STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-80-R-15

Study No.: 230761

Title: Walleye dynamics in Michigan's Inland Waterway: the Burt-Mullett-Pickerel-Crooked lake system

Period Covered: October 1, 2013 to September 30, 2014

Study Objective: The objectives of this research are to: (1) Quantify timing and rates of walleye movement among lakes, in order to better understand potential source-sink dynamics of walleye in these lakes, with an emphasis on the implication for the co-management of this species; (2) Identify important spawning locations within Mullett Lake and to determine the dynamics of larval and early juvenile walleye, with an emphasis on determining factors potentially limiting their growth and survival; (3) Determine the diet of post-YOY walleye in all of the lakes within the Inland Waterway, with an emphasis on comparing food web structure among these lakes, and the potential shift in food webs as the limnology of these lakes change over time; and (4) Determine the diet of larval yellow perch in all of the lakes within the Inland Waterway, with an emphasis on comparing diet selection among these lakes, and the potential limitations imposed by zooplankton abundance.

Summary: Assessment of larval fish density was expanded to include Black Lake and other lakes near the Inland Waterway in order to provide context and contrast to Inland Waterway results. Initial diet analysis of larval yellow perch documented a rapid shift in first feeding at approximately 6–8 mm. Stomach analysis of walleye from the waterway was complimented with stable isotope analysis to quantify trophic ecology of walleye among the lakes. At the completion of the stomach analysis data collection, 1,484 stomachs were turned in and analyzed with most of the samples from Burt Lake. Observed walleye diets vary by lake and season with nonnative species such as round goby being prevalent in the diet from Mullett and Burt Lakes and crayfish dominating the diet from walleye in Crooked and Pickerel Lakes. Stable isotope analysis illustrated similar results with walleye targeting round goby within Burt and Mullett lakes, which was indicated by a similar energy source and higher trophic position when compared with the other lakes. The stable isotope results also determined that walleye within the waterway had variable feeding patterns.

Findings: Jobs 2 through 5 were scheduled for 2013-14, and progress is reported below.

Job 2. Title: Reproductive dynamics of walleye in Mullett Lake.–Ichthyoplankton trawls and drift nets were used to collect larval and early juvenile walleye from May to June 2011, April to June 2012, May 2013, and May to June 2014 in the Inland Waterway. A random sampling design was implemented when assigning sampling locations for ichthyoplankton trawls in both riverine and lake sites and included river mouths and reef habitat where spawning was expected. As previously reported, nearly 1000 ichthyoplankton samples were collected from 2011 to 2013. In 2014, a total of 78 ichthyoplankton and associated zooplankton samples were collected.

Collection efforts from previous field seasons (2010 to 2013) focused primarily on collecting larval walleye *Sander vitreus* and zooplankton from the major water bodies within the Inland Waterway, including Burt, Mullet, Crooked, and Pickerel lakes, as well as major tributaries of the waterway, including the Crooked, Sturgeon, Cheboygan, Indian, and Black rivers. As larval yellow perch *Perca flavescens*, also an important sport and forage fish in the Inland Waterway, are captured concurrently with larval walleye, analysis of their diet and distribution represents a "value-added" component to the study. Thus, previous efforts provide the necessary samples for analysis of zooplankton abundance as well as diet and distribution of larval yellow perch within these specific areas of the waterway.

In April of 2014, discussions with the region's fisheries biologists, primary investigators and respective graduate students revealed a need to compare both ichthyoplankton and zooplankton communities of the Inland Waterway to the planktonic communities found in additional large water bodies within the northern Lower Peninsula of Michigan. By comparing a multitude of systems across a range of size, productivity, forage base, and prevalence of invasive organisms, it is expected that relevant patterns will emerge and provide insight into the early life history and recruitment dynamics of both walleye and yellow perch. Therefore, we broadened the scope of icthyoplankton and zooplankton sampling in 2014 to include Black, Grand, Long, and Hubbard lakes in order to increase our understanding of the variation as well as similarity within and among multiple systems in the northern Lower Peninsula of Michigan.

Field sampling in 2014 began on May 19, with an emphasis on Black Lake. Weather conditions during the spring of 2014 limited our ability to conduct intensive sampling on Black Lake due to the late break up of ice and dangerous water conditions. Sampling events planned for the first week of May were cancelled at the discretion of the crew leader due to concerns of safety for the vessel and crew. Despite the unfavorable weather patterns and poor sampling conditions of Black Lake during the spring of 2014, a total of 36 icthyoplankton trawls (and matching zooplankton tows) were conducted during the five week field season (Table 1). A total of 208 icthyoplankton were collected with Centrarchidae the most prevalent (Table 2). Osmeridae and Percidae represented the remainder of the catch with the exception of one larval Coregonid captured during the first sampling event.

Sampling on Grand, Long and Hubbard lakes followed the same procedure with a zooplankton tow being conducted at the start of each icthyoplankton trawl in order to enumerate the available zooplankton community. On Grand Lake, 324 larval fish were captured during the 13 ichthyoplankton trawls (Table 2) with Percidae comprising the majority of the catch. Of the four lakes sampled during 2014, Grand Lake yielded the highest catch per effort for larval fish (Table 3). On Long Lake, catch per effort was also relatively high (Table 3) with 226 larvae captured during 11 trawls. Percidae were most prevalent, followed closely by Osmeridae in Long Lake. Hubbard Lake yielded only 10 larvae during 18 trawls and they were primarily Percidae. Of the four lakes included in this study, Hubbard Lake yielded the poorest catch per effort (Table 3). Laboratory processing of ichthyoplankton and zooplankton samples are ongoing.

Initial analysis of larval yellow perch diet from Mullett Lake shows a clear progression of first feeding with length (Table 4). Fish below 6 mm rarely contained any food, whereas fish above 10 mm nearly all contained some zooplankton prey. The diet of first feeding larval yellow perch consisted primarily of cyclopoid copepods, but shifted to include nearly 50% Bosmina as fish reached a length of 11 mm (Table 4).

Job 3. <u>Evaluate food web structure</u>.–Evaluation of food web structure consisted of various field sampling techniques to sample the benthic and pelagic forage communities. Additional information regarding the food web structure was collected through stomach samples submitted by anglers from recreationally-harvested walleye, performing gastric lavage on walleye collected during fishing tournaments and fall recruitment sampling, and also through collection of muscle tissue to be analyzed for stable isotope signatures ($\delta^{13}C$ and $\delta^{15}N$).

Walleye stomach content analysis

The results of the diet analysis revealed that walleye exhibited seasonal foraging patterns and integrated nonnative prey fish into their diets. The general pattern throughout the waterway was that walleye feed primarily on aquatic insects, in particular *Hexagenia spp.*, in the spring season and then transitioned into a piscivorous or crayfish dominated diet in the summer and fall/winter seasons (Table 5). The exception to that pattern was the walleye from Mullett Lake that feed primarily on Yellow Perch during the spring (Table 5). The other feeding pattern that emerged during the study was the diet of walleye from Crooked and Pickerel Lakes, which were less diverse and instead consisted of primarily crayfish (> 50% in the summer). Other prey fish (i.e., miscellaneous *Notropis spp.*) and insects made up the rest of the diet from walleye in those lakes (Table 5). Nonnative prey species were also integrated into walleye feeding patterns throughout the waterway. In Mullett and Burt lakes where Round Goby are present and abundant, these nonnative species made up the largest portion of the walleye diet during the summer and fall seasons (Table 5). In Mullett Lake, for example, Round Goby made up approximately 77% of the walleye diet during the fall/winter season, although low sample size may bias that value. Similarly, in Burt Lake, Round Goby were targeted as prey items and used more heavily in the summer and fall/winter, making up 36.4% and 42.9% of the diet, respectively, during those seasons (Table 5). The pelagic nonnative prey fish species (i.e., Alewife and Rainbow Smelt) were targeted to a lesser extent by walleye throughout the lakes within the waterway (Table 5). In fact, only walleye from Mullett Lake contained Alewife and/or Rainbow Smelt in their stomachs, and those two species represented only a low percentage of the walleye diet in the summer (6.9%) and fall/winter season (2.9%) within Mullett Lake. In Crooked and Pickerel lakes, crayfish were a primary diet item for walleye in the summer season, contributing approximately 50% of the total weight of prey items (Table 5).

Stable Isotope analysis

While there were many stomachs collected during the three year study, sample size issues were seen because of low seasonal and lake-specific collections and we complemented the stomach content analysis with stable isotope analysis. This portion of the study went beyond the scope of the proposed food web work, but because we were attempting to quantify the food web structure and information using only observed diets were lacking, we sought additional funding and were awarded resources that made this work possible. Stable isotope analysis was beneficial for this study because it allowed us to determine long-term prey assimilation patterns because $\delta^{13}C$ values tend to be conserved from prey to predator, thus providing insight on energy source, which can be derived from littoral (e.g., attached algae and detritus) or pelagic (e.g., phytoplankton) production. The ability to decipher energy sources is associated with the enrichment of the $\delta^{13}C$ at the base of the littoral food web relative to the base of the pelagic food web (Figure 1). Therefore, in 2014 the stable isotope data was analyzed to determine the trophic ecology of walleye within the waterway. Our analysis is still being finalized, but different isotopic patterns are emerging for walleye within the waterway. For example, the evaluation of the percent littoral distributions indicated a wide range of dependence upon littoral energy sources (Figure 2). Walleye from Pickerel Lake were most variable in the percent littoral estimates compared to fish from the other lakes (Figure 2), and only approximately 70 percent were dependent on littoral prey sources. In contrast, walleye from Crooked Lake were heavily dependent upon littoral energy with the majority (< 95%) of individuals relying on littoral prey (Figure 2).

Currently, the evaluation of the food web structure is being summarized and written into a manuscript entitled *Walleye Foraging Ecology in an Interconnected Chain of Lakes Influenced by Non-Native Species*. The anticipated completion date for this paper is December 2014.

Job 4. Write annual performance report.–The annual performance report was completed and is provided within, containing pertinent information regarding the progress of active jobs for the study.

Job 5. Write manuscript.–Two manuscripts (one on Job 1, evaluating the movement rates of walleye, and another based on adult walleye diet and isotope data) are in the process of writing and revision, with the anticipation that they will be submitted for publication in late 2014 or early 2015.

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Date: October 1, 2014

Table 1.–Number of ichthyoplankton and zooplankton tows collected for 2014. The start date of 2014 was May 19th, 2014. Each week consists of 7 consecutive calendar days.

Year	Week	Black Lake	Grand Lake	Long Lake	Hubbard Lake	Total
2014	1	15	8	5	0	28
	2	0	0	0	0	0
	3	10	5	6	5	26
	4	0	0	0	0	0
	5	11	0	0	13	24
Totals		36	13	11	18	78

Table 2.–Number of ichthyoplankton captured during 2014 in ichthyoplankton trawls. The – designate weeks in which no sampling occurred.

Year	Week	Black Lake	Grand Lake	Long Lake	Hubbard Lake	Total
2014	1	5	164	20	–	189
	2	–	–	–	–	0
	3	18	160	206	6	390
	4	–	–	–	–	0
	5	185	–	–	4	189
Totals		208	324	226	10	768

Table 3.–Mean catch per tow of larval fish in ichthyoplankton samples, 2014. The – designate weeks in which no sampling occurred.

Year	Week	Black Lake	Grand Lake	Long Lake	Hubbard Lake
2014	1	0.33	20.50	4.00	–
	2	–	–	–	–
	3	1.80	32.00	34.33	1.20
	4	–	–	–	–
	5	16.82	–	–	0.31
Overall average		5.78	24.92	20.55	0.56

Table 4.–Preliminary summary of diet of larval yellow perch in Mullett Lake.

Length (mm)	n	Percent empty	Percent of diet: Bosmina	Calanoid	Cyclopoid	Daphnia	Other
3	7	100	0	0	0	0	0
4	21	90	0	0	100	0	0
5	59	97	0	0	100	0	0
6	36	92	0	0	100	0	0
7	21	52	29	0	71	0	0
8	19	26	21	0	78	0	2
9	22	18	29	1	70	0	0
10	22	5	32	0	68	0	0
11	22	9	49	0	51	0	0
12	24	13	49	1	50	0	0
13	24	0	44	1	55	0	0
14	16	0	45	0	54	1	0
15	3	0	20	0	75	5	0
16	2	0	6	0	89	6	0
17	1	0	0	0	100	0	0
18	1	0	63	0	13	25	0

Table 5.–Seasonal diet composition (% wet weight (g)) for walleye from the Inland Waterway, 2011 to 2013. Seasons were arbitrarily defined as spring (April–June), summer (July–September), and fall/winter (October–March). N is the total number of stomachs that were analyzed for prey items. Unk. fish category consisted of unidentifiable bones and the "other" category consisted of miscellaneous fish species such as emerald and spottail shiners.

	Diet item								
Location	Aquatic insects	Yellow perch	Round goby	Crayfish	Unk. fish	Alewife and smelt	Other	N	% empty
Spring									
Burt Lake	62.5	10.3	6.6	17.3	2.0	0.0	1.3	579	25.4
Crooked Lake	58.7	2.8	0.0	6.3	29.1	0.0	3.1	46	21.7
Mullett Lake	24.6	62.3	0.4	0.0	4.7	0.0	8.0	32	40.6
Pickerel Lake	53.3	0.0	0.0	43.6	1.3	0.0	1.8	60	38.3
Summer									
Burt Lake	10.3	21.1	36.4	22.1	7.3	0.0	2.8	148	50.7
Crooked Lake	12.6	13.3	0.3	52.1	7.5	0.0	14.2	191	46.1
Mullett Lake	3.8	38.8	17.2	6.9	19.3	6.9	7.1	143	55.2
Pickerel Lake	15.1	9.8	0.0	54.8	12.8	0.0	7.5	67	47.8
Fall/winter									
Burt Lake	0.3	33.3	42.9	5.9	15.4	0.0	2.2	185	27.0
Crooked Lake	0.8	7.0	0.0	0.0	84.7	0.0	7.5	23	30.4
Mullett Lake	0.0	10.2	77.3	0.0	0.1	2.9	9.5	10	10.0
Pickerel Lake	–	–	–	–	–	–	–	0	–

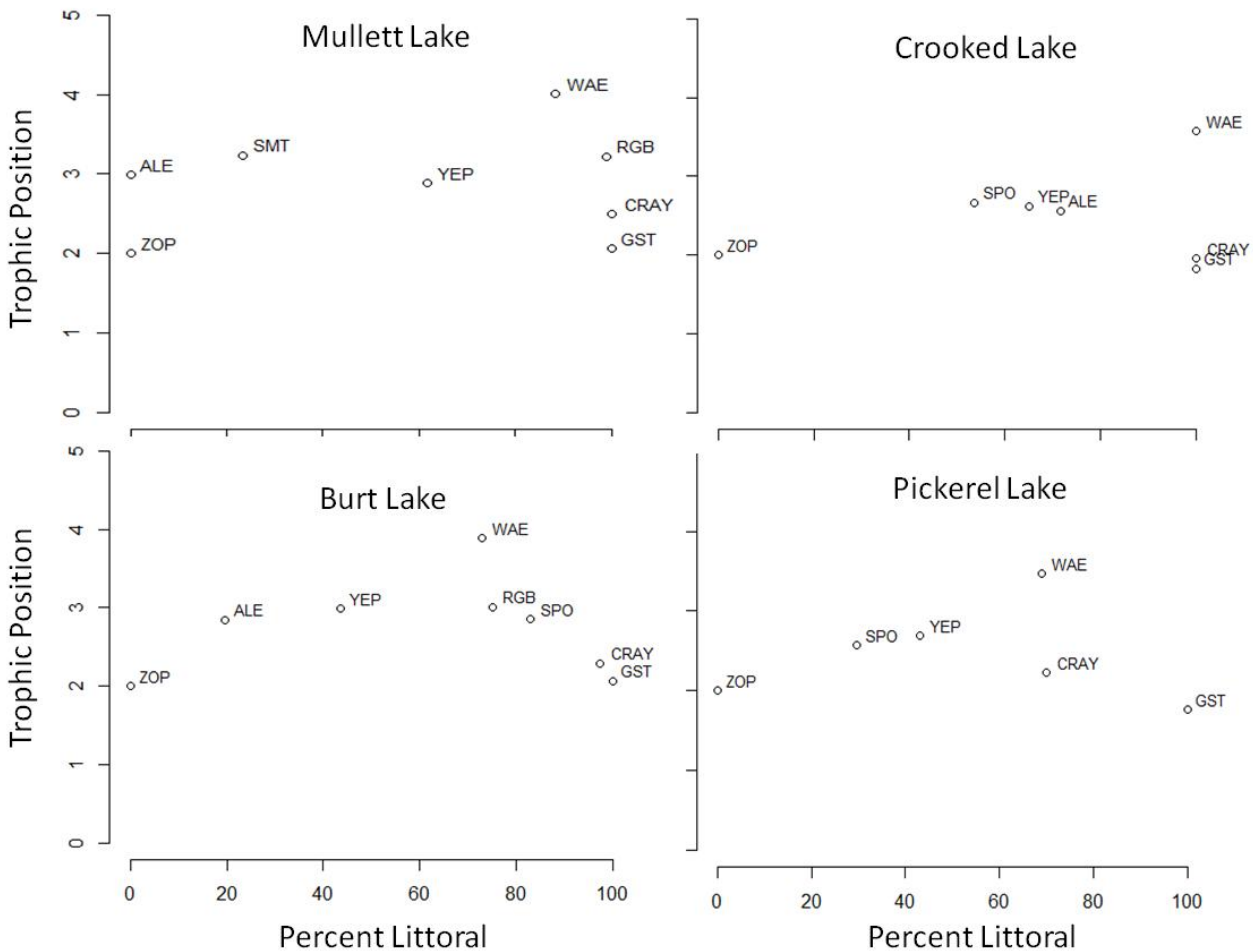

Figure 1.–Isotope bi-plots illustrating the trophic position and percent littoral signature of food web members among each lake within the Inland Waterway.

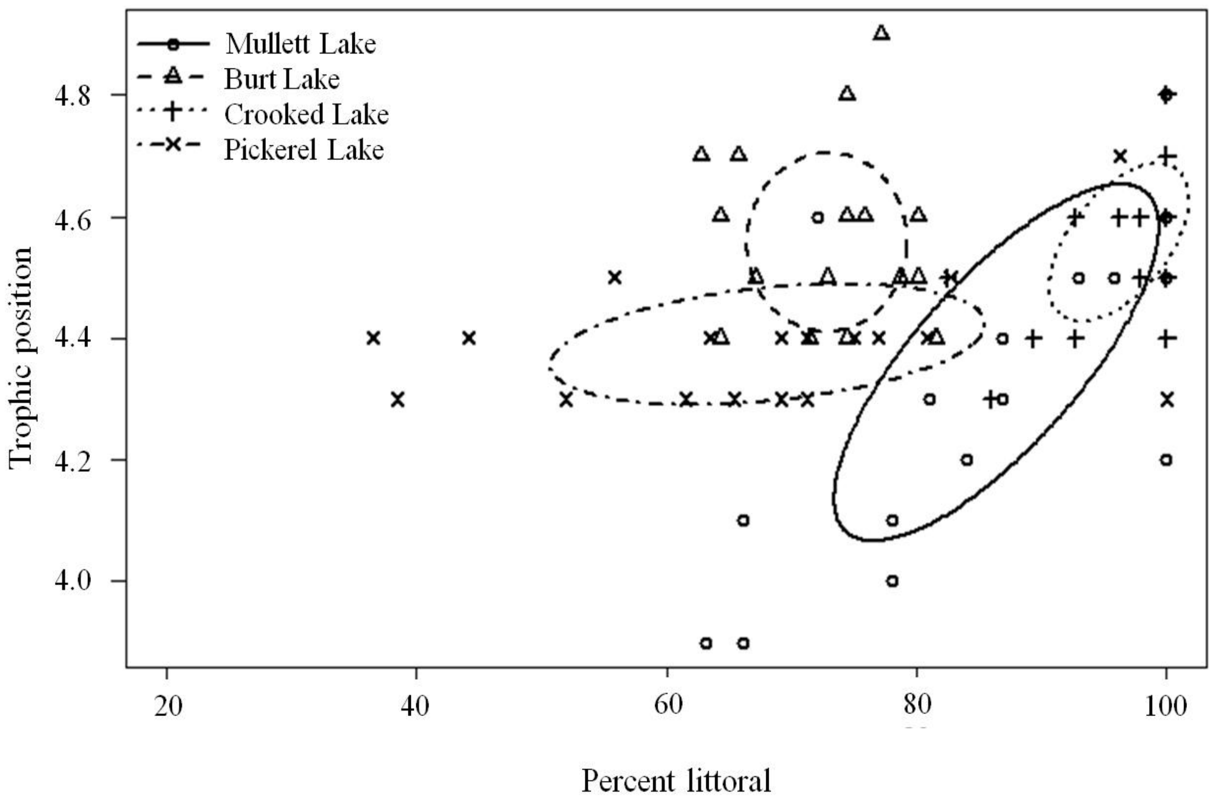

Figure 2.–Stable isotope bi-plot representing the percent littoral and trophic position for walleye collected from each of the lakes within the Inland Waterway, MI. The lines enclose the standard ellipse areas (SEAc) and represent the total isotopic niche area for walleye within each of the lakes. The symbols are data points that indicate the isotopic signature of individual walleye from Burt (open triangle), Crooked (cross hatch), Mullett (open circle), and Pickerel ("x") lakes.