

NATURAL REPRODUCTION OF SALMONIDS IN LAKE MICHIGAN TRIBUTARIES OF WISCONSIN

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Photo credit: Kristina Kroening, Ozaukee Co.



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INTRODUCTION/BACKGROUND

Lake Michigan and its tributaries support a diverse fish community of both resident and migratory species. Potamodromous salmon and trout were introduced in the 1960's in part to control the explosive population growth of invasive alewife (*Alosa pseudoharengus*) and to provide a sport fishery. These introduced Pacific salmon and trout species such as Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), rainbow trout (*O. mykiss*) and brown trout (*Salmo trutta*) have adapted to the new ecosystem and created a major sport and charter fishing industry. The initial stocking of coho salmon occurred in 1966 and Chinook salmon in 1967. These species feed almost exclusively on alewife and helped control their abundance (Dettmers et al. 2012). To sustain a successful fishery and balance the predator-prey base agencies around the lake have developed well-planned stocking programs for salmon and trout. The Wisconsin Department of Natural Resources (WDNR) has three egg collection facilities to raise fingerling and yearling fish that are annually stocked in various tributaries (Burzynski 2014).

The potamodromous salmon and trout grow and mature in the lake and swim upstream in search of suitable spawning locations. In this process they also support a great stream fishery both in the spring and in the fall. Chinook salmon and coho salmon spawn in the fall creating a fall fishery in the tributaries while steelhead rainbow trout spawn in the spring. Although the tributary streams along the Wisconsin shoreline are not as high quality streams compared to those on the Michigan side (Seelbach 1993), there have been sporadic occurrences of naturally reproduced salmon smolts in selected Wisconsin rivers. The first evidence of occurrence of a naturally reproduced coho salmon smolt was reported on September 12, 1992 by a WDNR game warden. This fish was accidentally captured in Mineral Springs, a tributary to Sauk Creek in Ozaukee County. Subsequently WDNR staff has documented smolts of Chinook salmon, coho salmon, rainbow trout and brown trout in other streams while conducting baseline monitoring of wadeable streams (WDNR database). In 2002 smolts of Chinook salmon, coho salmon and rainbow trout were documented at Willow Creek in Sheboygan County. Similarly, in 2006 rainbow trout smolts were documented in Pigeon Creek in Ozaukee County. All of these detects of smolts were part of different surveys and there was no systematic evaluation to identify potential streams and quantify salmonids smolts in these streams.

Therefore, the main objectives of this project were: 1) to identify potential tributary streams with naturally-reproduced salmon and trout, and 2) to document their relative densities.

METHODS

Based on the sporadic data from previous surveys and knowledge of the streams, we selected five streams for a systematic survey and conducted these surveys in summers of 2011 and 2012. These streams include: Pigeon Creek, a tributary to Milwaukee River in Ozaukee County; Sauk Creek in Ozaukee County which drains directly to Lake Michigan at Port Washington; Sucker Creek in Ozaukee County which drains directly to Lake Michigan north of Port Washington; Willow Creek, a tributary to the Sheboygan River in Sheboygan County; and the Pike River in Kenosha County which drains directly to Lake Michigan (Figure 1). Of these tributaries, the Pike River and Sauk Creek receive annual plantings of trout and salmon. While Willow Creek and Pigeon Creek do not receive annual plantings, their receiving waters (Sheboygan and Milwaukee Rivers, respectively) are stocked. In addition to the extensive sampling effort in 2011 and 2012, we also carried out surveys in 2013 and 2014 but with reduced effort.

Site description

Pigeon Creek

The Pigeon Creek subwatershed is drained by Pigeon Creek (Figure 2). It is located in southwest Ozaukee County. The perennial stream is 6.8 miles long and drains into the Milwaukee River in the Village of Thiensville. The channel substrate is mainly comprised of cobble and gravel. There are small wetland parcels and groundwater seeps. The habitat quality and water quality are considered “fair” to “poor”. Habitat and water quality are impacted by low flow, sedimentation, channelization, and draining of wetlands. Historically Pigeon Creek has supported a diverse fish community (WDNR Surface Water Inventory database).

Sauk and Sucker Creek

The Sauk and Sucker Creeks Watershed is the southernmost watershed in the Sheboygan River Basin. Sauk Creek (Figure 3) originates within Ozaukee County north of Fredonia and enters Lake Michigan in the City of Port Washington. Sauk Creek is classified as a Warm Water Sport Fish community stream. The water quality is good to poor based on fish and macroinvertebrate communities and water chemistry. Run off from farm fields have contributed to the high concentration of nutrients and sedimentation. Although the Sauk and Sucker Creek watershed does not have quality water for resident trout population, trout and salmon stocked in Lake Michigan swim up the tributary stream for spawning. Most of the watershed has moderate groundwater recharge potential.

Sucker Creek (Figure 4) originates in Sheboygan County and flows south along the I43 corridor entering Lake Michigan north of the City of Port Washington. Sucker Creek is the second largest stream in the Sauk and Sucker Creeks watershed. Trout and salmon swim up the stream during the spawning season. According to previous stream habitat surveys, water quality and habitat rankings ranged from fair to poor. The substrate in the lower sections is mostly gravel covered with silt. Previous fish surveys have documented diverse forage fish species in Sucker Creek.

Willow Creek

Willow Creek (Figure 5) is a five-mile long stream that drains into the Sheboygan River in Sheboygan County. Lake Michigan trout and salmon are known to spawn in this stream. The substrate is composed of gravel and silt. The lower 1.6 miles of Willow Creek is designated as a Class II trout stream.

Pike River

The Pike River (Figure 6) has two main tributaries, the North and South Branches. The North Branch originates in the Town of Mt. Pleasant and the South Branch originates near Highway 50 in Kenosha County; the two branches later join in Petrifying Springs Park. It discharges directly into Lake Michigan. According to the Pike River Watershed Plan 2010, (WDNR) the water quality of the 42-mile long rivers and streams in the Pike River Watershed ranged from severely degraded to good. It supports a Warm Water Sport Fish community. The stream channels are steep with eroded banks. Although agriculture remains the dominant land use within the watershed, the area has experienced high rates of residential growth during the last two decades (Pike River Watershed Plan 2010, WDNR).

Fish sampling

Fish were collected using a backpack electroshocker unit (pulse rate between 50 and 60Hz, duty cycle about 12.5% and voltage about 125 volts) with a single upstream pass of the survey section in July and August. No block nets were used to enclose the sampling area. The start and end points of the stream section sampled were marked with GPS coordinates. The distance of the section sampled varied depending on the stream condition and flow rates. The goal was to sample each of the five streams once per week for four consecutive weeks in each year during the summer.

All salmonids smolts and yearlings were kept alive. Fish were identified to species, measured, counted, marked with an upper caudal clip and released. Any fish captured with a hatchery fin clip was identified as a stocked fish. Furthermore, we discussed with WDNR Kettle Moraine State Fish Hatchery the growth rate of smolts in the hatchery, and the stocking size. Thus we determined anything less than 100mm in total length in late summer as wild produced. In the hatchery the Chambers Creek and Ganaraska strain steelhead reach an average length of 79mm by September-October (Andy Hron, Hatchery Manager, personal communication).

RESULTS

Five tributary streams to Wisconsin waters of Lake Michigan were sampled for presence of salmonid smolts. These streams were located in Kenosha, Ozaukee and Sheboygan Counties and results from previous baseline surveys had indications of naturally produced salmonids. Although our goal was to survey each site four times in the summer of 2011 and 2012 we were not able to meet our sampling goal due to high water conditions and scheduling issues. However, in 2011 we were able to sample Pigeon Creek, Sauk Creek, Sucker Creek and Pike River four times and Willow Creek twice (Table 1).

Table 1. Salmonid smolt survey – Stream sampled, dates, location and distance sampled in 2011.

Stream name	Dates sampled	Start of station	End of station	Distance (m)
Pike River – upstream of CTH A	7/25/2011, 8/03/2011, 8/08/2011	42.65329N/87.85015W	42.65028N/87.85328W	550
Pike River – at Petrifying Springs park	7/25/2011	42.65431N/87.87476W	42.65652N/87.87309W	550
Pike River at UW-Parkside	8/16/2011	42.65063N/87.85468W	42.64998N/87.85915W	500
Pigeon Creek at Highland Road	8/03/2011, 8/09/2011, 8/17/2011, 8/24/2011	43.25104N/87.99054W	43.25194N/87.99149W	175
Sauk Creek	8/09/2011, 8/17/2011, 8/24/2011	43.38637N/87.87439W	43.38836N/87.87808W	450
Sauk Creek – High school upstream to 1 st falls	8/01/2011	43.39172N/87.88062W	43.39527N/87.8828W	500
Sauk Creek – Kdam to upstream end of habitat project	8/02/2011	43.3864N/87.87232W	43.38638N/87.87432W	165

Sauk Creek – upstream of the falls	8/02/2011	43.3954N/87.883W	43.39739N/87.88469W	300
Sucker Creek at Sucker Brook Lane	8/02/2011, 8/09/2011, 8/17/2011, 8/24/2011	43.42401N/87.83798W	43.42709N/87.8365W	550
Willow Creek at Greendale Cemetery	8/24/2011, 8/30/2011	43.74511N/87.75982W	43.74694N/87.76041W	275

2011 survey results

In 2011 we began our survey on July 25th and ended on August 30th covering five locations.

Pigeon Creek

A 175 m reach of Pigeon Creek produced a wide variety of fish each time we sampled. We caught fifteen rainbow trout in four trips, of which eleven were less than 100mm (16 per 1000m; Tables 2 and 3, Figure 7). The water temperature on the sampling days ranged from 69° F to 72° F.

Even though it is a very narrow creek, it is quite productive and sustains a diverse fish community with abundant creek chub, darter species (fantail and johnny), and stoneroller species. Other species commonly found were central mudminnow, blacknose dace, green sunfish, black crappie, white sucker and common shiner. We also caught YOY bluegill, smallmouth bass, largemouth bass, and northern pike. In addition, a few bluntnose minnow and spotfin shiner were caught occasionally. The presence of YOY northern pike in this reach may indicate that Pigeon Creek is used for spawning by adult fish. Cold spring in the upstream waters might be keeping the temperature suitable for building nest for rainbow trout and produce smolts. The daily water temperature averaged around 65 F in Pigeon Creek (Figure 8)

Sauk Creek

Sauk Creek was by far the most productive stream for salmonid smolts in our 2011 survey, producing 155 rainbow trout and one coho salmon smolt (Table 2). Sauk Creek was sampled five times in 2011. The water temperature in Sauk Creek during the month of August ranged from 67 F to 71 F. On August 01, 2011 we caught nine rainbow trout (1 at 100mm, 8 <100mm). On August 02, 2011 we caught two rainbow trout less than 100mm and ten larger than 100 mm, and three brown trout larger than 100mm. On August 09, 2011 we caught thirty rainbow trout smolts less than 100mm, and another

seventeen ranging from 141 to 195mm. In addition, we caught three larger brown trout. On August 17, 2011 we caught nineteen rainbow trout smolts less than 100mm and one coho salmon smolt less than 100mm. Also, thirteen rainbow trout larger than 100mm, and four brown trout larger than 100mm were caught. We also had four recaptured smolts on this day. The fifth sampling was done on August 24, 2011 when 56 rainbow trout and two brown trout were caught. Of the 58 salmonids captured thirteen were recaptured fish. There were 31 rainbow trout smolts less than 100mm. Overall, the number of rainbow trout smolts captured per 1000 meters was 37 which puts it at the top among the four streams sampled (Figure 7). The number of coho salmon smolts captured per 1000 meters was 0.4 (Table 3, Figure 9).

Sauk Creek had a diverse fish community with abundant mottled sculpins, and creek chub, white sucker, longnose dace being common. In addition, creek chub, johnny darter, green sunfish, black bullhead, channel catfish, brook stickleback, bluegill sunfish, pumpkinseed sunfish, and central mudminnow were also present.

Sucker Creek

During the four days of sampling we caught eleven sub-adult brown trout and four sub-adult rainbow trout (Table 2) of which three were recaptured brown trout and one was a recaptured rainbow trout. We also caught one rainbow trout of 87mm on 8/24/2011 (Table 3, Figure 7). Other fish species included in the catch were longnose dace, creek chub, Johnny darter, round goby, fathead minnow, green sunfish, pumpkinseed sunfish, bluegill sunfish, yellow perch, white sucker, black bullhead, bluntnose minnow, smallmouth bass, brook stickleback, golden shiner, and central mudminnow. The water temperature at this time ranged from 67° to 72° F.

Willow Creek

We were able to get only two days of sampling completed at Willow Creek. On August 24, 2011 we caught thirteen rainbow trout of which ten were less than 100mm. On August 30, 2011 we caught fourteen rainbow trout of which ten of them were less than 100mm. Four of the fourteen rainbow trout were recaptured. Willow Creek had the second highest capture rate among the four streams surveyed with 36 rainbow trout smolts per 1000 m (Table 3, Figure 7). The water temperature at Willow Creek ranged from 59° to 63° F. Other fish species observed were white sucker, creek chub, johnny darter, longnose dace, brook stickleback, bluegill sunfish, northern pike, and largemouth bass.

Pike River

We surveyed the Pike River from July 25, 2011 through August 16, 2011. We did not capture any salmonids. The water temperature during this time ranged from 73° F to 81° F. The flow conditions varied and the water was very warm. Fish species observed in Pike River included creek chub, green sunfish, longnose dace, white sucker, bluegill

sunfish, black bullhead, yellow perch, fathead minnow, blacknose dace, and common carp.

2012 survey results

The goal in 2012 was to complete 4 sampling events in each stream but due to scheduling and weather conditions we conducted fewer sampling trips in 2012 compared to 2011. In 2012 we started the survey on July 8th and ended on August 28th. Infrequent precipitation before and during the 2012 sampling period led to reduced flows on the streams, which hindered sampling efforts.

Pigeon Creek

Pigeon Creek was sampled twice in 2012, on July 30 and on August 8. On both sampling days there were very low flow conditions compared to the previous year. The water temperature (68°-72° F) was comparable to the 2011 sampling period. Only three rainbow trout smolts were caught on July 30, and none on August 8. However, the number of rainbow trout smolts caught per 1000m (17) was similar in both years (Figure 7). Creek chubs and fantail darters were abundant throughout the section, and bluegill sunfish were common. Other species that were present in the stream included green sunfish, stoneroller, central mudminnow, Johnny darter, pumpkinseed sunfish, black crappie, largemouth bass, smallmouth bass, yellow bullhead, and longnose dace.

Sauk Creek

In 2012, we sampled Sauk Creek on July 10, July 30 and August 8; however, due to backpack shocker problems we conducted an abbreviated survey on July 10th. On July 30th and August 8th the stream flows were good for shocking and water temperature on the days of sampling ranged from 66° F to 68° F. We caught good numbers of rainbow trout smolts, a few brown trout smolts and two coho salmon smolts. Sauk Creek had the highest number of rainbow trout per 1000 m (49 per 1000m; Table 3, Figure 7) among the four streams surveyed, and it was the only stream where brown trout smolts (8 per 1000m) were found (Figure 10). The daily water temperature from the thermistor data stayed below 70 F for the most part in the summer of 2012 (Figure 11). Sauk Creek has a diverse fish community. Longnose dace were abundant followed by mottled sculpin. Creek chub, common shiner, green sunfish, and Johnny darter commonly occurred.

Sucker Creek

In 2012, Wisconsin experienced low rainfall totals throughout most of our study area. Streams like Sucker Creek were affected more than other streams and exhibited very low flows and warmer temperature (68° F) compared to 2011. Because of these conditions, we only sampled on one day (July 8, 2012) and only a small section of the stream. This limited our catch to two unclipped yearling brown trout.

Willow Creek

Willow Creek was sampled on July 8 and July 10, 2012. The water temperature varied between 60° F and 62° F. We caught a fair number of rainbow trout smolts (29 per 1000 m, Table 3 and Figure 7), a few coho salmon smolts (5.5 per 1000 m, Table 3 and Figure 9), and yearling brown trout. Longnose dace, creek chub, green sunfish, and Johnny darter were present throughout the sampling section.

Pike River

We sampled two sections of the Pike River on August 28, 2012. We did not catch any salmonid smolts. Green sunfish were abundant in this area along with blacknose dace, creek chub, white sucker, bluegill sunfish, common shiner and black bullhead. We observed one adult steelhead trout present in the sampling section.

Table 2. Distance surveyed and the number of salmonids (all sizes) caught in four Lake Michigan tributary streams surveyed in 2011 and 2012.

Streams	Distance sampled (m)		# rainbow trout		# brown trout		# coho salmon	
	2011	2012	2011	2012	2011	2012	2011	2012
Pigeon Creek	700	175	15	3	0	0	0	0
Sauk Creek	2250	900	155	48	0	7	1	2
Sucker Creek	550	550	5	0	11	2	0	0
Willow Creek	550	550	25	18	0	1	0	3

Table 3. Distance surveyed and the number of salmonid smolts (<100mm) caught in four Lake Michigan tributary streams surveyed in 2011 and 2012.

Streams	Distance sampled (m)		# rainbow trout smolts		# brown trout smolts		# coho salmon smolts	
	2011	2012	2011	2012	2011	2012	2011	2012
Pigeon Creek	700	175	11 (15.7)	3 (17.1)	0	0	0	0
Sauk Creek	2250	900	84 (37)	44 (49)	0	7 (7.8)	1 (0.4)	2 (2)
Sucker Creek	550	550	1 (2)	0	0	0	0	0
Willow Creek	550	550	20 (36)	16 (29)	0	0	0	3 (5.5)

Note: Numbers in the parenthesis indicate number of smolts per 1000 m.

Combined data for the 2011 and 2012 surveys indicated that rainbow trout reproduced in the four streams surveyed north of Milwaukee (Table 3). A wide range of size classes

were represented in the sample (Figure 12). The samples were comprised of smolts less than 100mm to sub-adult rainbow trout ranging from 100mm to 229mm.

2013 survey results

Limited sampling was conducted in 2013 at Willow Creek, Pigeon Creek and Sucker Creek, with two days of effort at each site using a single backpack shocker.

Pigeon Creek

We sampled Pigeon Creek on May 13, 2013 and May 20, 2013. Water was clear with moderate flows and water temperature was 61° F. Stoneroller, common shiner and bluegill sunfish were common and white sucker, fantail darter, green sunfish, pumpkinseed sunfish, central mudminnow and yellow perch were noted as present. We also observed one adult steelhead.

Sucker Creek

Sucker Creek was sampled on May 13, 2013 and May 20, 2013. We caught four rainbow trout smolts, one yearling rainbow trout and four juvenile unclipped brown trout. Longnose suckers were abundant on both days. We also observed longnose dace, darters, fathead minnow, white sucker, golden shiner, common shiner and pumpkinseed sunfish.

Willow Creek

We sampled at Willow Creek on May 13 and May 20. Stream conditions were good for sampling, with temperatures 51° F on May 13, and 58° F on May 20. We captured 22 unmarked rainbow trout (>100mm) and one coho salmon smolt. Creek chub, longnose dace, common shiner, and Johnny darter were common; fantail darter, white sucker, stone roller, blacknose dace, and bluegill sunfish were present in lesser numbers in Willow Creek. We also captured one adult steelhead.

2014 survey results

In 2014 we spent one day of effort late in August at each of four sites - Pigeon Creek, Sauk Creek, Sucker Creek and Willow Creek,

Pigeon Creek

Pigeon Creek was sampled on August 20, 2014 and we caught three unclipped rainbow trout averaging 180 mm. The water temperature was 70° F. We also observed abundant numbers of creek chub, and central mudminnow, stoneroller, fantail darter and Johnny darter noted as common in the section. YOY largemouth bass, green sunfish, yellow bullhead, common shiner, yellow perch, and white sucker were also present. In addition, we captured five YOY/juvenile northern pike indicating northern pike spawning in Pigeon Creek.

Sauk Creek

Sucker Creek and Sauk Creek were sampled on August 26, 2014. We found 38 YOY and juvenile rainbow trout in Sauk Creek. The water temperature was 64° F. Creek chub and mottled sculpin were common in this section of Sauk Creek. We also observed white sucker, yellow bullhead, blacknose dace, longnose dace, bluegill sunfish, and stoneroller.

Sucker Creek

At Sucker Creek we caught one brown trout and three rainbow trout juveniles. The water temperature was 68° F. We observed abundant number of creek chubs followed by white sucker and green sunfish. Other species noted were round goby, brook stickleback, fathead minnow, blacknose dace, yellow perch, black bullhead, and yellow bullhead.

Willow Creek

Willow Creek was sampled on August 20, 2014 and we captured fourteen rainbow trout smolts. The water temperature was 60° F and flows were good for shocking.

Overall, a similar pattern of fish community was observed in 2013 and 2014 as that of previous years, except that Sucker Creek had more rainbow trout smolts.

Salmonid Natural Reproduction Survey Sites 2011 - 2014

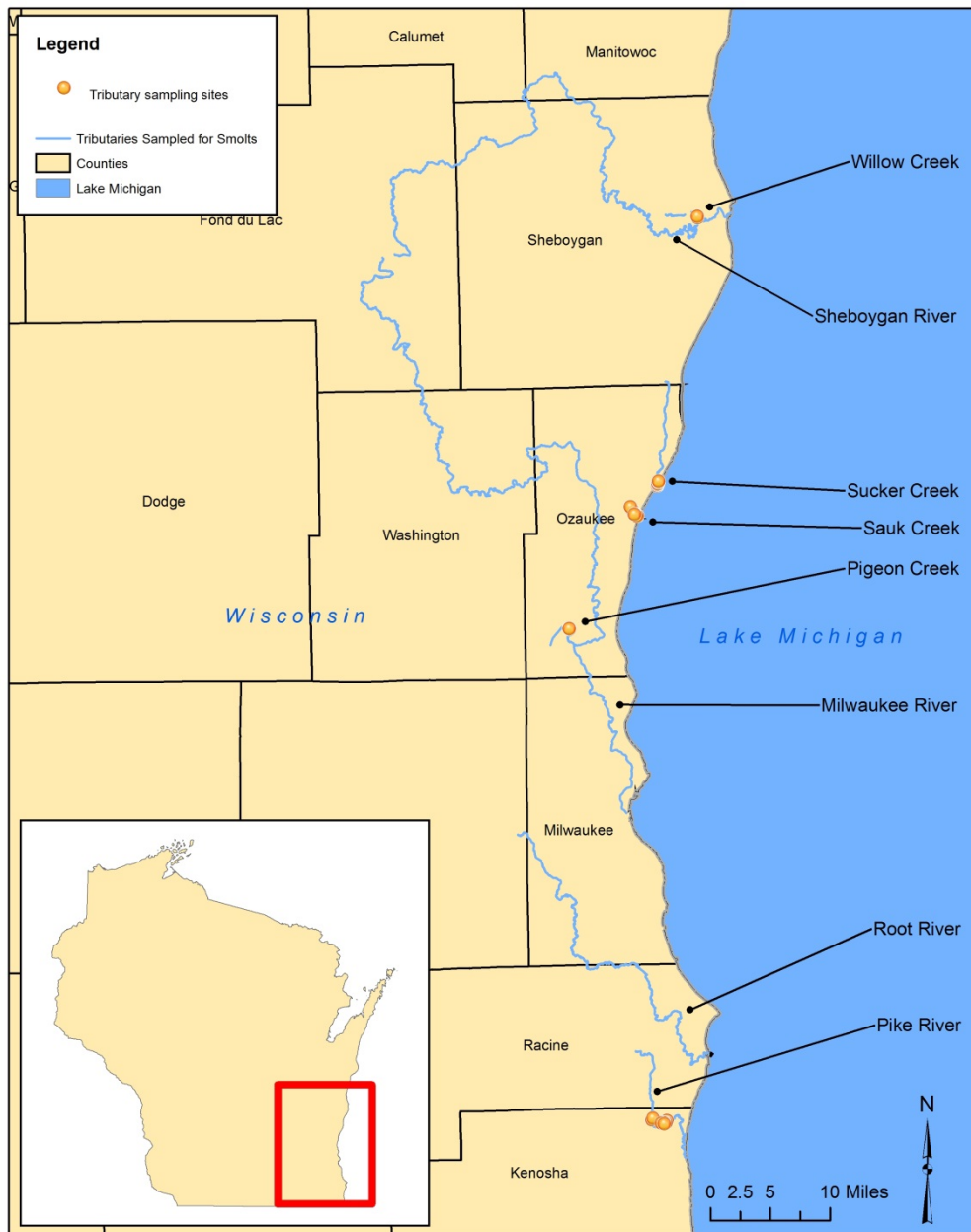


Figure 1. Lake Michigan tributary streams sampled from 2011 to 2014 to identify and quantify potential streams with natural reproduction of salmonids.



Figure 2. Pigeon Creek, a tributary to Milwaukee River near Highland Road, Mequon.



Figure 3. Sauk Creek downstream of Highway 33, Port Washington.



Figure 4. Sucker Creek near Sucker Brook Road, north of Port Washington.



Figure 5. Willow Creek, a tributary to Sheboygan River at Greenfield Cemetery, Sheboygan.



Figure 6. Pike River in Kenosha County near Route 31 and Highway A.

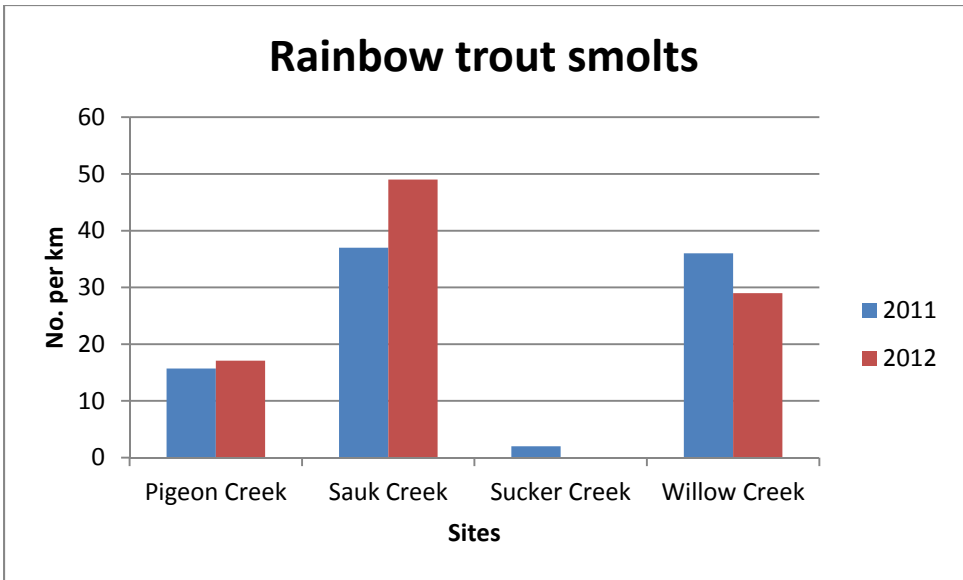


Figure 7. Distribution of Rainbow trout smolts (<100mm) in four Lake Michigan tributary streams in 2011 and 2012.

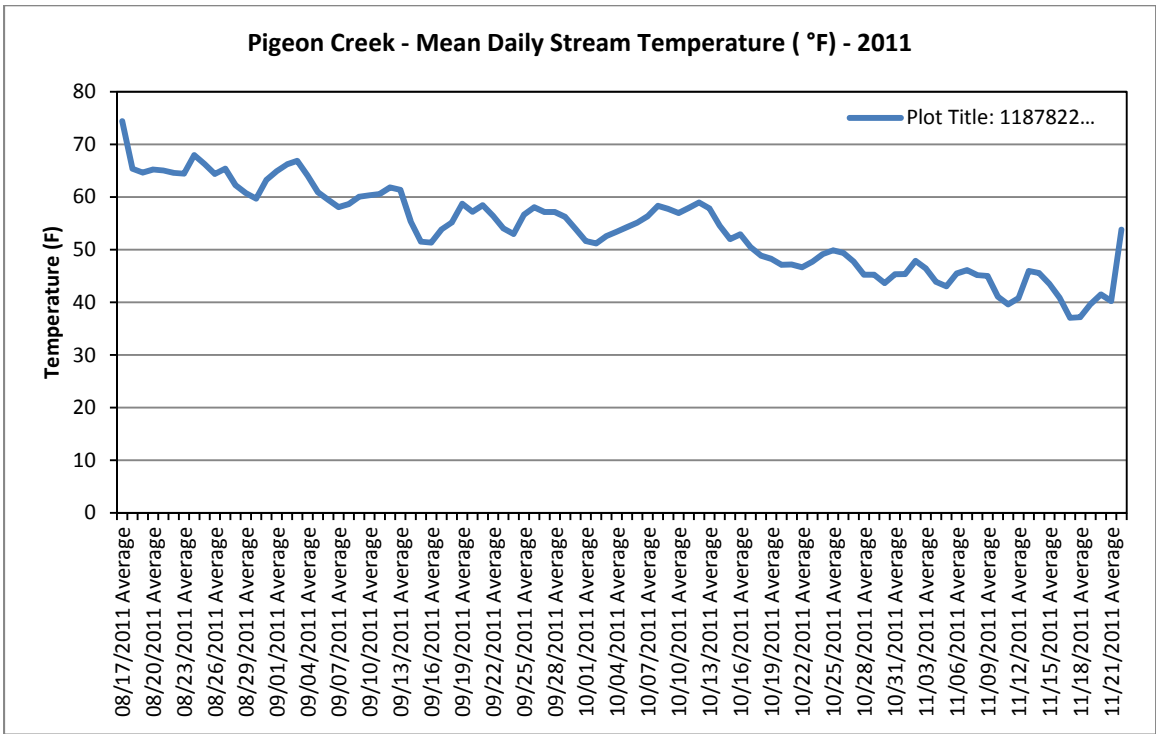


Figure 8. Average stream temperature (degree F) in Pigeon Creek in 2011.

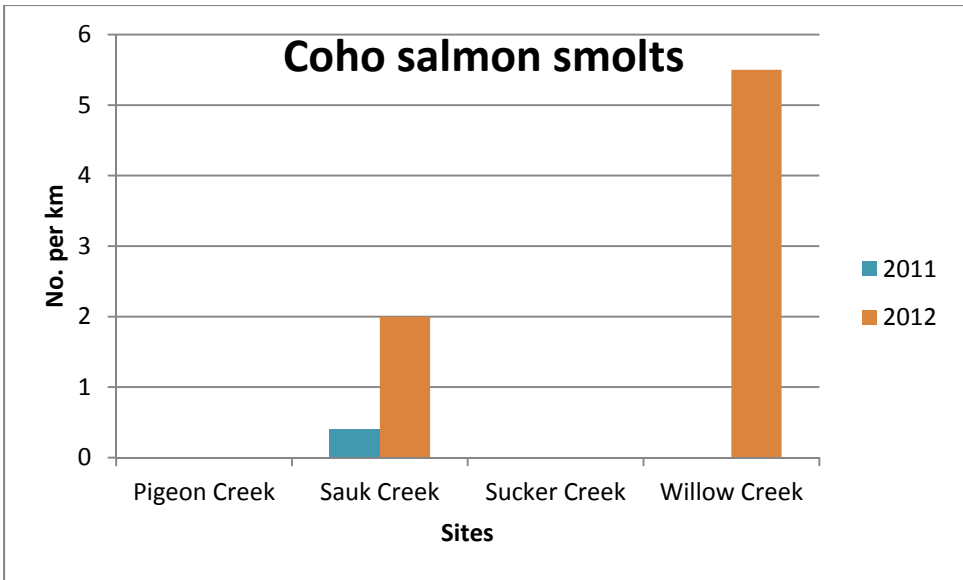


Figure 9. Distribution of Coho salmon smolts (<100mm) in four Lake Michigan tributary streams in 2011 and 2012.

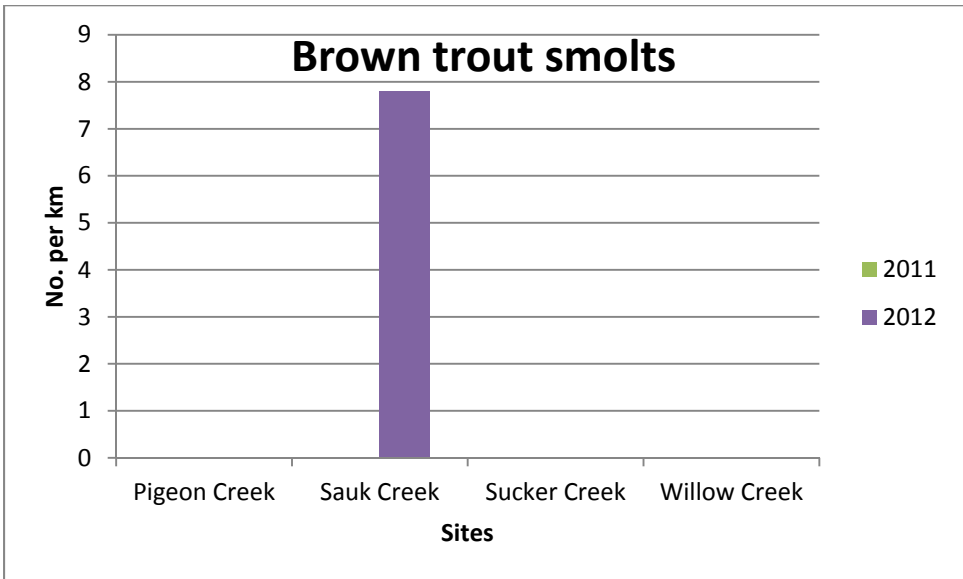


Figure 10. Distribution of Brown trout smolts (<100mm) in four Lake Michigan tributary streams in 2011 and 2012.

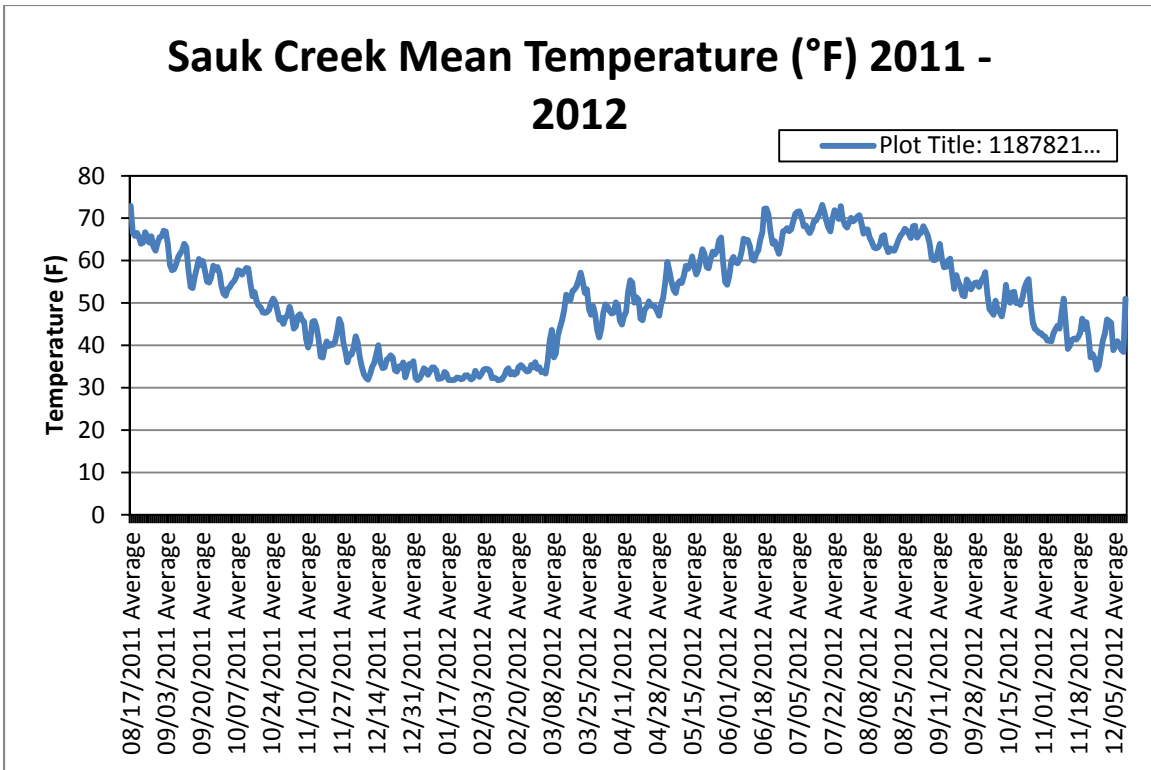


Figure 11. Average stream temperature (F) in Sauk Creek from August 2011 through December 2012.

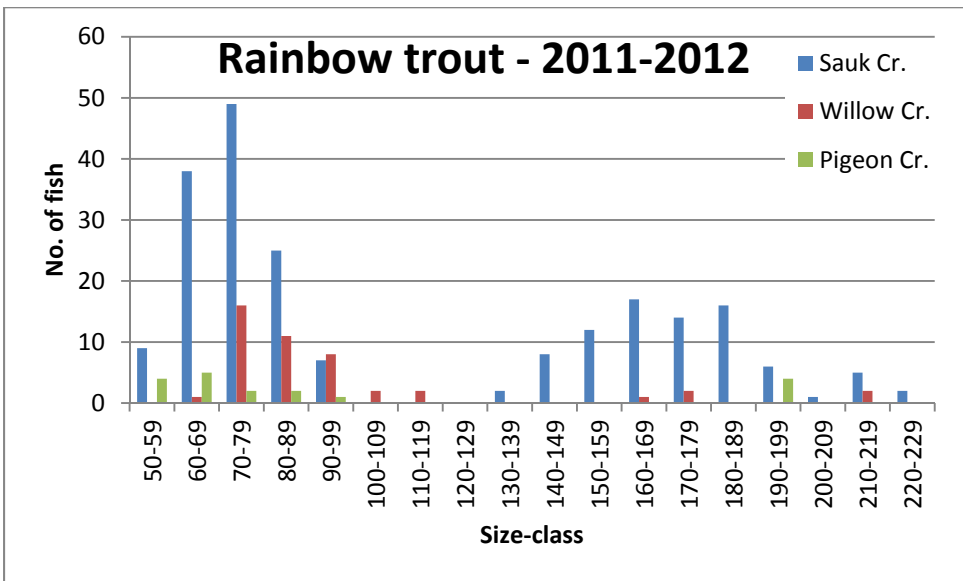


Figure 12. Length-frequency distribution of unclipped rainbow trout captured in Sauk Creek, Willow Creek and Pigeon Creek during 2011-2012 survey.



Figure 13. Fry capture location on Willow Creek. Note evidence of salmonid redd in center of photo.



Figure 14. Salmonid sac-fry captured on Willow Creek at Greenfield Cemetery, Sheboygan.

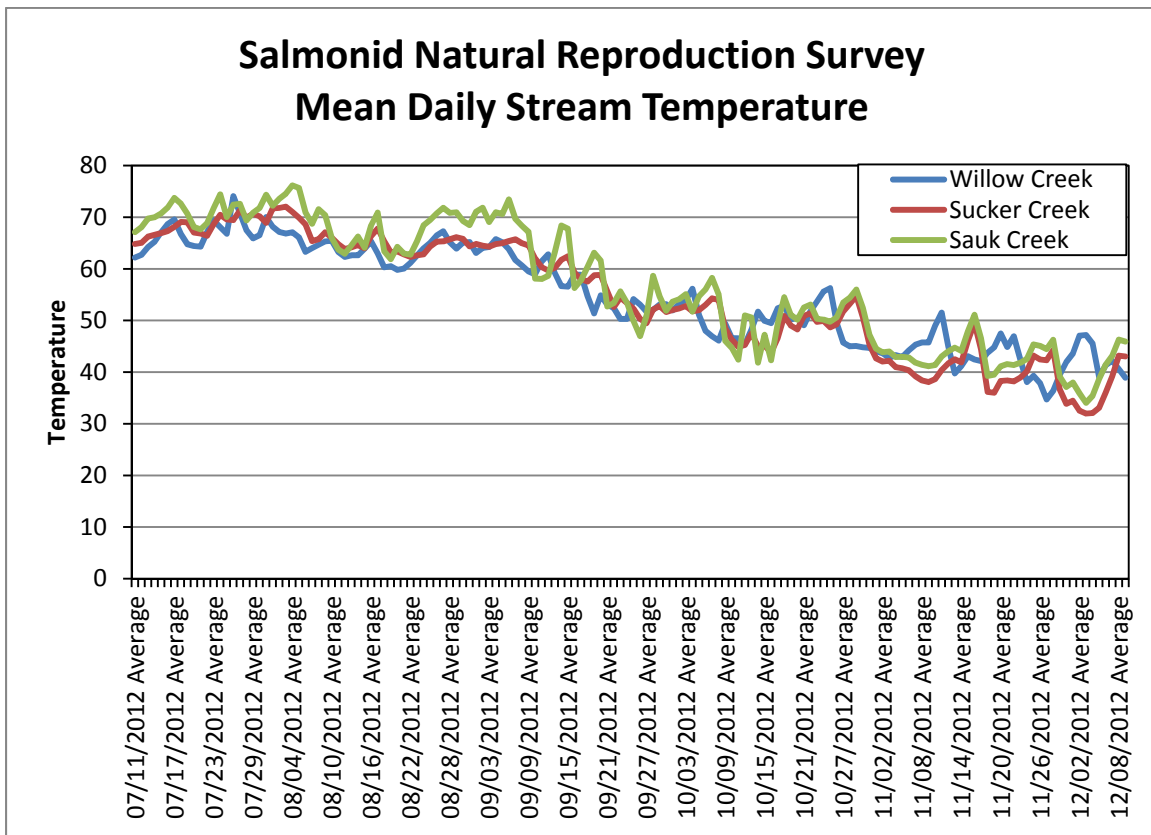


Figure 15. Average stream temperature (degree F) at three sampling sites – Willow Creek, Sucker Creek, and Sauk Creek in 2012.

DISCUSSIONS

Trout and salmon are very important components of the Lake Michigan sport fishery. Rainbow trout from the west coast and brown trout from Europe were introduced to the Great Lakes in late 1800s. Coho salmon were first stocked in Lake Michigan in 1966 followed by Chinook salmon in 1967 to capitalize on the abundant prey population of invasive alewife. The stocked potamodromous salmon and trout survived, grew fast, matured and returned to streams for spawning. Occasionally, naturally reproduced salmon smolts were observed in tributary streams across the Great Lakes indicating natural spawning success. Wild reproduction of stocked salmonids was first documented in eastern Lake Ontario streams in 1977 by Johnson and Ringler (1981). They observed that wild coho salmon and rainbow trout juveniles were abundant compared to Chinook salmon. Although, currently the Lake Michigan salmon and trout fishery is managed through extensive stocking of hatchery raised fingerlings, it is important to understand the contribution of wild fish to the overall numbers in the lake.

In Wisconsin, natural reproduction of salmonids was detected in early 1990s, and biologists conducting stream surveys in the Lake Michigan tributaries continued to encounter salmonids smolts in these streams (WDNR data). Based on these initial

collections and knowledge of the streams, we selected five streams for a systematic survey in 2011 and 2012 and extended this survey with less effort in 2013 and 2014.

Of the five streams sampled, the Pike River was the southernmost site. We did not detect any smolts in the Pike River even though there is substantial salmonid fish spawning run in the fall and spring. The water temperature, water quality and substrate are more suitable for warm water fish species like sunfish and creek chub which were abundant. The water temperatures in the summer in 2011 ranged from 73 to 81F. In addition, water flows during this time ranged between 5 and 100 cfs at the headwaters. Poor habitat quality due to sedimentation caused by bank erosion and run off are a major problem in this watershed and probably is a major cause for the nonexistent salmonid production in this stream. In general, Wisconsin streams are considered to be less viable for salmonid reproduction compared to the Michigan streams due to smaller drainage basin and extensive agricultural usage in their watersheds. However, Wisconsin does have some viable streams north of Milwaukee where we captured fair number of smolts.

Sauk Creek in Ozaukee County which directly drains into Lake Michigan turned out to be one of most productive streams in this study. Sauk Creek was not only the stream in this study that produced three species - rainbow trout, brown trout and coho salmon smolts of wild fish, it also produced the greatest number of rainbow trout per kilometer (49 in 2012) among the four streams that had smolts. The summer temperature data (Figure 11) indicate that the temperature ranged from 60° to 70° F and temperatures in the spring ranged from 40° to 60° F which is a suitable range for rainbow trout egg development (Becker 1983). Even though the flows can vary dramatically due to rain events in the summer, there remains some base flow throughout the year providing shelter for larger fish. In addition, there are deeper pools present throughout the creek and probably provide good overwintering habitat for these smolts. This is further supported by the presence of other cool to cold water species like mottled sculpin.

Willow Creek, which is a tributary to the Sheboygan River, has significant forest cover and good gravel substrate suitable for building redds. We documented several redds on these stream beds (Figure 13) as well as newly hatched fry with large yolk sacs (Figure 14). The water temperature was slightly cooler than that of Sauk Creek (Figure 15) probably due to spring water as well as dense tree cover. This stream was the second best stream in this study in producing rainbow trout smolt at 36 per kilometer of stream in 2011. In addition, there were a few coho salmon smolts in the Willow Creek sample. Most of the smolts were in 70mm to 89mm size range, with very few larger individuals. It is possible that there is not enough refuge for the larger individuals to hide in the winter.

Pigeon Creek is a tributary to the Milwaukee River with a diverse fish community. Although most of the species that we captured were warm/cool water species that included bass and sunfish, a fair number of rainbow trout smolts were captured. No other species of salmonids were present in Pigeon Creek. Potential groundwater inputs to Pigeon Creek may be keeping water temperatures in the 60s in August (Figure 8), thus

providing suitable conditions for smolts to survive. Bank erosion and sedimentation may limit suitable spawning areas for trout and salmon.

Only one individual rainbow trout smolt was caught in Sucker Creek during the 2011-2012 sampling season. However, it does indicate that there is active spawning in this stream. In 2013 we caught four rainbow trout smolts, and one yearling rainbow trout. Our thermistor data suggested that the summer temperature in Sucker Creek is similar to Sauk Creek and Willow Creek. But, the intermittent nature of flow, shifting course of the stream and sedimentation may have created adverse environmental conditions for successful incubation and survival of eggs and larvae.

Rainbow trout smolts were present in all four streams surveyed. Rainbow trout length frequency shows a distinct bimodal distribution pattern (Figure 12). The first mode mainly comprises of fish that range between 50 and 110 mm, and the second mode mainly comprises fish between 130 and 200 mm. There were some fish greater than 200 mm in length. According to Becker (1983) the rainbow trout smolts reach about 70-80 mm by August-October. Based on our discussion with WDNR hatchery staff (Andy Hron, Supervisor, Kettle Moraine State Fish Hatchery) with regard to growth rate of smolts and the size at stocking, we considered unclipped rainbow trout smolts less than 100 mm in late summer as wild produced. That includes the majority of fish under the first bell curve in Figure 12. Rainbow trout are known to spend 1-2 years in the stream where they were born. Those unclipped trout greater than 100 mm could be either stocked or wild fish that held over through the winter.

Sauk Creek was the only stream that produced some brown trout smolts. Brown trout prefer a 50°-65° F temperature range and hide in the pools. Coho salmon smolts were captured in Sauk Creek and Willow Creek. Coho salmon were first introduced to Lake Michigan in 1966. The coho fishery is supported mostly through continued stocking. Wild production of coho in Lake Michigan streams is sporadic. The success of larval emergence depends on the stream flow and substrate conditions, intergravel oxygen levels, winter temperature conditions and fluctuations in the flow rates. These factors may be limiting the coho production in Wisconsin streams even though there is a significant adult run in the fall. Although previous surveys have documented occasional occurrence of Chinook salmon smolts in Wisconsin tributaries, we did not capture any Chinook salmon smolts in the present survey.

CONCLUSIONS

Tributary streams in Wisconsin have smaller drainage areas compared to the streams in Michigan. The drainage area, stream flows, water temperature and bottom substrate all play very important roles in the successful production of natural salmonid smolts. Although the streams that we surveyed appeared to be marginal quality streams, certain sections of these streams have greater potential for natural reproduction when the right environmental conditions are met. In this survey, rainbow trout smolts were by far the most numerous salmonid caught during the 4 years of this project. We did not document any Chinook salmon smolts in this survey. In a study on natural reproduction of coho

and Chinook salmon in some Michigan streams Carl (1982) observed that most Chinook salmon reproduction was in the larger trout streams, which were fast flowing. The streams in Wisconsin are relatively smaller, and hence we saw mostly rainbow trout, brown trout and a few coho salmon smolts. Sauk Creek was the most productive water in this survey followed by Willow Creek, primarily for rainbow trout.

Various methods such as scale and otolith microstructure (Marcogliese and Casselman 1998, Smith et al., 2006, and Connerton et al. 2009) have been used to determine natal origin of Chinook salmon and rainbow trout. Such techniques may help quantify contribution of wild produced salmon and trout from all of Wisconsin streams to the Lake Michigan fishery. We have extended our cooperation to Jory Jonas, Research Biologist of Michigan Department of Natural Resources who is using otolith microchemistry to identify natal origin of steelhead. In light of the depressed prey abundance in Lake Michigan, such information on quantity and sources of production will help managers to proactively manage the predator-prey balance in the Lake Michigan to sustain long-term fishery.

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