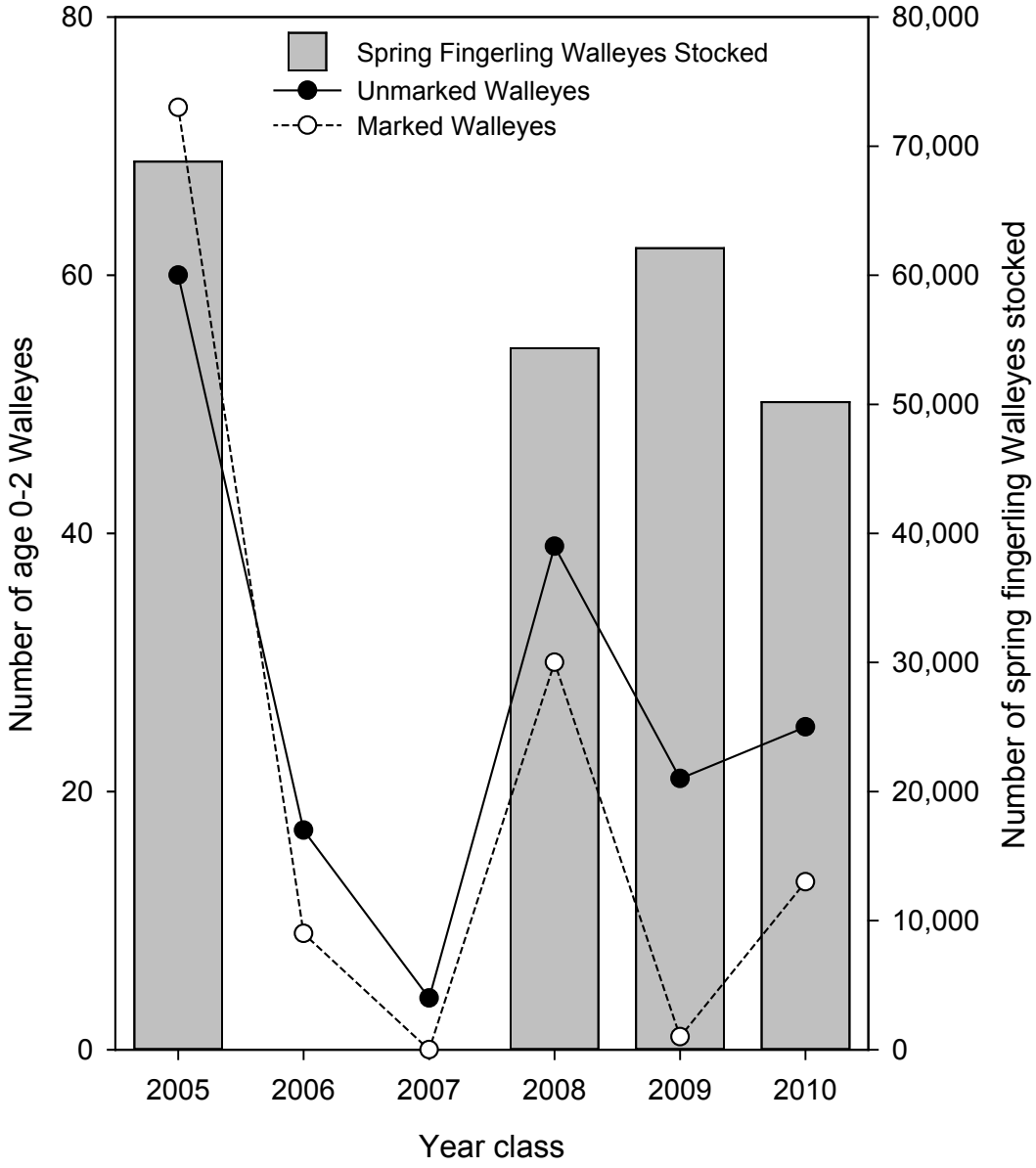

Figure 6.–Numbers of unmarked and oxytetracycline(OTC)-marked age 0–2 Walleyes captured in the St. Joseph River during fall electrofishing surveys (2005–2012) and numbers of spring fingerling Walleyes stocked between Niles Dam and Benton Harbor each year. (For example, the total catch for the 2005 year class includes the young-of-year catch in 2005, the yearling catch in 2006, and the catch of age-2 fish in 2007.) All stocked fish were marked with OTC.

Table 12.–Significance of correlations between spring fingerling Walleye stocking and electrofishing catch rates for unmarked and oxytetracycline(OTC)-marked Walleyes from each year class in the lower St. Joseph River, 2005–2012. Spearman rank correlation coefficients (r_s), t values, and P values are reported. Values in **bold** were significant at the 5% level.

Variable 1	Variable 2	r_x	t	P
Stocking [a]	Unmarked YOYs [b]	0.70	2.42	0.052
Stocking [a]	Marked YOYs [d]	0.78	3.05	**0.022**
Stocking [a]	Unmarked Juveniles [c]	0.81	2.81	**0.049**
Stocking [a]	Marked Juveniles [e]	0.61	1.56	0.194
Unmarked YOYs [b]	Marked YOYs [d]	0.77	2.94	**0.026**
Unmarked Juveniles [c]	Marked Juveniles [e]	0.94	5.66	**0.005**

[a] Stocking = number of spring fingerling Walleyes stocked between the Niles Dam and Benton Harbor during each year
[b] Unmarked YOYs = total catch of unmarked young-of-year (YOY) Walleyes from each year class
[c] Unmarked Juveniles = total catch of unmarked age 0–2 Walleyes from each year class
[d] Marked YOYs = total catch of OTC-marked YOY Walleyes from each year class
[e] Marked Juveniles = total catch of OTC-marked age 0–2 Walleyes from each year class

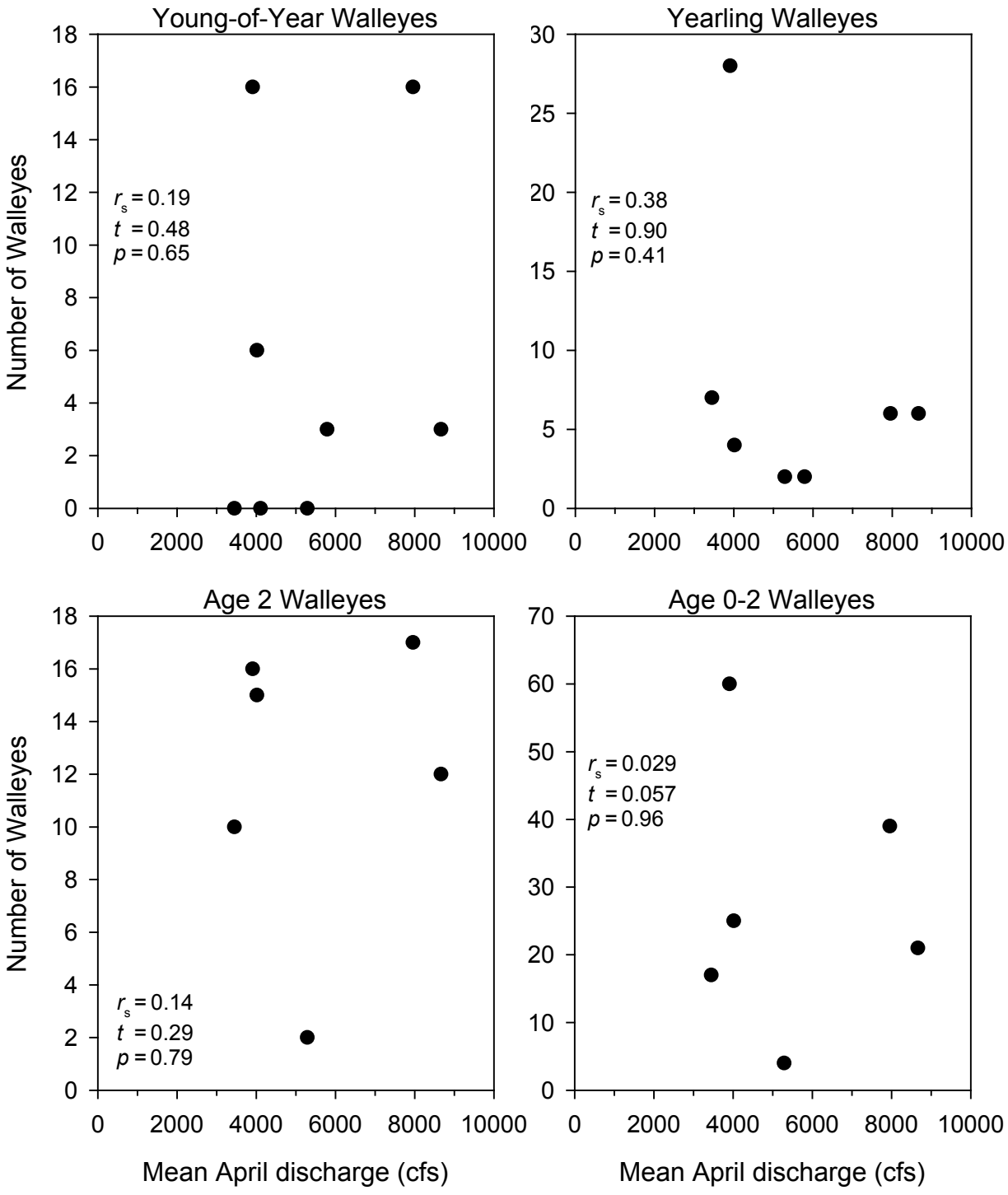

Figure 7.–Total catch of unmarked young-of-year, yearling, and age 2 Walleyes during the 2005–2012 fall electrofishing surveys in the St. Joseph River versus the mean April discharge at the United States Geological Survey gauge station in Niles during the year of larval emergence.

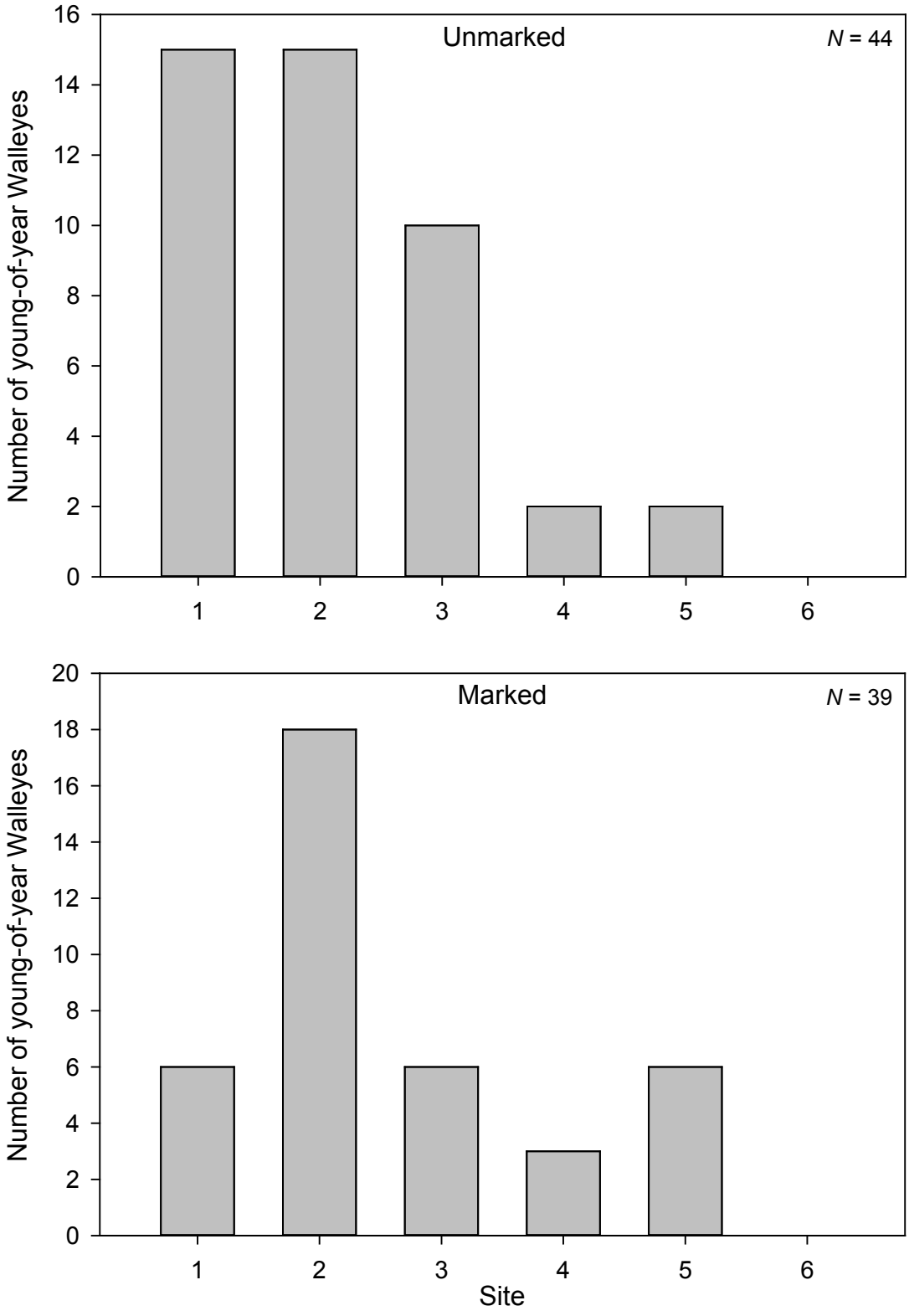

Figure 8.–Numbers of unmarked and oxytetracycline-marked young-of-year Walleyes collected at each electrofishing station on the St. Joseph River during 2005–2012. See Figure 1 for site locations.

Young-of-year Walleyes in the St. Joseph River grew rapidly. The mean total length for YOY Walleyes in the St. Joseph River was 9.5 inches, which is about 2.4 inches greater than the state average (Figure 9). Mean lengths at age remained approximately 2.5 inches above average through age 3, whereas mean lengths at age for Walleyes age 5–6 were less than 1 inch greater than state averages. Walleyes in the St. Joseph River typically reached legal size (i.e., 15 inches) during their third year of life. Analysis of spine samples revealed abrupt changes in growth of individual fish that presumably were caused by changes in the type or abundance of prey consumed.

General linear model results indicated that sampling year had a significant effect on marginal mean lengths for yearling Walleyes (Table 13). No effects of sampling year were observed for other age classes. Marginal mean lengths at age for marked and unmarked Walleyes were not significantly different (Figure 10; Table 13).

Marginal mean lengths for YOY Walleyes captured upstream and downstream of the Berrien Springs Dam were similar (Figure 11). However, age-1 and older Walleyes captured downstream of the Berrien Springs Dam were larger than Walleyes collected upstream of the dam. Significant differences in marginal mean lengths at age were observed for Walleyes ages 1, 2, 3, and 5 (Table 13). Small sample sizes reduced the likelihood of detecting significant differences for age-4 and older Walleyes. Only seven age-4 or older Walleyes were collected upstream of the Berrien Springs Dam during the 2009–2012 electrofishing surveys.

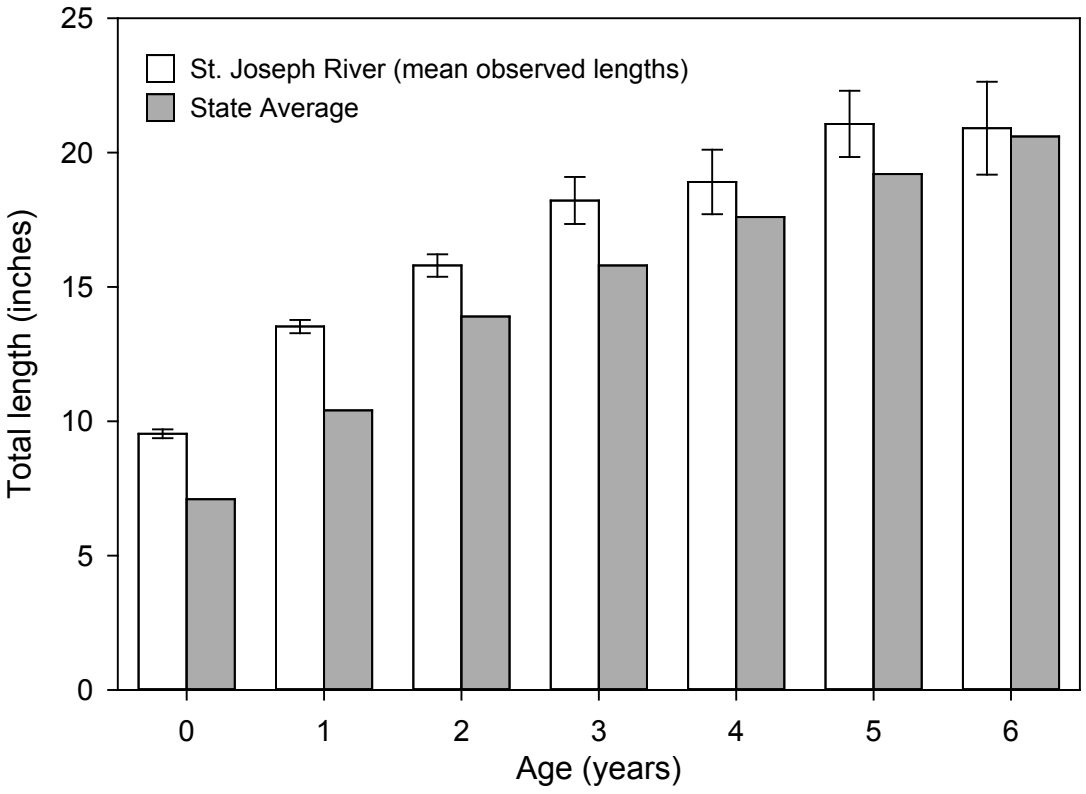

Figure 9.–Growth of Walleyes in the lower St. Joseph River, as determined from dorsal spine samples collected during fall electrofishing surveys, 2005–2012. Lines represent two standard errors. State average lengths for October–December are from Schneider et al. (2000).

Table 13.–Significance of factors affecting mean lengths at age for unmarked and oxytetracycline (OTC) marked Walleyes collected in the St. Joseph River upstream and downstream of the Berrien Springs Dam during 2005–2012. *P* values, *F* values, and degrees of freedom from the general linear model are reported. Values in bold were significant at the 5% level. Age-7 Walleyes only were collected in 2012. Thus, the effects of sampling year on mean lengths at age for age-7 Walleyes could not be evaluated.

Metric	Source of variation	*F*	*P*	*df*
Mean length at age-0	Sampling year	0.702	0.404	1, 79
N = 83	Upstream vs. downstream	0.086	0.770	1, 79
	OTC mark	0.000	0.993	1, 79
Mean length at age-1	Sampling year	15.277	**0.000**	1, 143
N = 147	Upstream vs. downstream	6.362	**0.013**	1, 143
	OTC mark	0.225	0.636	1, 143
Mean length at age-2	Sampling year	1.101	0.297	1, 104
N = 108	Upstream vs. downstream	7.121	**0.009**	1, 104
	OTC mark	0.062	0.803	1, 104
Mean length at age-3	Sampling year	0.460	0.502	1, 34
N = 38	Upstream vs. downstream	7.767	**0.009**	1, 34
	OTC mark	1.681	0.204	1, 34
Mean length at age-4	Sampling year	0.179	0.675	1, 26
N = 30	Upstream vs. downstream	0.174	0.680	1, 26
	OTC mark	2.983	0.096	1, 26
Mean length at age-5	Sampling year	0.126	0.730	1, 10
N = 14	Upstream vs. downstream	8.624	**0.015**	1, 10
	OTC mark	1.583	0.237	1, 10
Mean length at age-6	Sampling year	3.173	0.173	1, 3
N = 7	Upstream vs. downstream	3.242	0.170	1, 3
	OTC mark	0.388	0.577	1, 3
Mean length at age-7	Sampling year	N/A	N/A	N/A
N = 4	Upstream vs. downstream	142.370	0.053	1, 1
	OTC mark	37.926	0.102	1, 1

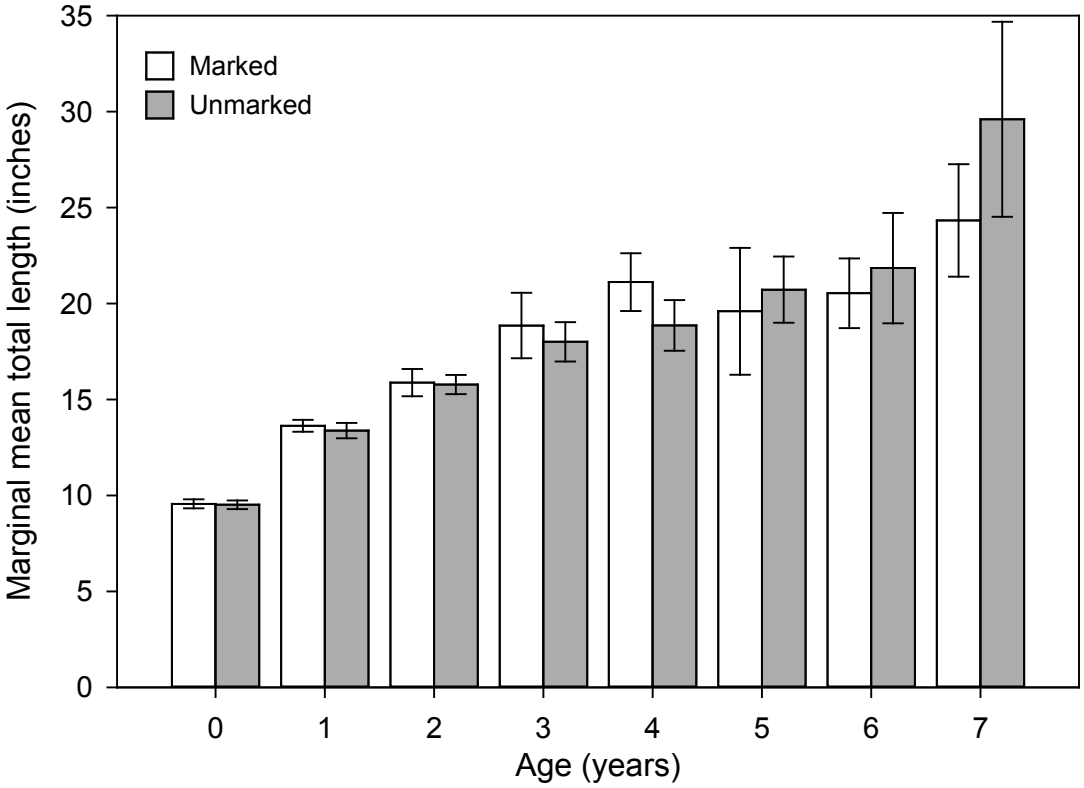

Figure 10.–Marginal (least squares) mean lengths at age for oxytetracycline-marked and unmarked Walleyes collected in the St. Joseph River, 2005–2012. Only fish from the 2005–2012 year classes were included in this analysis. Lines represent two standard errors.

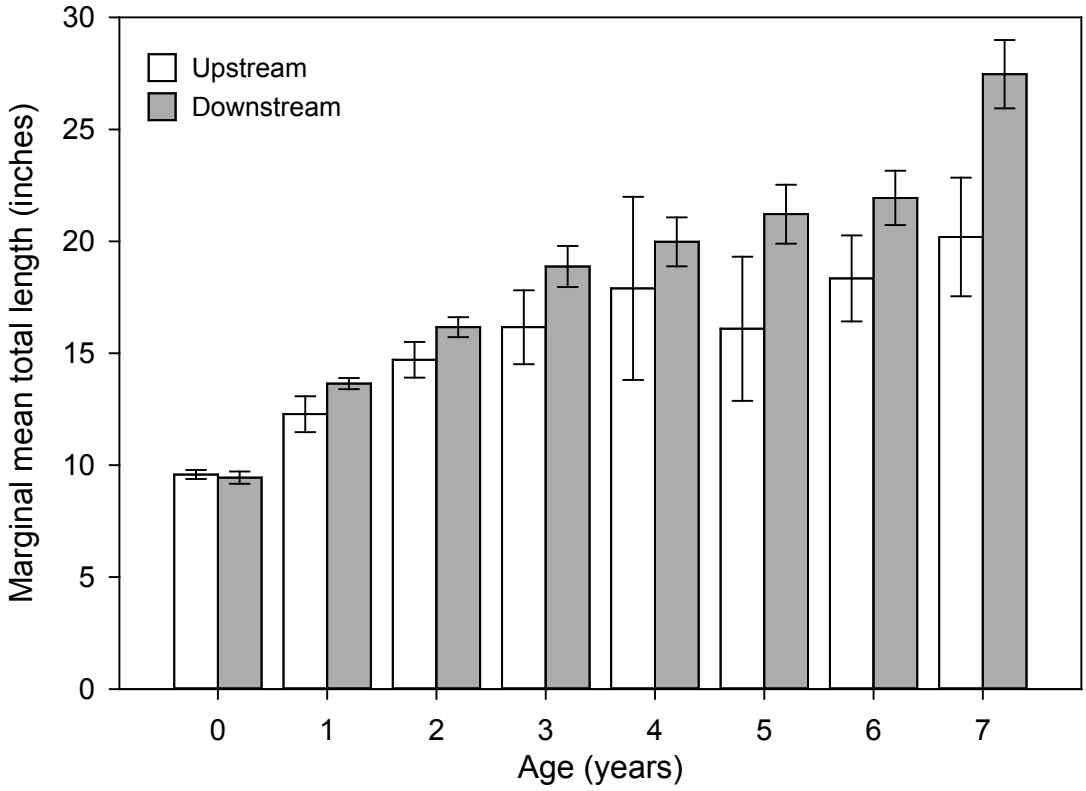

Figure 11.–Marginal (least squares) mean lengths-at-age for Walleyes collected in the St. Joseph River upstream (sites 1–2) and downstream of the Berrien Springs Dam (sites 3–6), 2005–2012. Only fish from the 2005–2012 year classes were included in this analysis. Lines represent two standard errors.

Discussion

The Walleye stocking program in the St. Joseph River appears to be necessary to maintain this fishery. Despite the disruptions to the Walleye stocking program in 2007–2009, marked fish were nearly half of the catch during the 2005–2012 electrofishing surveys. This does not necessarily indicate that the stocking program has roughly doubled the Walleye catch-per-angler hour in the St. Joseph River. Two additional factors must be considered when interpreting relative abundance data: vulnerability of marked and unmarked fish to angling and the effects of fish stocking on natural recruitment of Walleyes.

Creel surveys were not conducted as a part of this evaluation. Thus, it was not possible to estimate harvest of marked and unmarked Walleyes in the study area. Given that the Walleyes stocked in the St. Joseph River were offspring of wild broodstock and were stocked as spring fingerlings (and therefore spent little time in the hatchery), vulnerability to angling likely was similar for both stocked and naturally produced Walleyes.

Li et al. (1996b) found that Walleye stocking can decrease abundance of adjacent year classes through competition and cannibalism. In systems with considerable natural recruitment, stocking often has no effect on abundance and can negatively affect growth and condition of Walleyes (Li et al. 1996a). Li et al. (1996a) concluded that "stocking is most likely to contribute to Walleye population abundance in lakes [or rivers] where Walleye reproduction is limited but food is not limiting." The St. Joseph River appears to meet that description. Spawning habitat is limited to the stream reaches immediately

downstream of the Niles, Buchanan, and Berrien Springs dams. Forage is abundant and mean lengths-at-age for Walleyes exceeded state averages. During the present study, no negative correlations were observed between catch rates of unmarked Walleyes and the number of spring fingerling Walleyes stocked in the lower St. Joseph River (Figures 5–6; Table 12). Thus, stocking did not appear to suppress natural recruitment. On the contrary, significant positive correlations were observed between catch rates of unmarked and marked Walleyes. These findings suggest that survival of both stocked and wild fish are influenced by the same factors, such as flow fluctuations, predation and the availability of suitable prey.

There was substantial inter-cohort variation in relative contributions of unmarked and marked fish. The ratio of unmarked to marked fish in each cohort was determined by several factors, including the number of fish stocked, stocking locations, survival of stocked fish, and natural recruitment. Only one marked fish from the 2009 year class was captured during this study, which suggests that survival was unusually poor that year. The factors responsible for the poor performance of fish stocked in 2009 are unclear. The fish appeared to be in good condition at the time of stocking. Discharge was not abnormally high, and water temperatures in the stocking trailer and the stream were similar. The spring fingerlings were small (mean total length = 1.02 inches) in 2009, but spring fingerlings from 2010 were of comparable size and apparently had much higher survival. One possible explanation is that the OTC mark quality was poor in 2009 and some stocked fish were classified as unmarked. Spring fingerling marks are readily identifiable whereas fry marks are slightly harder to detect. Since 2011, MDNR has assessed OTC mark quality for Walleyes in various rearing ponds throughout the state. In most instances fry marks were detected in 100% of the fish examined from each pond, but there have been occasional instances where fry marks were not detected in fish that were known to have been exposed to OTC (D. Fielder, MDNR – Fisheries Division, unpublished data).

For the St. Joseph River Walleye population, there were no significant correlations between river discharge during April and CPE for unmarked juvenile Walleyes. This information does not necessarily indicate that river discharge during fry emergence has no effect on survival of larval Walleyes. Two aspects of the current study reduced the likelihood of finding a significant correlation. First, this study was conducted to evaluate the relative contributions of stocked and wild fish to the St. Joseph River Walleye population and was not designed to generate quantitative abundance estimates for each year class. Catch-per-effort for juvenile Walleyes as collected by this study only provided a rough index of year class strength and, when coupled with the small sample sizes for each year class, was not sufficient for detailed quantitative analysis. Second, the mean discharge for the month of April was used for the correlation analysis because no sampling was conducted to exactly identify the period of peak larval emergence to pair with appropriate river discharges in any given year. If the exact timing of larval emergence were known, temporally relevant estimates of river discharge could have been used for the correlation analysis. River discharge is only one of several factors that influence Walleye survival through the early life history stages. Other factors known to affect natural recruitment of Walleyes include water temperatures during incubation (Busch et al. 1975, Koonce et al. 1977; Ivan et al. 2010), predation (Hansen et al. 1998; Ivan et al. 2010), and prey availability (Leis and Fox 1996).

Riverine Walleyes typically spawn over gravel or cobble substrate (Kerr et al. 1997). These substrate types are most common in the stream reaches immediately downstream of the Niles, Buchanan, and Berrien Springs dams (sites 1–3). Most of the unmarked young-of-year Walleyes were collected near these suspected spawning locations. The catch data for the 2005 and 2006 year classes also suggest that young-of-year Walleyes generally remained near their hatching or stocking location. No downstream movement of marked 2005 young-of-year fish past the Berrien Springs Dam or of 2006 year class fish from Indiana into the study area was detected. By contrast, marked yearling Walleyes frequently were captured more than 10 miles downstream of their stocking locations.

The observed differences in movement patterns for YOY and yearling Walleyes can be attributed to four factors:

1. Yearling Walleyes had more time to disperse within the river system than YOYs that were stocked only 4–6 months prior to sampling.
2. Yearling Walleyes have a greater swimming ability than YOY Walleyes. Stevens (1990) reported that YOY Walleyes in Wisconsin streams typically utilized microhabitats with water velocities less than 0.6 ft/s, whereas preferred velocities recorded for juvenile Walleyes (i.e., age 1 to maturity) range from 0.8–2.0 ft/s (Kerr et al. 1997).
3. Yearling Walleyes are larger and thus less vulnerable to predation than YOYs. This situation affords them greater freedom to move between habitats.
4. Yearling Walleyes target different prey organisms than YOY Walleyes. Galarowicz et al. (2006) found that Walleyes smaller than 1.0 inches consumed zooplankton, Walleyes from 1.5 inches to 4 inches consumed a mixture of benthic invertebrates and zooplankton, and Walleyes larger than 4 inches primarily ate fish.

As Walleyes continue to grow, the species and size of potential prey fish also change (Porath and Peters 1997; Campbell 1998). Changes in prey preference may prompt Walleyes in the St. Joseph River to move between habitats in the river or between the river and Lake Michigan. The spine samples from Walleyes captured in the St. Joseph River revealed marked changes in growth of individual Walleyes that may have been caused by a shift in the type or abundance of prey.

Differences in marginal mean lengths at age for Walleyes collected upstream versus downstream of the Berrien Springs Dam likely are related to prey availability and foraging strategies. Walleyes in the stream reach downstream of this dam benefit from seasonal influxes of prey fish (e.g., Yellow Perch and Alewives) from Lake Michigan. Walleyes inhabiting this stream reach also have the option of following schools of prey fish into and out of the lake, whereas Walleyes in upstream reaches forage exclusively within the river.

The mechanisms responsible for the variation in marginal mean lengths of yearling Walleyes collected in the St. Joseph River during different sampling years are not entirely understood. McMahon et al. (1984) reported that Walleye growth is dependent on prey availability, temperature, and population density. Prey fish that Walleyes consume average 29% of body length (Porath 1996). Thus, growth of yearling Walleyes in the St. Joseph River is likely influenced by the abundance of 3–4 inch forage fish. During periods of high Walleye abundance, intraspecific competition can affect growth rates for juvenile Walleyes by reducing prey availability. Walleye growth typically peaks at water temperatures near 71.6° F (Koenst and Smith 1976), and growth essentially stops at temperatures below 53.6° F (Kelso 1972). Based on this information, it appears that short winters and cool summers facilitate rapid growth of Walleyes. These variables act in concert and the present study was not designed to evaluate the relative importance of each factor in determining growth rates for Walleyes in the St. Joseph River.

The Walleye movement data from this study support the hypothesis that upstream movement of Walleyes through the Berrien Springs fish ladder is minimal. This corroborates previous fish passage counts at that facility. During 1999 through 2010, annual upstream passage counts for Walleyes at the Berrien Springs ladder rarely exceeded 20 fish. Thus, stocking downstream of the Berrien Springs Dam does not affect the Walleye fishery upstream of the dam. However, stocking upstream of the dam can affect the Walleye fishery downstream of Berrien Springs.

Management Recommendations

The St. Joseph River supports a popular Walleye fishery and the results of this study indicate that stocking strongly contributes to the Walleye population in this system. Thus, continued stocking is warranted. Two life stages of Walleyes are available for stocking: fry and spring fingerlings. It costs approximately $0.60 to produce 1,000 fry, whereas the estimated cost for spring fingerling Walleyes

produced in southwest Michigan rearing ponds during 2011–2013 was $0.076 per fish. Survival of stocked fry is highly variable (Mitzner 2002) and most studies involving paired plants of fry and spring fingerling Walleyes have demonstrated that the benefit-cost ratio is more favorable for spring fingerling stocking (Fielder 1992; Koppelman et al. 1992; Paragamian and Kingery 1992; Brooks et al. 2002).

MDNR stocking programs typically are reviewed at least once every six years. During 2015–2020, approximately 100,000 spring fingerling Walleyes will be stocked biennially in the Berrien County portion of the St. Joseph River. This equates to a stocking density of 46 spring fingerlings/acre. The fish will be distributed among five stocking locations: Niles City Park, Buchanan City Launch, Shamrock Park, the Berrien County Sportsmen's Club launch, and the Benton Township boat launch (Table 14). A biennial stocking schedule is preferred for Walleyes, but the actual stocking schedule will be dependent on the availability of spring fingerlings.

Table 14.–Recommended spring fingerling Walleye stocking numbers and locations on the lower St. Joseph River, 2015–2020. A biennial stocking schedule is preferred, but the actual stocking schedule is dependent on the availability of spring fingerlings. The objective is to stock fish in three years of this six-year period.

Stream reach	Stocking location	Number of fish
Niles Dam to Buchanan Dam	Niles City Park	25,000
Buchanan Dam to Berrien Springs Dam	Buchanan City Launch	25,000
Berrien Springs Dam to mouth	Shamrock Park	15,000
	Berrien Co. Sportsmen's Club	20,000
	Benton Township Launch	15,000

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