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A Comparison of Three Paired Modified Fyke Nets for Characterizing Fish Assemblages in the Nearshore Zone of Lake Michigan

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Abstract
We performed a gear comparison between three types of paired fyke nets used to monitor fish communities in the nearshore zone of Lake Michigan. Our objective was to identify a single net design that would maximize species diversity and catch. The three types of paired fyke nets included a small frame model with 3-mm bar mesh (Mini-fyke), a larger-framed model with 13-mm mesh (Fyke), and a large frame model with 13-mm mesh recommended by the American Fisheries Society (AFS-fyke). We set all three gear types in triplicate on similar nearshore littoral habitat at 16 sites in Green Bay, an embayment of Lake Michigan. Total catch was dominated by Gizzard Shad Dorosoma cepedianum, Round Goby Neogobius melanostomus, Spottail Shiner Notropis hudsonius, Trout-perch Percopsis omiscomaycus, and Yellow Perch Perca flavescens, which represented 99.3% of all individuals captured. We found that Mini-fyke nets selected for smaller individuals, caught relatively few species, and had the highest catch per unit effort; this was largely driven by high catches of Spottail Shiner and Gizzard Shad. Fyke nets captured the largest individuals, had the lowest catch per unit effort, and the greatest diversity of species. Results for AFS-fyke nets were typically intermediate between Mini-fyke and Fyke nets for most parameters. Species accumulation curves indicated that Fyke nets acquired more total species at a higher rate than the other two net types. Given the need to balance effort, gear bias, and sampling efficiency, we found that AFS-fyke nets recommended by the AFS effectively characterized the nearshore fish community of lower Green Bay, especially if used in conjunction with complementary sampling gears.

Modified fyke nets are frequently used to index fish assemblages in littoral zones of freshwater systems because they are easy to use and effectively capture many species. Typically, modified fyke nets are affixed perpendicular to shore with a lead that directs fish towards the net (Bonar et al. 2009). In contrast, in coastal and nearshore environments of the Great Lakes, modified fyke nets are often deployed in tandem and not affixed to shore, allowing them to be fished in deeper waters (Kraft and Johnson 1992; Seilheimer and Chow-Fraser 2007). Though modified fyke nets are useful and effective, there are well-known biases associated with this gear. Physical dimensions of the net—including frame, mesh size, throat diameter, and throat restriction—limit the size and number of fish captured (Hubert et al. 2012). Behaviorally, these nets tend to attract mobile cover-seeking species, particularly sunfishes of the genus Lepomis that are drawn to groups of conspecifics (Miranda and Boxrucker 2009). Species that are less mobile or less likely to aggregate with conspecifics (e.g., Smallmouth Bass Micropterus dolomieu) are not adequately sampled with these gears (Bacula et al. 2011). For sampling to be effective, the physical dimensions and use of the modified fyke net should fit the needs of the sampling question.

Beginning in 2013, the U.S. Fish and Wildlife Service (USFWS) started sampling the nearshore zone of Lake Michigan in areas identified as being vulnerable to invasion by new aquatic invasive species. A suite of sampling gears was deployed with the objective of characterizing the
nearshore fish community at each site for the purpose of detecting new aquatic invasive species. Two general types of paired fyke nets were used during this initial sampling, including a small-frame small-mesh variety, hereafter referred to as a Mini-fyke net, and a large-frame, large-mesh variety referred to as Fyke nets. The Mini-fyke nets selected primarily for a few small species <150-mm TL (e.g., Round Goby Neogobius melanostomus, Spottail Shiner Notropis hudsonius) but were not effective at capturing larger-bodied species. Fyke nets selected for larger-bodied species because their larger bar mesh size of 13 mm and wider throat diameter allowed more small fish to escape. Both varieties of fyke nets lacked throat restrictions, potentially allowing for high escapement rates. To adequately sample fishes in nearshore zones, a single, more effective design of modified fyke nets was desired.

The American Fisheries Society (AFS) recommends standard gears and methods for sampling freshwater fishes, including modified fyke nets (Bonar et al. 2009). The AFS standard modified fyke net, hereafter referred to as AFS-fyke nets, has mesh and frame dimensions similar to current Fyke nets, but contains a recommended throat restriction that has been demonstrated to reduce escapement, thereby increasing total catch (Smith et al. 2016). We wanted to identify the net(s), preferably one standardized design, that would maximize catch and species richness for use alongside other sampling gears (i.e., electrofishing, gill nets) used during a typical survey. With these concerns in mind, we designed a study with two objectives: (1) identify whether AFS-fyke nets provided fish community data that overlapped with both fyke net designs currently used by USFWS, and (2) compare the ability of each fyke net type to effectively characterize nearshore fish assemblages. Based on dimensions of all three aforementioned gears, we hypothesized that AFS-fyke nets would provide fish community data most similar to Fyke nets, but perhaps complimentary to Mini-fyke nets.

METHODS

Study area.—Our study area was the southernmost 3 km of Green Bay, Lake Michigan (Figure 1). This shallow (<5-m) portion of the bay is eutrophic-hypereutrophic, unstratified during summer, and inhabited by a diverse assemblage of at least 50 fish species (USFWS, unpublished data). Most effort was concentrated in the shallow (<3-m) western half of the study area comprising reconstructed barrier islands and coastal wetlands. Sampling took place during May 16–23, 2016. "Water temperatures reached 15–20°C, corresponding with increased movement and activity of most fishes (Bonar et al. 2009).

Gear description.—All nets were paired in that two identical nets were joined by their leads and set in tandem. Fyke nets (5.4 m long × 0.91 m high; 13-mm bar mesh; 24-m lead) were constructed with two rectangular frames 0.91 m high × 1.22 m wide, followed by four hoops 0.86 m in diameter that contained two unrestricted throats. Mini-fyke nets (4.2 m long × 0.67 m high; 3-mm bar mesh; 12.3-m lead) were constructed with two rectangular frames 0.67 m high × 0.90 m wide, followed by four hoops 0.61 m in diameter and containing one throat. The AFS-fyke nets (4.1 m long × 0.91 m high; 13-mm bar mesh; 30.5-m lead) were constructed with two rectangular frames 0.91 m high × 1.8 m wide, followed by four hoops 0.77 m in diameter. We used AFS-fyke nets with a recommended throat constriction constructed with 24 lengths of #15 twine approximately 380 mm long to reduce escapement (Smith et al. 2016). Catch per unit effort for these gears was the number of fish caught for the combined pair of fyke nets per night (i.e., number of fish per paired net-night).

Study design.—We used a paired sampling design whereby the three types of modified fyke nets set in tandem were fished simultaneously in triplicate at targeted sites sampled in a randomized order. Position of gears relative to one another was randomized with each gear set approximately 100 m from the other two gears in similar habitats. Sampling sites were at least 300 m apart. All nets were fished overnight and retrieved in the same order in which they were set. To identify how many replicates were required, we conducted a priori power analyses in G* Power with species richness data collected from lower Green Bay during 2015 (Faul et al. 2007). We calculated that at least 14 replicates, or 42 individuals net sets, were required to identify significant differences in species richness between fyke net types while achieving a realized power (1-β) of 0.95 assuming α = 0.05 with a 0.65 effect size. We adopted a more liberal sample size of 16 replicates, or 48 individual net sets, to account for potentially higher variability and provide a balanced and consistent weeklong workload for...
two sampling crews. This amount of sampling effort was consistent with that of a previous study which found 14 units of effort were required to optimally monitor species diversity with fyke nets (Fago 1998).

Statistical analysis.—We identified five metrics to compare between gears that would allow us to address our study questions. Size structure data included mean TL of all fish captured for each gear deployment. Species richness was the number of species captured for each paired fyke net. Species diversity and evenness were calculated using Shannon’s diversity ($H'$) and evenness ($J'$) indices (Kwak and Peterson 2007). Catch per unit effort, the number of fish captured for each paired fyke net set (fish per set), was used as an index of relative abundance. Prior to analysis, all data were compared against a normal distribution using the Shapiro–Wilk test, and nonnormal data were log$_{10}$ transformed to meet the assumption of normality. If log transformation did not normalize data sufficiently, then the nonparametric methods were used. Heteroscedasticity was tested using Levene’s test. Comparisons between fyke net types for all response variables were performed in R using ANOVA with site as a blocking factor. If significant differences were detected between gears for any response variable, we performed a post-hoc Tukey’s honestly significant difference (HSD) test to identify directionality of differences. For nonparametric data, the Friedman test was used and post-hoc analysis was performed using the Conover test (Conover 1999). Data for each response variable was presented visually using bar plots of means and SEs. To address our second study objective, species accumulation curves were calculated using 10,000 unique permutations, then plotted using the vegan package in R (R Core Team 2016) and visually compared between net types. Extrapolated species richness for each net type was calculated using bootstrapping methods reported with SE. Jaccard’s similarity index was used to compare species overlap between net types.

RESULTS

The AFS-fyke nets yielded fish community and size structure metrics intermediate between Mini-fyke and Fyke nets. For several fish community metrics, the AFS-fyke net produced results closer to the Mini-fyke net, while the Fyke net was most distinct due to higher measures of species richness, diversity, and evenness (Figure 2). The AFS-fyke and Fyke nets, both constructed with 13-mm bar mesh, tended to collect larger-bodied (>150-mm) fish, while the Mini-fyke nets with 3-mm bar mesh collected smaller-bodied species (<150-mm). The AFS-fyke nets yielded estimates of CPUE greater than that of Fyke nets but less than that of Mini-fyke nets. All three

![Figure 2](image.png)

**FIGURE 2.** Means and SEs of four response variables for each of three net types (i.e., AFS-fyke, Fyke, and Mini-fyke nets). All nets were set in tandem, and sampling was performed during May 16–23, 2016, in Green Bay, an embayment of Lake Michigan. Results of Tukey’s HSD are shown with lowercase letters. Identical letters indicate no significant difference, whereas differing letters indicate significant differences.
net types identified Gizzard Shad *Dorosoma cepedianum*, Round Goby, Spottail Shiner, Trout-perch *Percopsis omisco- 
maycus*, and Yellow Perch *Perca flavescens* as the most abun-
dant species in the fish community. These five species 
represented 99.3% of all individuals, and almost all remaining 
differences in species richness, diversity, and evenness 
revolved around the 0.7% of individuals from all other spe-
cies. Approximately 23% of all unique species were repres-
sented by a single individual between all three gears (Table 1).

Log transformations could not normalize mean TL data, so 
we used the Friedman test and found significant differences in 
mean TL between net types ($\chi^2 = 25.125$, df = 2, $P < 0.001$). 
Post-hoc comparisons showed that Fyke nets caught the larg-
est fish, while AFS-fyke nets caught significantly smaller fish 
and Mini-fyke nets caught the smallest fish. Mean TL of fish 
captured in Fyke nets was $172 \pm 24$ mm (mean TL ± SE) 
compared with $155 \pm 26$ mm for AFS-fyke nets and $127 \pm 
21$ mm for mini-fyke nets. High catches of spawning Spottail 
Shiners resulted in lower-than-expected estimates of mean TL, 
particularly for Fyke and AFS-fyke nets. Estimates of mean 
TL were also slightly overestimated due to high catches of 
Spottail Shiners because only the first 50 individuals of the 
species were measured for each net, and Spottail Shiners were 
among the smallest species captured in these nets. Significant 
site-level differences in mean TL were also detected and were 
likely driven by heterogeneous distributions of adult Gizzard 
Shad and Spottail Shiners in lower Green Bay (site effect: $F = 
32.010$, df = 15, $P < 0.001$).

We identified significant differences in species richness 
between net types (ANOVA: $F = 8.2$; df = 2, 30; $P = 0.001$). 
Directionality of differences, identified using Tukey’s test, 
showed that species richness was highest for Fyke nets and 
similar between Mini-fyke and AFS-fyke nets, though esti-
mates of species richness were higher for AFS-fyke nets 
(Figure 2). Mean species richness was $5.4 \pm 0.4$ for Fyke 
nets, $4.0 \pm 0.4$ for AFS-fyke nets, and $3.5 \pm 0.3$ for mini-
fyke nets. In total, Fyke nets collected 19 species, AFS-fyke 
nets captured 15 species, and Mini-fyke nets caught 14 species 
(Table 1). Estimates of species richness were not influenced 
by site-level factors. 

Estimates of species diversity (ANOVA: $F = 13.6$; df = 2, 
30; $P < 0.001$) and evenness (ANOVA: $F = 5.5$; df = 2, 30; $P$

### TABLE 1. Catch per unit effort (fish per set ± SE) from a gear comparison performed using three types of paired fyke nets (i.e., AFS-fyke, Fyke, and Mini-

<table>
<thead>
<tr>
<th>Species</th>
<th>AFS-fyke</th>
<th>Fyke</th>
<th>Mini-fyke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banded Killifish <em>Fundulus diaphanus</em></td>
<td>0</td>
<td>0</td>
<td>0.31 ± 0.25</td>
</tr>
<tr>
<td>Black Crappie <em>Pomoxis nigromaculatus</em></td>
<td>1.13 ± 1.06</td>
<td>0.94 ± 0.94</td>
<td>0</td>
</tr>
<tr>
<td>Bluegill <em>Lepomis macrochirus</em></td>
<td>0</td>
<td>0.06 ± 0.06</td>
<td>0.06 ± 0.06</td>
</tr>
<tr>
<td>Bluntnose Minnow <em>Pimephales notatus</em></td>
<td>0</td>
<td>0</td>
<td>0.06 ± 0.06</td>
</tr>
<tr>
<td>Brown Bullhead <em>Amiaurus nebulosus</em></td>
<td>0</td>
<td>0.13 ± 0.09</td>
<td>0</td>
</tr>
<tr>
<td>Channel Catfish <em>Ictalurus punctatus</em></td>
<td>0</td>
<td>0.25 ± 0.25</td>
<td>0</td>
</tr>
<tr>
<td>Common Carp <em>Cyprinus carpio</em></td>
<td>0.38 ± 0.26</td>
<td>0.25 ± 0.14</td>
<td>0</td>
</tr>
<tr>
<td>Emerald Shiner <em>Notropis atherinoides</em></td>
<td>0</td>
<td>0</td>
<td>0.06 ± 0.06</td>
</tr>
<tr>
<td>Freshwater Drum <em>Aplodinotus grunniens</em></td>
<td>0.19 ± 0.14</td>
<td>0.5 ± 0.22</td>
<td>0</td>
</tr>
<tr>
<td>Gizzard Shad <em>Dorosoma cepedianum</em></td>
<td>44.44 ± 29.14</td>
<td>46.25 ± 32.90</td>
<td>17.50 ± 14.22</td>
</tr>
<tr>
<td>Green Sunfish <em>Lepomis cyanellus</em></td>
<td>0.06 ± 0.06</td>
<td>0</td>
<td>0.06 ± 0.06</td>
</tr>
<tr>
<td>Longnose Gar <em>Lepisosteus osseus</em></td>
<td>0</td>
<td>0.13 ± 0.09</td>
<td>0</td>
</tr>
<tr>
<td>Pumpkinseed <em>Lepomis gibbosus</em></td>
<td>0</td>
<td>0.06 ± 0.06</td>
<td>0</td>
</tr>
<tr>
<td>Quillback Carpiodes <em>cyprinus</em></td>
<td>0.50 ± 0.33</td>
<td>2.56 ± 1.99</td>
<td>0</td>
</tr>
<tr>
<td>Rock Bass <em>Ambloplites rupestris</em></td>
<td>0.13 ± 0.09</td>
<td>0.25 ± 0.11</td>
<td>0.13 ± 0.13</td>
</tr>
<tr>
<td>Round Goby <em>Neogobius melanostomus</em></td>
<td>2.94 ± 2.22</td>
<td>1.69 ± 0.52</td>
<td>4.81 ± 1.86</td>
</tr>
<tr>
<td>Smallmouth Bass <em>Micropterus dolomieu</em></td>
<td>0</td>
<td>0</td>
<td>0.06 ± 0.06</td>
</tr>
<tr>
<td>Shortnose Gar <em>Lepisosteus platostomus</em></td>
<td>0</td>
<td>0.06 ± 0.06</td>
<td>0</td>
</tr>
<tr>
<td>Spottail Shiner <em>Notropis hudsoni</em></td>
<td>401.56 ± 147.75</td>
<td>93.38 ± 34.16</td>
<td>890.50 ± 260.58</td>
</tr>
</tbody>
</table>
| Trout-perch *Percopsis omisco- 
maycus* | 4.63 ± 3.42 | 7.69 ± 3.59 | 5.75 ± 3.62 |
| Walleye *Sander vitreus* | 0.38 ± 0.20 | 0.38 ± 0.20 | 0         |
| White Bass *Morone chrysops* | 0.06 ± 0.06 | 0        | 0.06 ± 0.06 |
| White Crappie *Pomoxis annularis* | 0.06 ± 0.06 | 0        | 0         |
| White Perch *Morone americana* | 0.06 ± 0.06 | 0.31 ± 0.25 | 0         |
| White Sucker *Catostomus commersonii* | 0        | 0.38 ± 0.22 | 0.06 ± 0.06 |
| Yellow Perch *Perca flavescens* | 1.94 ± 0.63 | 5.44 ± 1.29 | 0.81 ± 0.26 |
and \( = 0.290 \). Using Tukey’s test, we found that Fyke nets yielded higher estimates of Shannon’s species diversity and evenness than the other two nets (Figure 2). The AFS-fyke and Mini-fyke nets produced similar estimates of \( H' \) and \( J' \), though values for AFS-fyke nets were slightly higher for both metrics. Fyke and AFS-fyke nets were more likely to capture larger-bodied species like Common Carp, Quillback, and Walleye, while the Mini-mesh nets selected for smaller-bodied species, including Banded Killifish, Bluntnose Minnow, and Emerald Shiner, which were only captured in this net type. Similar to other metrics, we found that species diversity \( (F = 2.54, df = 15, P = 0.015) \) and evenness \( (F = 2.082, df = 15, P = 0.043) \) varied by site, reflecting the heterogeneous distribution of fish in lower Green Bay.

Catch per unit effort varied between net types (ANOVA: \( F = 3.3; df = 2, 30; P = 0.051 \)). Due to highly variable catches of Spottail Shiners and Gizzard Shad between nets and sites, we log\(_{10}\) transformed the data prior to analysis, which improved normality of the data \( (W = 0.972; P = 0.290) \). Using Tukey’s HSD test, we found that AFS-fyke net CPUE was statistically similar to both Fyke and Mini-fyke net CPUE, but mini-fyke CPUE was greater than Fyke net CPUE (Figure 2). Mini-fyke net CPUE was higher than the other two net types due to higher catches of Spottail Shiner (Table 1). Significant site-level effects were detected for CPUE data \( (F = 2.319, df = 15, P = 0.024) \).

Species accumulation curves corroborated evidence from comparisons of species richness, diversity, and evenness by revealing that Fyke nets accumulated greater species diversity than the other two nets (Figure 3). Species accumulation curves for AFS-fyke nets were intermediate between Fyke nets, which collected the most species, and Mini-fyke nets, which collected the fewest species. Extrapolated species richness (estimate \( \pm SE \)) calculated using bootstrapping methods was highest for Fyke nets \( (21.3 \pm 1.6) \) and functionally identical between Mini-fyke nets \( (17.0 \pm 1.7) \) and AFS-fyke nets \( (16.9 \pm 1.3) \). Jaccard’s similarity index values indicated low species overlap between all gears. Species overlap was highest between Fyke and AFS-fyke nets \( (0.55) \) but equally low between Fyke and Mini-fyke \( (0.32) \) and AFS-fyke and Mini-fyke \( (0.38) \) nets. Low species overlap was mostly attributable to catches of rarely encountered species only captured in a single gear.

**DISCUSSION**

The goal of gear comparison studies is to identify biases between gears or methods that may confound or enhance understanding of a fish population, community, or assemblage, allowing for corrections to, or qualifications of, sampling data, for the purpose of research or management. We found consistent differences in all measured fish community metrics between the three gears, especially between Mini-fyke and Fyke nets, which appear to target slightly different fishes at varying catch rates. We hypothesized that AFS-fyke nets would produce fish community metrics intermediate to the other two net designs, but most similar to Fyke nets. Our results indicated that fish community metrics from AFS-fyke nets indeed overlapped with those of the other gears. Despite this high overlap, we were surprised to find that Fyke nets yielded such high values of species richness, diversity, and evenness relative to AFS-fyke nets because dimensions of both nets were very similar.

One explanation for the reduced diversity observed for AFS-fyke nets may have been a logistical problem encountered early during the field experiment. Leads for the AFS-fyke nets had been constructed with polyfoam core top rope and small floats that, combined, were positively buoyant near the middle of the lead. In deeper sets \( >1.5 \) m, the lead could not be pulled as tight as during a shallow set. The likely result was that several benthic-oriented species may have been able to swim under the lead of AFS-fyke nets deployed in deeper waters, where larger-bodied species were typically collected. This problem was addressed on the second and third days of the experiment by removing floats from the lead to make it sink completely when set. However, at least five sets may have had leads near the middle that were not set completely on the bottom. Evidence for this hypothesis includes the fact that AFS-fyke net catches of common species typically found off the bottom (i.e., Gizzard Shad and Spottail Shiner) were equal to or greater than catches in Fyke nets, while catches of...
Comparing fyke nets for fish assemblage characterization

common benthic-oriented species (i.e., Trout-perch and Yellow Perch) were captured in greater abundance in fyke nets, with the exception of Round Goby. Accordingly, we suspect that estimates of species richness, diversity, and evenness are slightly underestimated for AFS-fyke nets.

Mini-fyke nets are most often used to sample lentic fish communities in shallow (<1-m) waters (Bonvecchio et al. 2014a). Smaller meshes and openings prohibit entry to most larger-bodied species while selecting for more active species or those associated with cover, including centrarchids and cypriids (Fago 1998; Clark et al. 2007). These functional differences likely explain the low Jaccard’s similarity index scores between Mini-fyke and the other two net types. For some aquatic habitats, mini-fyke nets are among the most effective shallow-water gears for monitoring fish assemblages and collecting unique or rare species (Hayes 1989; Eggleton et al. 2010). However, our findings were similar to those of Fischer and Quist (2014) that found mini-fyke nets had the lowest rates of species accumulation. In predominantly shallow aquatic environments like floodplain lakes and wetlands, mini-fyke nets are efficient (Eggleton et al. 2010; Bonvecchio et al. 2014a), whereas in deeper waters the larger-framed versions are preferred. Most areas sampled by the USFWS on Lake Michigan lack the extensive shallow-water vegetated habitats considered ideal for sampling with mini-fyke nets. Lower Green Bay is one of the few places where mini-fyke nets can be used effectively because it lies at the mouth of a large estuary. In most instances, littoral habitats in Lake Michigan are all deeper than 1.5 m and dominated by sandy or rocky substrate, and because nets are set in tandem most mini-fyke net sets are relatively deep for this gear. Bonvecchio et al. (2014a) found that even a subtle difference in set depth of 0.4 m could have appreciable differences in CPUE and diversity for this gear, and we suspect similar influences for our study areas.

In littoral zones deeper than 1 m, the larger-framed fyke nets are often more effective than mini-fyke because the taller leads and larger frames intercept more and larger fish. We found that these larger-framed nets can be set in waters up to 5 m deep, assuming they are set on a gradual slope. Setting these nets in tandem, as is often done in the Great Lakes, allows for deeper sets away from the wind- and wave-swept shoreline. Historically, paired fyke nets and trap nets have been used in the Great Lakes to capture Yellow Perch (Kraft and Johnson 1992) and Lake Whitefish Coregonus clupeaformis (Ebener et al. 2008), and to sample general fish communities (Krueger et al. 1998; Chow-Fraser et al. 2006). Chow-Fraser et al. (2006) found that tandem set fyke nets were effective at collecting large sample sizes and up to 75% of known species in coastal wetlands of Lakes Erie and Ontario, particularly in degraded wetlands similar to those of lower Green Bay.

Relatively few studies have described the utility of AFS-fyke nets for monitoring fish communities, but the few that have tend to be in smaller glacial and artificial lakes. Fischer et al. (2010) compared the AFS-fyke net with a design very similar to our Fyke nets and found that AFS-fyke nets yielded higher catch rates and estimates of diversity. Smith et al. (2015) documented higher catches of some focal species but similar estimates of species diversity and evenness for AFS-fyke nets compared with fyke nets used by South Dakota Game, Fish, and Parks, which had slightly smaller frames (0.9 × 1.5 m) and larger mesh (19 mm). To our knowledge, this is the first study describing selectivity of AFS-fyke nets in the Great Lakes.

Though we used gear specifications outlined in Bonar et al. (2009), we deployed these nets in ways and in systems not originally envisioned by the authors of the AFS standards. According to AFS standards specified in Bonar et al. (2009), modified fyke nets are to be set independently and attached to shore by the lead. In many shorelines of the Great Lakes, this is not possible due to deep water and steep drop-offs. The solution in the Great Lakes for these passive entrapment gears has been to set nets in tandem. Reporting of standardized effort for this gear–method combination would require our catch rates to be divided in half to reflect the fact that each of our units of effort is actually two AFS-fyke nets. This, however, would not correct for the lack of independence between nets because they were tied together.

Despite our novel usage of AFS-fyke nets, we contend that tandem-set AFS-fyke nets are effective for sampling nearshore habitats of the Great Lakes, particularly shallow, vegetated estuarine habitats. We also found that AFS-fyke nets also provided some advantages over nets currently used by the USFWS program. First, AFS-fyke nets are constructed with rolled steel and are thus lighter and easier to use than Fyke nets constructed with 25-mm-diameter conduit. Second, the AFS-fyke net effectively overlaps in population metrics between both currently used net designs. Finally, assuming that our catch rates are adjusted as suggested, our data should be comparable to standard data being collected and uploaded by researchers across North America, allowing our data to be compared with those of similar studies using the AFS-fyke net (Bonar et al. 2015).

Our primary goal for sampling Lake Michigan is to characterize nearshore fish communities in areas susceptible to introduction by new nonnative species. All three fyke net configurations used in this study detected Round Goby, a known invasive species, but only Fyke and AFS-fyke nets captured Common Carp and White Perch, which are also widespread and invasive. During the early stages of population growth, nonnative species typically occur at low abundance, making them difficult to detect with typical sampling gears (Jerde et al. 2011). No single gear configuration in this study alone would be adequate to monitor the whole fish community, requiring a multiple-gear approach.

To address the biases of individual gears, most researchers recommend a combination of sampling gears with varying
species selectivities to sample fish community composition (Clark et al. 2007; Eggleton et al. 2010; Fischer and Quist 2014; Bonvechio et al. 2014b). For example, Fago (1998) noted that each of three gears used missed about four species that were collected by the other gears, similar to our findings. Most studies stress the importance of tailoring gears and methods to the sample area and study question (Ruetz et al. 2007; Bonvechio et al. 2014b; Fischer and Quist 2014). Clark et al. (2007) found that mini-fyke nets and seines can be effectively used in shallow habitats to collect most species. Electrofishing and fyke netting often provide complementary species data because together they target sedentary and active species, respectively (Ruetz et al. 2007; Eggleton et al. 2010). Though using multiple gears is advantageous, there are limits to the number of gears that can be effectively deployed (i.e., cost, time, personnel), so finding the right balance for the study area and question is required (Fischer and Quist 2014; Collins et al. 2015). In Lake Michigan, we currently use nighttime boat electrofishing, experimental gill nets, and paired fyke nets in a 40, 35, and 25% allocation, respectively. Eggleton et al. (2010) and Bonvechio et al. (2014b) both recommended using electrofishing, fyke netting, and gill netting, depending on the habitat being sampled. Most species found at low abundance for all three gear types in our study are more readily encountered by boat electrofishing and experimental gill nets during routine monitoring surveys, demonstrating the benefit of using multiple gears to sample large diverse ecosystems like the Great Lakes.

Where possible, we recommend the inclusion of paired fyke nets for sampling the nearshore fish communities of the Great Lakes, particularly in estuarine and other coastal wetland habitats where they will be most effective. Because the AFS-fyke net produced population metrics intermediate between both previous designs, we contend that this gear is adequate for our sampling needs and can replace current Fyke and Mini-fyke nets, with one potential exception. In shallow coastal wetlands <1 m deep, mini-fyke nets may be used because larger fyke nets may not be effective. By transitioning to one standardized modified fyke net, we will be able to reduce redundancy of sampling gears and provide data not only for our purposes but for the larger fisheries science community.

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