2016 Young of the Year Lake Whitefish Seining Report

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*Photos from cover: Biologists pull a beach seine along the shoreline of Lake Michigan, an underwater image of small fish captured in the beach seine, and six different species (from top to bottom: yellow perch, gizzard shad, round goby, banded killifish, emerald shiner, and white perch) captured in the seine at the Bay Beach Park sampling site.*
Introduction

Coregonid fishes (i.e., members of the genus *Coregonus*) of Lake Michigan have been an important source of food for humans dating back to some of the earliest Native Americans to settle in the Great Lakes region. Evidence of the use of lake whitefish (*Coregonus clupeaformis*) as a food source by Native Americans can be found at archaeological sites around Lake Michigan dating back 3,000-4,000 years (Cleland 1982). Some of the earliest European settlers to the area noticed the abundance of fish caught by the Native Americans and began their own commercial fishing in near shore environments in the late 1700s (Ebener et al. 2008). When near shore fisheries declined, these settlers moved offshore, first using European pound nets and then switching to gill nets (Struwe 2016). As human populations increased and technology improved, large scale commercial fisheries using steam tugs and gill net lifters sprang up around Lake Michigan during the late 1800s and catches of Coregonids greatly increased (Struwe 2016; Ebener et al. 2008). By the turn of the twentieth century, commercial fishermen were harvesting millions of pounds of coregonids (i.e., lake whitefish, lake herring [*Coregonus artedi*] and chubs [bloater; *Coregonus hoyi*]; Figure 1; Baldwin et al. 2009).

Since commercial fishing for coregonids began in Lake Michigan, catches of all species have gone through large fluctuations. For example, peak commercial catches of lake whitefish occurred around 1880 when fishermen caught over 10 million pounds (Ebener et al. 2008; Baldwin et al. 2009). By 1900, commercial catches were only 10-20% of what they were just 2 decades earlier (Baldwin et al. 2008). Between 1900 and 1950, annual lake whitefish catches never recovered to the levels experienced around 1880 as catches fluctuated between 1 and 5 million pounds (Baldwin et al. 2009). By the mid-1950s, the lake whitefish population had collapsed and commercial fishermen caught 20,000 to 50,000 pounds. One reason for the collapse of the lake whitefish population was loss of estuarine and tributary spawning habitat (Wells and McLain 1973; Ebener et al. 2008). The lake whitefish population quickly recovered from its collapse in the 1950s and currently supports the largest commercial fishery for any species in the Great Lakes (Ebener et al. 2008; Baldwin et al. 2009). Over the last decade, lake whitefish have begun using many of the rivers that were historically used for spawning but were abandoned due to poor spawning habitat. Intense river cleanup and habitat restoration is thought to be the reason for the return of whitefish to these historic spawning rivers. Coinciding with the return of lake whitefish to these historic spawning rivers in places such as southern Green Bay, an economically important sport fishery under the ice has grown with sport angler harvest exceeding 50,000 lake whitefish every year since 2008 (Scott Hansen, personal communication).

Lake herring and chubs historically showed similar and even more dramatic population fluctuations than lake whitefish. While lake whitefish catches were declining in the late 1800s, lake herring/chub catches were increasing, with catches peaking in the early 1900s at over 25 million pounds (Baldwin et al. 2009). By 1920, commercial catches of lake herring and chubs had declined to 10-20% of their peak (Figure 1; Baldwin et al. 2009) and the effects of commercial fishing could be seen as lake herring/chub fishing had stopped in many ports because none were caught (Koelz 1926). As the whitefish population collapsed in the 1950s, lake herring and chub catches increased likely due to diverted effort from lake whitefish to the more abundant lake herring and chubs (Figure 1; Baldwin et al. 2009). Increases in lake herring
catches didn’t last long because they too collapsed by 1960 (Figure 1; Baldwin et al. 2009). Since 1970, commercial catches of lake herring have not exceeded 10,000 pounds in Lake Michigan (Figure 1; Baldwin et al. 2009). Since their collapse in late 1950’s, lake herring catches by commercial fishermen, sport anglers, and fisheries assessment surveys by state, federal, or tribal biologists have remained extremely rare until the last 10-20 years. Since the mid 1990’s, catches of lake herring have increased in Grand Traverse Bay and a localized sport fishery for them has started in Grand Traverse Bay. Lake herring have also been caught in other areas around Lake Michigan. The related chub population has also fluctuated through time with annual catches ranging from 5-10 million between 1950 and 1970, decreasing to 3-4 million between 1970 and 2000, and decreasing even further to 1-2 million during the 2000s (Figure 1; Baldwin et al. 2009).

Given their economic importance as both sport and commercial fish species, coregonids, especially lake whitefish, have historically been and still remain some of the most intensively managed fish species in Lake Michigan. Every year, state, federal, and tribal agencies spend countless hours conducting population assessments and collecting biological data from commercial fishermen’s lake whitefish catches to serve as the foundation of statistical catch at age models used to set annual commercial harvest quotas for this species. Data that goes into the lake whitefish statistical catch at age models include proportional age structure of the population, growth metrics such as mean lengths at age and length-weight relationships, relative abundance from standard net sampling that has taken place for decades, natural mortality estimates, and much more. Although a statistical catch at age model does not exist for chubs, scientific data collected by management agencies who monitor commercial fishermen catches is used to set harvest quotas for this species as well. Despite such intensive effort to gain the best possible knowledge about the coregonid populations, most of this effort is aimed towards harvestable size fish and little is known about the recruitment dynamics of these species. Knowledge of these recruitment dynamics could help manage these commercially important species, especially if knowledge of relative abundance of age-0 coregonids can be used as an index for year class strength and future adult abundance. Furthermore, sampling young of the year coregonids could provide data on the reproductive success of lake herring, information that could be used to enhance the recovery efforts of that species in Lake Michigan.

Realizing that significant informational gaps exist regarding coregonid recruitment combined with the potential management value that could be gained from this information, biologists from management agencies around Lake Michigan began to sample for young of the year coregonids in 2013 and 2014 (Donner SOP). Over the past couple of years, the number of agencies conducting age-0 coregonid sampling has increased and biologists are hopeful that results from these surveys can be used to develop a coregonid recruitment index that can be used to quantify which abiotic and biotic factors are most important drivers of coregonid recruitment (Donner SOP). The objective of this report is to provide a summary of the results of the 2016 coregonid recruitment survey conducted by the Green Bay US Fish and Wildlife Service Office as a part of this lakewide coregonid monitoring effort.
Methods

Field Sampling

As part of a basin wide effort, beach seining was performed to monitor age-0 coregonids by the Green Bay US Fish and Wildlife Service office at 13 sites around Green Bay waters as well as the main basin of Lake Michigan (Figure 2). Five sampling sites were in Green Bay waters, while eight were along the western shore of the main basin extending from northern Door County to Port Washington, just north of Milwaukee (Figure 2). Many sampling locations were located near historical or suspected current coregonid spawning areas. Seining during late spring and early summer of 2016 began on June 2 and ended on July 5. The goal was to sample at least three seine hauls at each site, which was achieved at seven of the 13 sites, whereas other sites had only one or two seine hauls due to reasons like lack of suitable area for seining (Table 1). A total of 31 seine hauls were conducted among the 13 sites. All sampling for a given site was done on the same day, except for the Liberty Grove and Portage Park sites that were sampled on multiple days. During each seine haul, a Sea Bird water profiler was deployed to collect water quality data.

All seine hauls were pulled using the standard net specified for the survey, a 150 ft long x 6 ft tall seine with a 6 ft x 6 ft x 6 ft bag in the center, constructed of 1/8 inch delta mesh. Seine hauls followed the methods described by Donner (SOP) in which one end of the seine remained on shore and the other was pulled until it was fully extended 150’ perpendicular to shore or until water got too deep to seine. When either of these occurred, the net was circled around and brought back to the starting point. The mean area sampled for a single seine haul using this technique was 845 square meters (SE = 56 square meters). All but two of the 31 seine hauls were pulled on sand or gravel with the other two being pulled on cobble or a mix of gravel and cobble. Per the guidance, seine hauls were spaced at least 50 meters apart to minimize influence of one seine haul on the others.

Lab Processing

The sampling crew collected a subsample (approximately 100 lake whitefish) of the total catch and brought them back to the lab for processing with the remainder of the fish counted and released alive. In addition to whitefish, approximately 50 individuals from other species were brought back to the lab with the remainder counted and released. Once brought to the lab, the fish were measured for length and weight. The crew also extracted aging structures (otoliths) from a number of lake whitefish in June of 2016 that were believed to be age 1 (72 to 169 mm). The crew utilized a fish identification key in cases where fish species were difficult to identify. The majority of the lake whitefish were sent to a genetics lab for species verification, ensuring that they were properly identified.
Data Analyses

Total numbers of lake whitefish were plotted by location and date for comparisons and mean lengths and weights were obtained. Maps were made to compare catch rates of *Coregonus* spp. caught and species composition. Within sites, seine hauls were compared to assess variation.

Water, air temperature and dissolved oxygen values were plotted for each site and date to analyze impacts on lake whitefish catches. Length and weight relationships were summarized for other coregonid species sampled during the 2016 beach seining survey.

Results

In 2016, a total of 6,743 individual lake whitefish were caught by the GBFWCO and an additional 6,185 by the Wisconsin Department Natural Resources at Whitefish Dunes, a site that was previously surveyed by the GBFWCO in 2015. These 2015 results are available in a previous report. Two sites (Fox Point and Liberty Grove) accounted for 97% of all the lake whitefish caught during 2016 (Figure 3). Fox Point accounted for 79% (5315 individual fish) while Liberty Grove accounted for 18% (1192) lake whitefish. Lake whitefish accounted for 98% of the total catches at Fox Point and Liberty Grove. By early July, only a small number of lake whitefish remained at Liberty Grove, as juvenile whitefish move offshore in mid-summer. The remaining sites of Marinette, Baileys Harbor, Two Rivers, Kewaunee, and Portage Park accounted for 4% (237) lake whitefish. The total area covered during each seine haul ranged from 267 m² at Port Washington to 1571 m² at Two Rivers with an average area covered of 846 m² over the entire survey (Figure 11). The average area sampled at Fox Point was 1184 m².

The largest lake whitefish were sampled at Kewaunee, Portage Park and Two Rivers on June 27th (Figure 6). These 15 lake whitefish were over two and a half times longer and 14 times heavier than the average length and weight of the lake whitefish sampled on June 21st at Marinette, indicating that these fish were likely yearling fish that were still inshore, with only one fish of lengths consistent with young of year. On June 23rd, at Liberty Grove, 736 lake whitefish were caught with an average length of 46 mm and weight of 0.7 g. Two weeks later, on July 5th, 456 lake whitefish were caught with an average length of 53 mm and weight of 0.9 g.

Lake whitefish accounted for 23% of the 29,549 total fish caught during the survey with 29 different fish species caught. Figure 7 shows the proportion of each fish species with the total number of each species during the survey. Lake whitefish, spot-tailed shiner and the
Invasive alewife accounted for 86% of all fish sampled with alewife representing just under 50% of the total catch.

Bay Beach was chosen as a site based on the knowledge of lake whitefish spawning in the nearby Fox River. On June 15th, crew seined Bay Beach and caught 13 different species including a few less common species including: walleye, yellow perch, white perch and banded killifish. There were 306 probable shiners caught at Bay Beach that were unidentifiable due to their small size and loss of their identifiable characteristics. Figure 8 shows the average total length of each species caught in the two seine hauls at Bay Beach. Not depicted on the graph are one walleye and several freshwater drum as they were released alive. The species diversity and high catches indicates species competition and is one possible explanation for no lake whitefish caught at Bay Beach.

Average numbers of lake whitefish sampled were compared to average water temperature, dissolved oxygen levels, and area swept in Figures 9, 10, 11. As can be seen in these plots, no clear relationship with any of these factors is obvious, and catch numbers are more dependent on site. Young of year whitefish were sampled in waters ranging from 9.7 °C (June 27, Kewaunee) to 20 °C (June 20, Liberty Grove). Dissolved Oxygen ranged from 9.8 to 13.8 mg/L throughout the survey, well above the threshold of 5 mg/L for freshwater fish survival (Herb et al. 2017)(Figure 10).

In addition to young of year whitefish, 27 bloater *Coregonus hoyi* were caught during the survey at four different sites on June 9th and June 27th (Figure 12). Nearly half of the bloaters were caught at Two Rivers on June 27th. Of note is that the bloaters in the southern site of Port Washington were of a size range not reached by their brethren in the northern sites until almost 2.5 weeks later.

**Discussion**

As can be seen in the results above, young of year lake whitefish were locally concentrated in Green Bay and the Lake Michigan shoreline during the survey period with the two highest catches at Fox Point, in Green Bay, and Liberty Grove on the Lake Michigan side of Door County. Fox Point was definitely the most productive juvenile lake whitefish site sampled and will continue to be sampled in upcoming years. Two factors that possibly contributed to the higher lake whitefish catches at Fox Point are higher larval survival in early spring and more food sources compared to other sampling sites. Liberty Grove was the only site where lake whitefish were sampled two weeks apart providing sufficient comparison data on these fish sampled and addressing the objective of multiple sampling days per site.
The largest lake whitefish encountered were caught at sites on the lake on June 27th and were confirmed to be age-1 fish based on whole viewing and aging of otoliths. All other lake whitefish were assumed to be age-0 based on previous knowledge of length at age relationships and that age-0 lake whitefish utilize nearshore sandy habitats prior to moving into deep water in summer. At Liberty Grove, it appears that the lake whitefish sampled on June 23rd grew 7 mm and 0.2 g in two weeks based on the averages from June 23rd and July 5th.

Species diversity is high during spring in the shallow beach environments, especially in Green Bay, based on the 29 different species caught throughout the survey. It was clear that lake whitefish, spot-tailed shiner and alewife occupied the sampling areas more often than the other 26 species sampled based on total catches. Two out of the three highest alewife catches were at sites previously documented (Conservation Biology Institute) as potential spawning sites for alewife (Solona Road and Two Rivers) which typically begins in June and goes through August.

Bay Beach had the highest species diversity among sites, which may be the result of more suitable habitat (vegetation providing protection from predators) or higher levels of zooplankton (daphnia) and phytoplankton as prey for the juvenile fish. Bay beach is located in far southern Green Bay, where the highly productive Fox river empties into the bay and is relatively shallow, allowing waters to warm faster than other parts of the bay and lake. Bay Beach was also the only site in Green Bay that caught adult walleye, possibly feeding on the several juvenile yellow perch and other prey fish caught in the same haul. Based on length measurements, it is likely that several age-1 quillback, gizzard shad and white perch were sampled at Bay Beach.

Average water temperature and dissolved oxygen varied slightly from north to south on the bay and lake however, no water quality results was an indicator of presence or absence of lake whitefish across the sites. The three southern most Green Bay sites were sampled on June 15th with no lake whitefish sampled, an average water temperature of 20.5 °C which was 5 °C warmer than the average temperature at the northern Green Bay sites where lake whitefish were sampled on June 21st. This indicates the possibility that lake whitefish may have moved to deeper water at the 3 southern Green Bay sites prior to sampling, or not been present at all. High numbers of spawning whitefish in the Fox River each fall indicate that it is likely that young of the year are being produced, so it is possible that expanded effort is needed to identify nursery areas.

The majority of juvenile lake whitefish were caught at Fox Point and Liberty Grove, both sites are near known lake whitefish spawning sites. There is also a low probability of species competition at Fox Point and Liberty Grove based on the high numbers of lake whitefish and low by-catch numbers. The highest CPUE in 2016 was seen at Fox Point where each of the three
hauls produced more than twice the amount of lake whitefish of any other site during the survey.

Bloaters sampled were estimated to be age-1 and age-2 based on length and weight comparisons with prior bloater data. It was surprising to see bloater in these beach sites, as they spawn in depths of 80-120 m.

One key take away from the beach seine efforts in 2016 was the importance of sampling each site twice to analyze the difference in catch rates, growth and water quality measurements that may help explain differences in catch. Liberty Grove was the only site where lake whitefish data was collected on dates roughly two weeks apart where the abundance, size, and water quality changes were analyzed. Factors that limited the ideal two week sampling period included weather, suitable seining area at certain sites, and staff availability. Lake whitefish data collected will be useful in determining the recruitment index throughout Lake Michigan and Green Bay once the data from all contributing agencies has been combined and reviewed by managers.

References
Conservation Biology Institute (CBI). Map of alewife spawning areas generated from http://gis.glin.net/ogc/services.php#lm_spawn_alewife_gsa
Donner, Juvenile Coregonid Assessment-Standard Operating Procedure. 2015
Hansen, Scott. Personal Communication. Fisheries Biologist. Wisconsin Department of Natural Resources, Sturgeon Bay Office.
TABLE 1. Number of seine hauls pulled at each of the 13 sites sampled as part of the young of the year coregonid sampling in Lake Michigan between June 2, 2016 and July 5, 2016. Number of sampling days in parentheses.

<table>
<thead>
<tr>
<th>Site</th>
<th>Number of Seine Hauls (number of days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baileys Harbor</td>
<td>3(1)</td>
</tr>
<tr>
<td>Bay Beach Park</td>
<td>2(1)</td>
</tr>
<tr>
<td>Fox Point State Park</td>
<td>3(1)</td>
</tr>
<tr>
<td>Harrington Beach</td>
<td>2(1)</td>
</tr>
<tr>
<td>Kewaunee</td>
<td>1(1)</td>
</tr>
<tr>
<td>Liberty Grove</td>
<td>4(2)</td>
</tr>
<tr>
<td>Marinette</td>
<td>3(1)</td>
</tr>
<tr>
<td>Point Comfort</td>
<td>1(1)</td>
</tr>
<tr>
<td>Port Washington</td>
<td>3(1)</td>
</tr>
<tr>
<td>Portage Park</td>
<td>3(1)</td>
</tr>
<tr>
<td>Red River County Park</td>
<td>2(1)</td>
</tr>
<tr>
<td>Salona Road</td>
<td>1(1)</td>
</tr>
<tr>
<td>Two Rivers</td>
<td>3(1)</td>
</tr>
</tbody>
</table>
FIGURE 2. Locations where seining was conducted to sample young of the year coregonids in Lake Michigan between June 2, 2016 and July 5, 2016.
Figure 3. These maps show the two sites (Fox Point MI. and Liberty Grove WI.) where 97% of the total juvenile lake whitefish were sampled. Individual seine hauls are represented along with total number of lake whitefish and the proportion of total for each haul.
Figure 4. The map shows all of the sampling sites during the 2016 beach seining efforts with total lake whitefish numbers sampled at each site.
Figure 5. The histogram shows the total amount of lake whitefish caught at each site during the 2016 beach seining survey, with the legend indicating the date that each site was sampled on. The numbers in parentheses following Liberty Grove were necessary to indicate that the fourth haul was completed on a different date than the first three.

Total Lake Whitefish Caught per Seine Haul

- Fox Point - 6/21/2016
- Marinette-6/21/2016
- Liberty Grove (1:3)-6/23/2016
- Baileys Harbor-6/23/2016
- Two Rivers-6/27/2016
- Kewaunee-6/27/2016
- Portage Park-6/27/2016
- Liberty Grove (4)-7/5/2016
Figure 6. Total lengths and weights of all subsampled lake whitefish separated by sampling date. The curved lines represent non-linear best fit lines for all sites on the four different dates where lake whitefish were caught during the survey.
Figure 7. The pie chart illustrates the proportion of each fish species sampled during the entire survey including the percentages of the three most abundant species. The total numbers of each species sampled are listed in the legend.
Figure 8: The histogram shows the average lengths of each fish species sampled off the shore of Bay Beach Amusement Park on June 15th. The legend shows the total number of each fish species caught. Total lengths were not obtained for freshwater drum, walleye, or spot-tailed shiner.
Figure 9: Each point represents the average number of lake whitefish caught and water temperature at each site on each day. The number of lake whitefish sampled is listed above each point. The legend indicates the average water temperature, sample data and site associated with each point.
Figure 10. Each point represents the average number of lake whitefish caught and dissolved oxygen levels at each site on each day. The number of lake whitefish sampled is listed above each point. The legend indicates the average dissolved oxygen, sample date and site associated with each point.
Figure 11. Each point represents the average number of lake whitefish caught and average area covered at each site on each day. The number of lake whitefish sampled is listed above each point. The legend indicates the average area covered, sample data and site associated with each point.
Figure 12: The map shows site, number of bloater sampled and percentage of the total number sampled. The two scatter plots indicate length and weight relationships for bloater sampled on the 2 dates they were encountered.