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[Article]

# A Comparison of Methods for Sampling Fish Diversity in Shallow Offshore Waters of Large Rivers

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*Abstract*.—Few studies of fish assemblages have been conducted in large rivers owing to the difficulties of sampling such complex systems. We evaluated the effectiveness of six different gear types (seine nets, boat electrofishers, hoop nets, Windermere traps, trap nets, and minnow traps) in sampling the fish assemblage at 30 sites in the shallow offshore waters of the middle Detroit River in July and August 2003. A total of 2,449 fish representing 38 species in 15 families were captured by seining (1,293 fish, 29 species), boat electrofishing (398 fish, 23 species), hoop nets (524 fish, 26 species), and Windermere traps (234 fish, 14 species). Trap nets and minnow traps were not effective in sampling offshore littoral sites. Significantly higher fish species richness and abundance were obtained and more unique species were captured by seine nets than by any other gear type. When effort is constant, the highest richness and abundance are obtained by seine nets. Windermere traps produced significantly lower abundance and richness than all other gear types, but proportionally more benthic species. Total species accumulation rates were not markedly reduced when Windermere trap data were excluded. Use of additional Windermere traps at each site could increase abundance, but samples taken by Windermere traps had the lowest rarefied richness among gear types at any level of abundance. Nonmetric multidimensional scaling showed that seine-net catches, which were dominated by midwater schooling species (brook silverside *Labidesthes sicculus*, emerald shiner *Notropis atherinoides*, and mimic shiner *N. volucellus*), were most dissimilar from Windermere trap catches, which were dominated by centrarchids. Seine nets were the most effective gear for sampling offshore waters.

Of the many studies of lotic fish assemblages, few have focused on large rivers (Lobb and Orth 1991; Mihuc and Feminella 2001). This is largely due to the deep waters and high flows that make fish sampling difficult in large rivers (Casselman et al. 1990; Grossman and Ratajczak 1998). Researchers often sample either channel (i.e., deep water, high flow) (e.g., Wolter and Bischoff 2001) or shallow-water and shoreline (Cao et al. 2001) habitats. The littoral zone is often studied due to its ease of sampling as well as its importance as a nursery for some fishes and as adult habitat for others (Dauble and Gray 1980).

Fishing efficiency is often much lower in large rivers than in small streams (Mann and Penczak 1984; Grossman and Ratajczak 1998). Although many techniques have been developed for sampling fish habitat in small streams, few can be directly applied to large rivers (Bain et al. 1999). However, conservation of large-river fish assemblages requires a firm understanding of community dynamics and habitat use (Petts et al. 1989); therefore, studies of habitat use by fish assemblages are recommended over studies focusing on single-species habitat use (Lobb and Orth 1991). Because fish species richness cannot be accurately estimated in large rivers with a single gear, multiple gears are used to sample all species present in large-river fish assemblages (Casselman et al. 1990; Weaver et al. 1993).

Several gears are available for sampling the littoral zone of rivers, but few comparisons of gear effectiveness have been made (Casselman et al. 1990). Most gears, such as hoop nets or beach seines, have been designed to sample the shoreline rather than the offshore waters of the littoral zone (Hayes et al. 1996; Hubert 1996). Samples are often taken by transect during boat electrofishing or trawling. Such methods are useful for species surveys, as large areas can be sampled quickly (Hayes et al. 1996; Reynolds 1996). However, data from transect samples cannot readily be used to determine microhabitat preference, as several discrete habitats may be encountered along a single transect. A specific point abundance sampling technique by electrofishing has been used to sample

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large rivers, but this method is designed to determine fish density and focuses on early life stages (Copp and Penaz 1988). Gill nets could be used to effectively sample offshore sites; however, they are known to cause high stress (Hopkins and Cech 1992) and mortality among captured fish (Hubert 1996). An evaluation of gear effectiveness for sampling the offshore littoral zone is warranted.

Each gear captures fish in a different manner and therefore may capture a different portion (species or age-classes) of the fish assemblage (Weaver et al. 1993; Fago 1998). Passive gears capture more mobile fishes, while active gears are better at capturing sedentary species (Weaver et al. 1993). The physical characteristics of a site may reduce the effectiveness of a given gear. Seine-net efficiency, for example, is higher in areas of high macrophyte density than in areas of low macrophyte density, lower over boulders or snags than over level areas, and lower for benthic fishes than for midwater fishes (Lyons 1986; Pierce et al. 1990). Thus, the composition of the captured assemblage is dependent on the gear type used and on the environmental conditions of the sample site.

Our objectives were to (1) compare the suitability of a suite of gear types for sampling shallow offshore areas of a large river and determine whether a subset of gears is necessary to accurately represent the composition of the fish assemblage, (2) determine how environmental conditions affect capture by each gear type, (3) test a method of point electrofishing, and (4) test a method of seining offshore areas of a large river.

## Methods

*Site description*.—The Detroit River, which connects Lake St. Clair to Lake Erie, has a mean annual discharge of 5,094 $m^3/s$ (Bolsenga and Herdendorf 1993). Sites were located within a 10-km stretch of the Canadian waters of the middle Detroit River from the confluence with Turkey Creek to the confluence with the River Canard (Figure 1). Here, the river is characterized by braided channels and wide, shallow flats with a maximum width of 4 km and a maximum depth of 10 m (Bolsenga and Herdendorf 1993).

*Sampling*.—Site selection was based on a related project involving substrate maps produced by means of RoxAnn sonar. We sampled the centroids of eight polygons that were randomly selected from 77 polygons (>1,000 $m^2$) with uniform substrates that were identified by RoxAnn sonar sampling (National Water Research Institute, unpublished data). In shallow areas that were not mapped by sonar, we randomly selected 22 sites from among 233 sites where substrates were sampled manually at 150-m intervals. Sites were located in areas less than 3 m deep and 15–730 m offshore. Fish and habitat sampling was undertaken at these sites from July 22 to August 29, 2003, between 0800 and 1800 hours. At each site, water temperature, conductivity (YSI; Model 33 S-C-T meter), turbidity (Secchi disk), and flow (Ott; Z21 current meter) were measured. Substrate (including macrophyte density) was estimated qualitatively in the field. Sites with low (≤25%) macrophyte density were classified as mud, sand, or gravel, whereas sites with high (>25%) macrophyte density were classified as weeds on soft or weeds on hard.

Sites were sampled by means of two active (seine nets, boat electrofishers) and four passive (hoop nets, Windermere traps, minnow traps, trap nets) gears (Table 1). We used a 15-m-long, 2.5-m-high seine net with a 2.5-m bag and 0.64-cm ace mesh to sample offshore sites in a method similar to that of Bayley and Herendeen (2000). Our method differs from the conventional method (wherein one end of the net is attached to shore) and therefore deserves a detailed description. Offshore sites were seined in triplicate by anchoring one end at the center of the site, deploying the net in a straight line, and using the boat to loop the net back to the anchor (Figure 2). A king anchor was deployed with a 4-m rope attached, and a loop was tied at the end of this rope. The net was clipped to the loop by use of a carabiner; a short (<1 m) rope led to the lead line of the net, and a longer (>2 m) rope led to the float line, allowing it to float freely. A buoy was tied to the loop by use of a second 3–4-m rope to mark the anchorage point (Figure 2a). The boat was used to draw the net out in a straight line with the bag deployed on one side. At the opposite end of the net, the lead and float lines were tied to a brail (Figure 2b). The boat was used to pull the net into a loop (with the bag opening facing inwards) by bringing the brail end back to the buoy; the brail was used to keep the lead line on the substrate. By means of the buoy line, the carabiner was retrieved and unclipped from the anchor line. The buoy (and thus the anchor) was fastened to the boat, preventing drift during retrieval of the net. Wings were hauled in together while keeping the lead lines low to the water and trapping fish in the bag (Figure 2c). This method permitted retrieval of the net without displacing the anchor, which minimized retrieval times and allowed replicate hauls at the same location.

Sites were electrofished with a Smith-Root boat electrofisher that had a single anode array and pulsed DC (30 Hz; 1,000 V; 3,600 W). The boat was held in place over the center of the site while shocking was conducted for 1 min. At each site, hoop nets, Windermere traps, and minnow traps were set on the same day and passive gears were fished overnight for 18–24 h. Hoop nets (92-cm diameter, 15-cm opening, 8-m

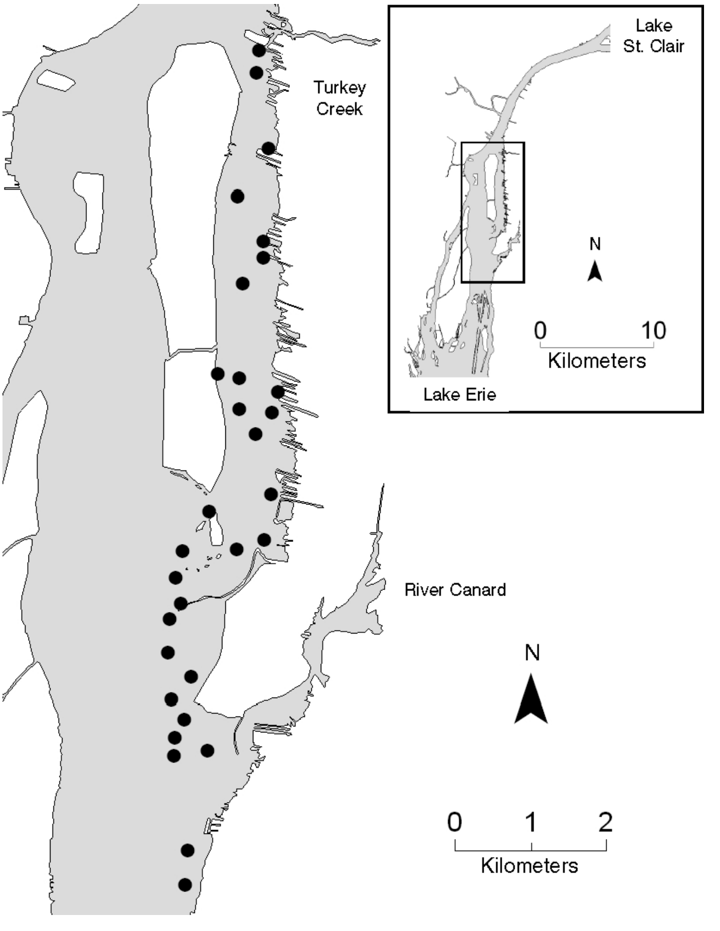


FIGURE 1.—Map of the middle Detroit River, where the effectiveness of four gear types for sampling fish diversity was evaluated; sampling sites are marked by black circles.

lead, and 0.64-cm mesh) were set with the lead perpendicular to and facing shore or with the lead attached to shore at one site. Windermere traps (Steingraeber et al. 1996) are identical in design to minnow traps but are larger (Windermere traps: 113-cm long, 67.5-cm diameter, 10-cm opening, 0.5-cm mesh; minnow traps: 41-cm long, 18-cm diameter, 2.5-cm opening, 0.5-cm mesh), and both were baited with cat food. As has been demonstrated in other studies (Weaver et al. 1993), minnow traps were ineffective and were not used after the first 10 sites were sampled with no fish captures. Trap nets (2.5 × 2.5 m; 7-m wings, 35-m lead, and 2.5-cm mesh) were set in a manner similar to that of hoop nets wherein the lead line was perpendicular to and facing shore. Trap nets also were deemed ineffective and were not used after

TABLE 1.—Description of gear types that were evaluated for their effectiveness in sampling shallow offshore waters of the Detroit River in 2003.

| Gear type | Active/passive | Baited | Time per sample | Number of sites | Sampling period |
|---|---|---|---|---|---|
| Seine net | Active | No | 4–8 min | 25 | Jul 30–Aug 28 |
| Boat electrofisher | Active | No | 1 min | 30 | Aug 19–Aug 20 |
| Hoop net | Passive | No | 18–26 h | 26 | Jul 22–Aug 28 |
| Windermere trap | Passive | Yes | 18–26 h | 30 | Jul 22–Aug 29 |
| Trap net | Passive | No | 20–24 h | 7 | Jul 21–Jul 31 |
| Minnow trap | Passive | Yes | 19–23 h | 10 | Jul 22–Jul 31 |

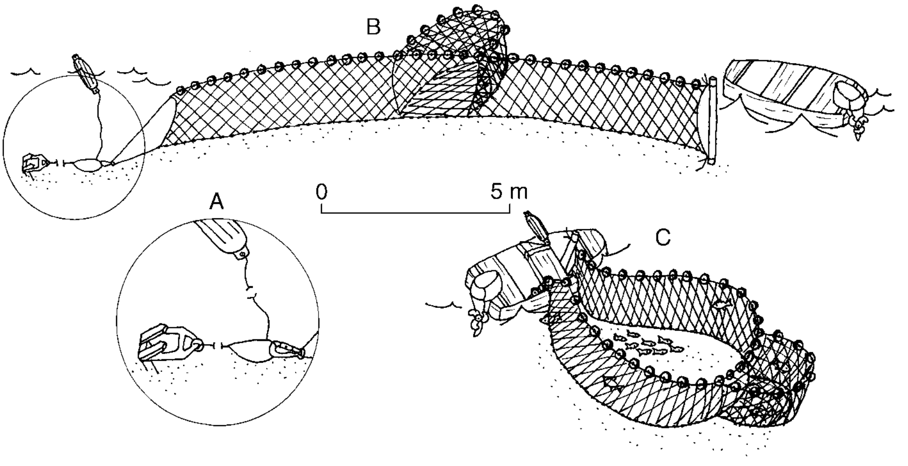


FIGURE 2.—Diagram of an offshore seine-net haul showing the anchor, buoy, and seine-net rigging (A); the deployed net prior to the haul (B); and retrieval over the side of the boat (C).

sampling at the first seven sites. Although trap nets did capture several fishes (means = 3.1 species, 5.7 fish) including channel catfish *Ictalurus punctatus* (additional scientific and common names according to Nelson et al. 2004 are provided in Table 2), which were not captured by any other method, this gear type was difficult to set and retrieve with a crew of two people.

At each sampling event, fish were counted and identified to species. The total lengths of the longest and shortest fish of each species were measured. At each site, two individuals of each species (to a maximum length of 200 mm) were kept as vouchers and were fixed with 10% formalin. All other fish were released.

*Analyses*.—Species accumulation curves can be used to determine whether the sample size is large enough to sufficiently represent a community (McCune and Grace 2002). Curves were generated for each gear type by randomly sorting samples 100 times and determining the average number of new species found throughout the study area at each increase in sample size. Species accumulation curves were used to compare individual gears and all combinations of two to four gear types.

Species richness tends to increase with abundance (Bunge and Fitzpatrick 1993); therefore, rarefaction was used to compare richness among gears while holding abundance constant (Hurlbert 1971). Rarefaction curves were created for each gear by plotting the estimated richness for sample sizes of 10–200 fish in increments of 10.

To compare abundance among active and passive gears, we simulated a week-long sampling protocol for each gear (Table 3). Hoop nets took the longest to set and retrieve (15 min); therefore, we used a single replicate for each sample. To match this time, each seine-net sample consisted of three hauls (5 min each), and each boat electrofishing sample consisted of three 5-min shocks. Sampling by Windermere traps is not limited by time but rather by how many traps can be transported on a boat. Therefore, we assumed that three traps could be transported at a time and simulated three replicates per sample. The average abundance per sample for hoop nets and seine nets was estimated directly from the 2003 data. For Windermere traps, we assumed that additional traps would not deplete the available abundance, and therefore we simulated the abundance obtained per sample by tripling the average abundance from a single Windermere trap in 2003. For boat electrofishing, we accounted for depletion by using data collected in 2004 to correct our estimate of the average abundance per sample. Data were simulated for three replicate shocks of 5 min each.

The total time sampled by passive gears varied by up to 8 h. Increases in catch with time would require standardization of the data by catch per unit effort (CPUE). Therefore, relationships between total time and richness or abundance (all normally distributed, Kolmogorov–Smirnov test) were determined by linear regression analysis. No significant relationship existed between the total time set for hoop nets and fish species richness ($r^2 = 0.05$, $P = 0.81$) or abundance ($r^2 = 0.06$, $P = 0.27$) or between the total time set for Windermere traps and fish species richness ($r^2 = 0.00$, $P = 0.45$) or abundance ($r^2 = 0.01$, $P = 0.96$). Therefore, CPUE was not used to standardize passive gear data.

TABLE 2.—Fish species sampled by four gear types (S = seine net, B = boat electrofishing, H = hoop net, and W = Windermere trap) in shallow offshore waters of the Detroit River during July and August 2003. Data are the total abundance of each species, summed across 23 sites.

| Species | S | B | H | W |
|---|---|---|---|---|
| Banded killifish *Fundulus diaphanus* | 1 | 1 | | |
| Black bullhead *Ameiurus melas* | | | 3 | 1 |
| Black crappie *Pomoxis nigromaculatus* | 3 | | 1 | |
| Bluegill *Lepomis macrochirus* | 44 | 3 | 19 | 7 |
| Bluntnose minnow *Pimephales notatus* | 292 | 118 | 111 | 26 |
| Bowfin *Amia calva* | | 1 | 3 | |
| Brook silverside *Labidesthes sicculus* | 68 | 14 | | |
| Brown bullhead *Ameiurus nebulosus* | | | 1 | |
| Common carp *Cyprinus carpio* | 4 | 3 | 6 | |
| Emerald shiner *Notropis atherinoides* | 17 | 19 | 1 | |
| Freshwater drum *Aplodinotus grunniens* | | | 1 | |
| Gizzard shad *Dorosoma cepedianum* | 13 | | 8 | |
| Johnny darter *Etheostoma nigrum* | | 3 | | 2 |
| Largemouth bass *Micropterus salmoides* | 67 | 14 | 3 | 1 |
| Logperch *Percina caprodes* | 4 | 1 | | 3 |
| Longnose gar *Lepisosteus osseus* | | | 6 | |
| Mimic shiner *Notropis volucellus* | 12 | 49 | 6 | 1 |
| Muskellunge *Esox masquinongy* | 6 | | | |
| Northern hog sucker *Hypentelium nigricans* | 1 | 2 | | |
| Northern pike *Esox lucius* | | | 3 | |
| Pumpkinseed *Lepomis gibbosus* | 12 | 4 | 18 | 19 |
| Rock bass *Ambloplites rupestris* | 38 | 6 | 27 | 14 |
| Round goby *Neogobius melanostomus* | 6 | | | 4 |
| Silver redhorse *Moxostoma anisurum* | | 2 | 3 | |
| Smallmouth bass *Micropterus dolomieu* | 22 | | 9 | 5 |
| Spotfin shiner *Cyprinella spiloptera* | 11 | | | |
| Spottail shiner *Notropis hudsonius* | 278 | 84 | 220 | 134 |
| Spotted sucker *Minytrema melanops* | 1 | | | |
| Striped shiner *Luxilus chrysocephalus* | 9 | 1 | 1 | |
| Sunfish *Lepomis* spp. fry | 84 | 5 | 4 | 9 |
| Trout-perch *Percopsis omiscomaycus* | 1 | | | |
| Tubenose goby *Proterorhinus marmoratus* | 1 | | 1 | |
| Walleye *Sander vitreus* | 2 | | | |
| White bass *Morone chrysops* | 8 | 1 | 2 | |
| White perch *Morone americana* | 24 | 1 | 15 | |
| White sucker *Catostomus commersonii* | 17 | 11 | 2 | |
| Yellow bullhead *Ameiurus natalis* | | 1 | | |
| Yellow perch *Perca flavescens* | 247 | 54 | 50 | 8 |

Differences in fish species richness and abundance were determined for gear type (four classes: boat electrofisher, hoop net, seine net, and Windermere trap), macrophyte density (two classes: low and high), and flow (presence or absence) by means of factorial analysis of variance (ANOVA; STATISTICA 6.1). Macrophyte density and flow were included in the analysis to determine (by examining the interaction terms) whether gears were more effective under particular environmental conditions. Richness and abundance were tested for normality (Kolmogorov–Smirnov test), and abundance was transformed ($\log_{10}[N + 1]$) to fit the normal distribution. Tukey's honestly significant difference post hoc tests were performed on significant factors and interaction terms.

The difference in the number of species that were unique to a gear type at a given site (termed unique species richness) and rare (<1% of total abundance) species richness did not fit the normal distribution, even after transformation (Kolmogorov–Smirnov test). Therefore, differences in these variables were determined among gear types by means of the nonparametric Schierer–Ray–Hare two-way ANOVA test (Sokal and Rohlf 1995). Because flow was not a significant factor in a factorial ANOVA of richness and abundance, it was omitted from this test and only gear type and macrophyte density were used as independent variables. Post hoc analyses on significant factors and interaction terms were performed by use of Kruskal–Wallis ANOVA (STATISTICA 6.1).

To examine how the captured assemblage differed among gear types, we used nonmetric multidimensional scaling (NMS; PC-ORD 4.14: McCune and Mefford 1999) based on a Sorenson distance matrix derived from presence/absence data and plotted sample scores by gear type. Rare species (<1% of total abundance) and unidentified fry were removed from the data set prior to analysis.

## Results

Of the 30 sites, seven were not sampled by all gear types because of problems with depth, flow, or macrophyte density. Therefore, 23 sites were sampled with all four gears. Water temperature varied from 19°C to 27°C, and conductivity ranged from 180 to 440 μS/cm. Secchi disk transparency values ranged from 0.5 to 3.0 m, where the disk could be seen on the bottom. Flow ranged from 0.0 to 16.4 cm/s, and flowing water was present at five sites. Thirteen sites had a high macrophyte density.

We captured a total of 2,449 fish representing 38 species in 15 families (Table 2). Seining captured 1,293 fish (29 species, 11 families), including five unique species (spotfin shiner, muskellunge, spotted sucker, trout-perch, and walleye). Boat electrofishing captured 398 fish (23 species, 9 families) and one unique species (yellow bullhead). There were 524 fish (26 species, 12 families) captured in hoop nets, including four unique species (brown bullhead, freshwater drum, northern pike, and longnose gar). There were 234 fish (14 species, 5 families) captured in Windermere traps, but none of the species was unique.

Rates of species accumulation increased with the number of species captured by a given gear type or combination of gears. A combination of all four gears produced the highest richness, although removing the Windermere trap data caused little change in the rate of accumulation (Figure 3). Of the six possible combinations of two gear types, hoopnetting and seining produced the highest richness, followed by electrofish-

TABLE 3.—Design and results of a simulated week-long sampling protocol for active and passive gear types used to sample fishes in the Detroit River.

| Variable | Seine net | Boat electrofishing | Hoop net | Windermere trap |
|---|---|---|---|---|
| Active/passive | Active | Active | Passive | Passive |
| Active time per sample (min) | 5 | 5 | 15 | 1 |
| Number of replicates per sample | 3 | 3 | 1 | 3 |
| Travel time per sample (min) | 15 | 15 | 30 | 30 |
| Average abundance from one sample | 56.2 | 27.8 | 22.8 | 30.5 |
| Number of samples per week | 36 | 36 | 28 | 28 |
| Abundance per week | 2,023.8 | 999.0 | 637.9 | 854.6 |

ing and seining. Species accumulation rates for single gears appeared to level off for seine nets and Windermere traps and continued to increase slightly for hoop nets and strongly for boat electrofishing.

When abundance was held constant, rarefaction estimates showed that seine nets produced the highest fish species richness at all sample sizes and that Windermere traps the lowest (Figure 4). At small sample sizes (<40 individuals), boat electrofishing produced higher richness than did hoop nets, but this pattern was reversed with increased abundance.

For the simulated week-long sampling, more samples were taken by active gears because travel time was reduced and an extra half-day of sampling was possible (Table 3). Assuming equal effort with respect to hours worked, seine nets produced the greatest abundance—double that of any other gear. Boat electrofishing ranked second, followed by Windermere traps and hoop nets.

Fish species richness differed significantly among gear types ($P < 0.001$) but not between macrophyte densities, flow rates, or interaction terms. Post hoc analysis revealed that seine nets produced significantly higher richness than all other gear types and that Windermere traps produced significantly lower richness than all other gear types (Figure 5a). Boat electrofishing did not differ significantly from hoop nets in terms of fish species richness.

There were significant differences in abundance among gear types ($P < 0.001$), but no differences were found between macrophyte densities, flow levels, or interaction terms. Post hoc analysis revealed that seine nets produced significantly higher abundance than all other gear types and that Windermere traps produced significantly lower abundance than all other gear types (Figure 5b). Boat electrofishing did not differ significantly from hoop nets in terms of abundance.

There were significant differences in unique species richness among gear types ($P < 0.05$) but not between macrophyte densities; the interaction term was not significant. Post hoc analysis revealed that seine nets captured significantly more unique species than all other gear types (Figure 5c). No other gears differed significantly in unique species richness. We found no significant differences in rare species richness between gear types or macrophyte densities, and the interaction term was nonsignificant (Figure 5d).

Thirteen species were considered common (i.e.,

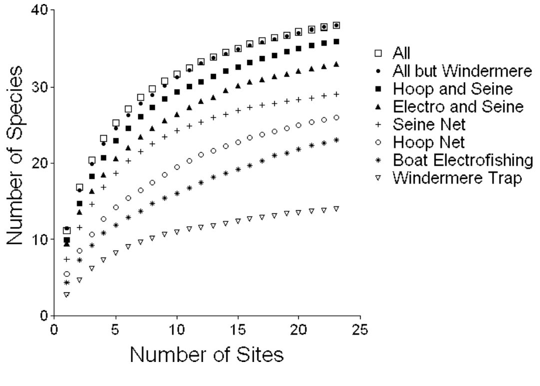


FIGURE 3.—Species accumulation curves for a selection of gear combinations (seine nets, boat electrofishers, hoop nets, and Windermere traps in various combinations; $n = 23$ sites) used in offshore littoral zones of the Detroit River during 2003.

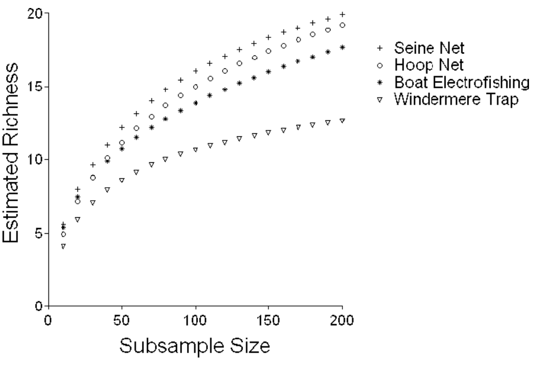


FIGURE 4.—Rarefaction curves for seine nets, boat electrofishers, hoop nets, and Windermere traps used in offshore littoral zones of the Detroit River during 2003.

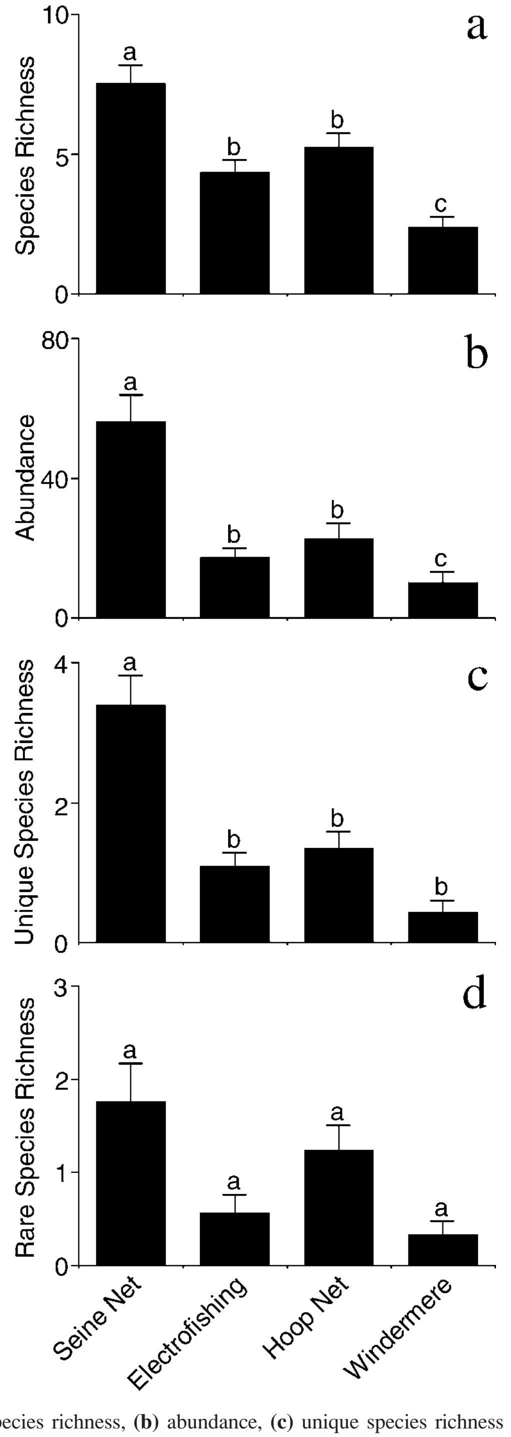


FIGURE 5.—Mean (+SE) **(a)** species richness, **(b)** abundance, **(c)** unique species richness (the number of species that were unique to a gear type at a given site), and **(d)** rare species richness (the number of species encompassing <1% of total abundance) captured by four gear types ($n = 23$ sites) in the middle Detroit River during 2003. Differing letters above bars within each panel indicate significant differences among gears.

>1% of total abundance) and were used in assemblage analysis. The same species were most common (although with different ranks) even if the numerically dominant seine-net data were removed. All common species were captured by seine nets; however, smallmouth bass were not captured by hoop nets, brook silversides were not captured by boat electrofishing, and four species (white sucker, brook silverside, white perch, and emerald shiner) were not captured by Windermere traps. Nonmetric multidimensional scaling ordination produced a highly stable three-dimensional solution that explained 82% of the variation in the common species assemblage data (Table 4). Rock bass had the highest positive association with axis 1, whereas the brook silverside and emerald shiner had the highest negative associations with axis 1. The mimic shiner had the highest positive association with axis 2, whereas the pumpkinseed and bluegill had the highest negative associations. Windermere trap samples appeared to be more positively associated with axis 1 than did seine-net samples, which in turn were more positively associated with axis 2 (Figure 6). These differences suggest that seine-net and boat electrofishing catches were dominated by midwater schooling fishes and were most dissimilar from Windermere trap catches dominated by centrarchids. Gear types did not differentiate strongly along axis 3.

TABLE 4.—Summary of nonmetric multidimensional scaling ordination of presence/absence data for common Detroit River species (>1% of total abundance), including axis loadings for each species and the variation explained by each axis.

| Variation explained or species | Axis 1 | Axis 2 | Axis 3 |
|---|---|---|---|
| $R^2$ | 0.18 | 0.41 | 0.24 |
| Cumulative $R^2$ | 0.18 | 0.58 | 0.82 |
| Rock bass | 0.44 | −0.03 | −0.04 |
| White sucker | −0.23 | 0.22 | 0.13 |
| Brook silverside | −0.34 | 0.37 | 0.16 |
| Pumpkinseed | 0.03 | −0.67 | 0.17 |
| Bluegill | −0.04 | −0.65 | 0.39 |
| Smallmouth bass | 0.26 | 0.40 | 0.12 |
| Largemouth bass | −0.18 | −0.06 | 0.05 |
| White perch | −0.06 | 0.24 | 0.23 |
| Emerald shiner | −0.39 | 0.27 | 0.30 |
| Spottail shiner | −0.09 | 0.29 | −0.24 |
| Mimic shiner | 0.09 | 0.56 | 0.05 |
| Yellow perch | −0.16 | −0.03 | 0.02 |
| Bluntnose minnow | −0.15 | 0.26 | 0.20 |

## Discussion

Seining was the most effective method for sampling shallow offshore sites and for capturing schooling midwater fishes. Seining produced the highest abundance when effort was held constant (simulated data) as well as the highest richness when abundance was held constant (rarefaction) and exhibited abundance and richness measures that were significantly higher than those of other gears (direct comparisons). The greatest difficulty in seining is caused by snags in the form of woody debris or boulders, which lift the lead line off the bottom and allow fish to escape (Pierce et al. 1990). The riparian zone is a primary source of woody debris in lotic environments (Pusey and Arthington 2003; because our sites were located offshore, no such debris was encountered. In addition, substrates were not coarse enough to cause gaps between the lead line and the river bottom. However, a large gap was created when the lead line was retrieved. Bayley and Herendeen (2000) found that a similar method of hauling seine nets over the side of the boat was significantly less efficient than methods in which the lead line remained on the substrate during retrieval. Although it may not be the most efficient method of operating a seine net, anchoring the seine in open water was the most effective method for sampling shallow offshore sites.

Boat electrofishing was less successful than seining but produced higher fish species richness and abundance than did Windermere traps. Species accumulation rates did not level off for boat electrofishing, indicating that more samples would increase the

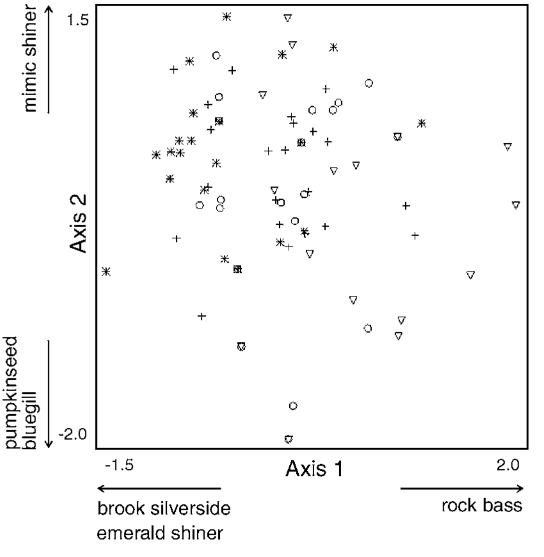


FIGURE 6.—Scatter plot of samples from four gear types across nonmetric multidimensional scaling axes 1 and 2 based on presence/absence data ($n$ = 89 samples; 3 null samples were removed) for common species (>1% of total abundance). Species with the most strongly positive and negative loadings on axes 1 and 2 are shown. Gear types are denoted by the following symbols: plus signs = seine nets ($n$ = 23 samples); asterisks = boat electrofishers ($n$ = 22 samples); circles = hoop nets ($n$ = 23 samples); and triangles = Windermere traps ($n$ = 21 samples).

number of species captured. We were able to electrofish all sites quickly, as sites were shocked once for 1 min. Additional time spent electrofishing (e.g., by taking replicate samples or resampling sites at later dates) would probably have increased the abundance and richness of the catch. However, electrofishing equipment is labor and cost intensive, which may limit the amount of time available for use of this gear.

Samples obtained by hoop nets and boat electrofishing were similar in richness and abundance; however, several species were retrieved in hoop nets that were not captured by boat electrofishing and seining, indicating that hoop nets complement these gear types well in synoptic studies of species richness. Pugh and Schramm (1998) found that boat electrofishing was far more effective than hoop nets at sampling large-river fishes; however, they used a transect method, which is inappropriate for microhabitat studies. Hoop-net catches are often dominated by ictalurids and other large benthic fishes (Pugh and Schramm 1998; Feyrer and Healey 2002), which move into shallow waters to feed at night. More catfishes were caught by hoop nets than by any other gear type in our study, although they represented only a small portion of hoop-net catches.

Windermere traps were the least effective gear type. Although 0.43 unique species per site and 0.30 rare species per site were captured on average by Windermere traps, the rate of species accumulation did not decrease when Windermere trap data were removed. Windermere traps captured the lowest number of common species and are therefore the least effective at representing the common fish assemblage. However, Windermere trap catches were dominated by centrarchids and had a higher proportion (4.3%) of benthic species (suckers, catfishes, darters, and gobies) than other gear types (~1%). Most benthic species were excluded from community analyses due to their rarity; therefore, differences in benthic species captured were not examined by NMS analysis. Use of several Windermere traps per site could increase abundance, but rarefaction curves showed that Windermere samples contained the lowest richness at any sample size.

None of the gears produced significantly different richness or abundance among habitats, indicating that the gears functioned similarly under all conditions. However, these results should be interpreted with caution, as areas with very dense macrophyte growth or very high flows were not sampled. Our designation of high or low macrophyte density may not have been biologically relevant, because some fishes seem to prefer intermediate macrophyte densities (Grenouillet et al. 2000).

Passive gears will capture fish during both night and day in one sample, while several samples with an active gear may be necessary to evaluate the fishes present at a site over a 24-h period. This implies that passive gears may capture migratory species that have no specific association with the microhabitat of the sample site. Also, passive gears must be fished for at least several hours (Hayes et al. 1996), thus reducing the possible number of sites or replicates. Mesh screening is often secured across the opening of passive gears to exclude large piscivores that may feed on captured prey (Weaver et al. 1993).

A higher proportion of sampling time is lost due to schedule disruptions (e.g., poor weather, equipment malfunctions) when a passive gear is used than when an active gear is employed. Assuming a 5-d work week, only one sampling day is lost for active gears when a day-long schedule disruption occurs, permitting sampling on 4 of 5 d. However, with a passive gear, a similar disruption could result in the loss of samples for 2 d. Should a schedule disruption occur in the middle of the week, passive gears that have been set will be fished for 48 h, rendering the data unusable. Additionally, the gear cannot be set at a new site during that time, which doubles the number of samples lost. Similar proportions of time are lost when a specific haul or set is faulty; a single seine haul can be repeated in 5 min, but a hoop-net set requires another 24 h to complete.

Seine nets, hoop nets, and boat electrofishers were all effective at capturing common fishes as defined by this study. Benthic fishes, such as round goby, are common in shallow waters of the Detroit River but were rare in this study. Windermere traps failed to capture 4 of the 13 most common species. Additionally, NMS analysis revealed that samples taken by Windermere traps were the least similar to those of other gears, capturing higher proportions of centrarchids and lower proportions of midwater schooling fishes. This result, along with results from species accumulation curves, suggests that all gears but Windermere traps are effective for sampling the common fish assemblage of the Detroit River's offshore littoral zone.

In summary, seine nets were the most effective gear for sampling fish in the offshore littoral zone of the Detroit River. If assemblage data from similar ecosystems are required and if rare species are removed from analysis (Gauch 1982), we recommend use of seine nets. Large sample sizes can be collected quickly by seining, and samples will have relatively high richness and abundance. However, if synoptic species surveys are the goal, combining all four gears would increase the number of species captured by targeting different (active and benthic) portions of the fish assemblage. Most of our sites had low or no flow; thus, our results indicate the usefulness of these gears in the littoral zone of lakes.

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