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[Management Brief]

Efficiency and Selectivity of Gill Nets for Assessing Fish Community Composition of Large Rivers

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Abstract.—To evaluate the efficiency and selectivity of gill netting for assessing fish biodiversity in the upper Ohio River system, we compared the efficiency of five gill-net types for sampling large-bodied fishes (adult total length greater than 250 mm) during fall 2001 and spring and fall 2002. Mesh sizes ranged from 3.8 cm to 14 cm (bar measure). We set the gill nets in selected pools of the Allegheny, Monongahela, and Ohio rivers 186 times over three seasons for a total of 1,644 net-hours. Nets were attached to a variety of structures, including trees and rootwads, bridge pylons, lock and dam chambers, and channel marker buoys. Nets were fished from late evening to first light, and all fish captured were identified, enumerated, and released. A total of 823 individuals representing 30 species or hybrids were captured. All net types captured common carp *Cyprinus carpio* and flathead catfish *Pylodictis olivaris*, but we captured a significantly greater diversity of fishes in graded-mesh gill nets with small mesh (38 m in length with variable-bar mesh and 15.2 m in length with 3.8-cm-bar mesh). When adjusted for length, smaller-bar mesh nets (3.8-cm-bar mesh) were more efficient for capturing target species than graded-mesh nets. To maximize species richness, 200–225 h of effort were necessary to characterize target fish communities of large-bodied riverine species.

When sampling for fish diversity, electrofishing (Meador et al. 1993; Angermeier and Smogor 1995; Heimbuch et al. 1997), rotenoning (ORSANCO 1978), and gill netting (Minns and Hurley 1988; Colvin 2002) have been widely used by fisheries biologists but not without issues of cost, fish mortality, public perception, and size and species selectivity (Hamley 1975; Hubert 1996; Murphy and Willis 1996). Gill netting presents similar issues of public concern with respect to fish mortality, but can provide a cost-effective method for sampling a diversity of fishes, size-classes, and habitats. However, studies indicate that gill-net efficiency varies with mesh size and material, fish morphology (Hamley 1975), and sampling period (Carlander 1953). Therefore, the efficiency of gill netting must be understood to be used to sample target fish communities (TFCs) as part of a temporal monitoring program.

Most existing studies focus on comparisons among gear types (e.g., gill netting versus electrofishing) rather than efficiency within a specific gill-net mesh size (Elliott and Fletcher 2001; Colvin 2002) or on one target species or several target species with the objective of developing selectivity curves (Berst 1961; Hamley 1975). Unfortunately, these studies provide little information to discern gill-net efficiency for sampling a TFC.

Gill nets are primarily used to monitor fish populations in lakes (Minns and Hurley 1988; Colvin 2002), reservoirs (Jensen 1986), and marine environments (Carlander 1953; Berst 1961; Murphy and Willis 1996) rather than in large riverine habitats. The large rivers of the United States are home to a diverse assemblage of fishes (Lee et al. 1980) and present sampling challenges because of their size and habitat complexity. We theorized that gill nets could be used to efficiently sample large riverine habitats, especially for a clearly defined TFC. In this study, we defined the TFC as those fishes having an adult total length (TL) greater than 250 mm. This TFC excluded all cyprinids except common carp *Cyprinus carpio* and included a range of large-bodied riverine fishes representing several feeding (e.g., piscivore and detritivore) and habitat (e.g., benthic and midwater) guilds that are vulnerable to capture in gill nets. Of particular interest was the buffalo–carpsucker–redhorse (smallmouth buffalo *Ictiobus bubalus*, river carpsucker *Carpiodes carpio*, redhorse *Moxostomus* spp.) complex, which includes a number of ''species of special concern'' in Pennsylvania. Our objective was to determine which of five selected gill-net types was most effective for quantifying the large-bodied fish community composition in a large riverine system.

Methods

The Ohio River (from Pittsburgh, Pennsylvania, to Pike Island, West Virginia) and its major tributaries, the Allegheny and Monongahela rivers in Pennsylvania, consist of a series of navigational

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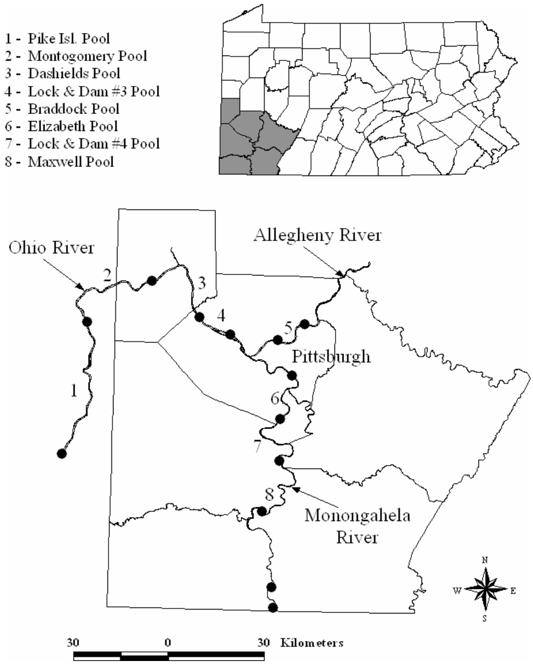

FIGURE 1.—Locations of eight pools in the Ohio, Allegheny, and Monongahela rivers in southwestern Pennsylvania where fish community structure was sampled from October 2001 through November 2002. Filled circles indicate locations of lock and dam chambers.

pools maintained by a basinwide lock and dam system (Figure 1). Pool lengths vary from 9 to 67 km and pool widths vary from 140 to 437 m. Fluvial dynamics and mean depths of these pools are constantly changing from the operation of the various locks for maintaining navigable channels. Our study area encompassed lock and dam chambers bounded to the west by Pike Island, West Virginia, to the south by Grays Landing, and to the north by Lock and Dam No. 3 in Pennsylvania (Figure 1).

To assess their relative capture efficiencies in these large rivers, we deployed five gill-net types of different lengths and mesh sizes (Table 1) from 5 October to 9 November 2001 and from 5 April to 11 November 2002, employing a stratified random sampling design for pool selection and net-set location. Eight pools were randomly selected from a total of 11 in the study area (the Pittsburgh pool was considered as one, even though it includes all three major rivers). The five gill-net types were randomly assigned to available fixed points (e.g., large woody debris, bridge abutments, barge pylons, island back channels, tributary mouths, gravel bars, and lock and dam chambers)

TABLE 1.—Dimensions of gill nets used to sample fish community structure in eight pools of the Ohio, Allegheny, and Monongahela rivers from October 2001 through November 2002.

Net type	Net depth (m)	Net length (m)	Panels (number)	Panel length (m)	Bar mesh (mm)
1	2.4	38.1	5	7.62	38, 64, 89, 114, and 140
2	1.8	45.7	5	9.12	38, 64, 89, 114, and 38
3	1.8	15.2	1	15.20	38
4	2.4	30.5	1	30.50	140
5	2.4	30.5	1	30.50	102

that varied by pool. Deployment frequency varied by net type as part of a multigear sampling strategy directed toward assessing population status of paddlefish *Polyodon spathula* in Pennsylvania (Table 2). All gill nets were deployed perpendicular to flow and the residual end of each net was anchored and identified with marker buoys. Gill nets were typically set once in the early evening, checked after 3–4 h, and then redeployed overnight. Nets fished overnight were checked immediately after first light. All captured fish were identified to species, measured to the nearest millimeter TL, enumerated, and released.

Catches were scaled by net length to permit comparisons of catch rate among each net type. First, we used one-way analysis of variance (ANOVA) to compare species catch rate, size of fish captured, and species composition (dependent variables) among net types (independent variable). Fisher's least-significant-difference (LSD) test was then used to determine which net types differed whenever the ANOVA was significant ($P \leq 0.05$;

TABLE 2.—Sampling protocol (number of net sets per net type) used to sample fish community structure in eight pools of the Ohio, Allegheny, and Monongahela rivers from October 2001 through November 2002. Dimensions of net types are shown in Table 1, and pool locations are shown in Figure 1.

Pool	Net type 1	2	3	4	5	Total
Pike Island	5	4	2	4	4	19
Montgomery	20	8	6	30	4	68
Dashields	4	2	2	7	2	17
Lock and Dam No. 3	5	4	3	3	2	17
Braddock	4	3	3	3	3	16
Elizabeth	4	2	2	3	2	13
Lock and Dam No. 4	5	3	3	4	3	18
Maxwell	4	3	3	5	3	18
Total	51	29	24	59	23	186

TABLE 3.—Numbers of fish captured in five gill-net types (Table 1) used to sample fish community structure in eight pools of the Ohio, Allegheny, and Monongahela rivers from October 2001 through November 2002. Pennsylvania status codes are as follows: E = endangered, T = threatened, and C = candidate for listing.

Species	Net type 1	2	3	4	5	Status
Longnose gar *Lepisosteus osseus*	18	21	10	0	0	C
Mooneye *Hiodon tergisus*	6	4	0	0	0	T
Skipjack herring *Alosa chrysochloris*	15	8	8	0	0	E
Gizzard shad *Dorosoma cepedianum*	19	16	8	0	0	
Common carp *Cyprinus carpio*	48	3	40	11	4	
River carpsucker *Carpiodes carpio*	3	0	1	0	0	E
Quillback *C. cyprinus*	8	1	1	0	0	
Highfin carpsucker *C. velifer*	0	0	1	0	0	
White sucker *Catostomus commersonii*	1	0	0	0	0	
Smallmouth buffalo *Ictiobus bubalus*	17	0	4	0	0	C
Bigmouth buffalo *I. cyprinellus*	0	0	0	0	1	E
Silver redhorse *Moxostoma anisurum*	2	0	0	0	0	
River redhorse *M. carinatum*	1	0	1	0	0	E
Black redhorse *M. duquesnei*	1	0	0	0	0	
Golden redhorse *M. erythrurum*	13	6	5	0	0	
Shorthead redhorse *M. macrolepidotum*	4	2	10	0	0	
Channel catfish *Ictalurus punctatus*	114	27	41	3	1	
Flathead catfish *Pylodictis olivaris*	16	4	6	13	11	
Northern pike *Esox lucius*	1	0	0	0	0	
Tiger muskellunge (Northern pike × muskellunge *E. masquinongy*)	0	1	0	0	0	
White bass *Morone chrysops*	9	3	7	0	0	
Hybrid striped bass (White bass × striped bass *M. saxatilis*)	26	5	22	2	0	
Rock bass *Ambloplites rupestris*	1	3	0	0	0	
Smallmouth bass *Micropterus dolomieu*	0	4	0	0	0	
Spotted bass *M. punctulatus*	6	13	12	0	0	
Black crappie *Pomoxis nigromaculatus*	2	1	0	0	0	
Sauger *Sander canadensis*	20	5	18	0	1	
Walleye *S. vitreus*	25	2	9	0	1	
Saugeye (sauger × walleye)	10	1	7	0	0	
Freshwater drum *Aplodinotus grunniens*	15	5	7	6	5	
Total	401	135	218	45	24	

Ott 1988). Second, we used catch data to estimate the time (effort) necessary to adequately sample the TFC. Accumulated catch was plotted against accumulated effort to empirically evaluate the resultant asymptotic relationship. Last, we compared our TFC with a data set derived from the Pennsylvania Fish and Boat Commission's (PFBC 2000) list of fishes expected to occur here and with a list of fishes collected over a 20-year period by means of electrofishing (EAEST 2001). We pruned the PFBC (2000) and EAEST (2001) fish lists to include only those fishes that met our TFC criteria and were native to the Ohio River drainage or had been stocked for sportfishing purposes.

Results

Sampling effort in eight randomly selected pools of the Allegheny, Monongahela, and Ohio rivers included 186 net sets for 1,644 net-hours (Table 2). Catches included 823 individuals of 30 species or hybrids (Table 3). Channel catfish (23%), common carp (13%), and hybrid striped bass (7%) dominated the catches. Several state endangered or threatened fishes were caught, including longnose gar, mooneye, skipjack herring, river carpsucker, highfin carpsucker, bigmouth buffalo, and smallmouth buffalo (Table 3).

Catch rates were significantly higher in graded-mesh or small-mesh gill nets (types 1–3) than larger-mesh types ($F = 15.7$; df = 4; $P < 0.001$; Figure 2). Catch rates did not differ significantly between the two graded-mesh gill-net types (types 1 and 2) or between the two large-mesh gill nets (types 4 and 5; Fisher's LSD). We captured 88% of fishes that were expected to occur in the Allegheny, Monongahela, and Ohio rivers (PFBC 2000; EAEST 2001).

Fish ranged in length from 139 to 1,280 mm TL, 66% of the total catch being in the 250- to 500-mm length-class (Figure 3). Fish shorter than 500 mm TL were captured significantly more often in graded-mesh (types 1 and 2) and small-mesh nets

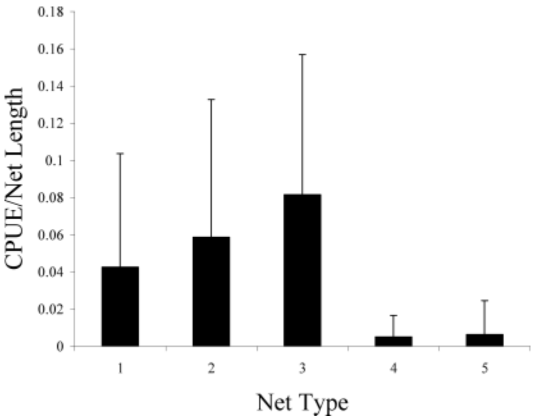

FIGURE 2.—Catch per unit effort (CPUE), scaled by net length, in five gill-net types (Table 1) used to sample fish community structure in eight pools of the Ohio, Allegheny, and Monongahela rivers from October 2001 through November 2002. Error bars denote one standard deviation from the mean.

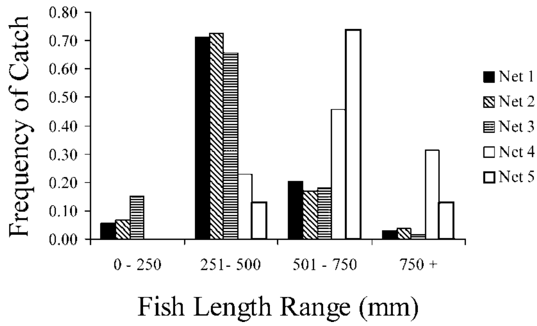

FIGURE 3.—Size frequency of fish captured in five gill-net types (Table 1) used to sample fish community structure in eight pools of the Ohio, Allegheny, and Monongahela rivers from October 2001 through November 2002.

(type 3) than in larger net types (types 4 and 5; $F = 43.5$; df $= 4$; $P < 0.001$). Larger-mesh net types (types 4 and 5) caught significantly more fish larger than 500 mm TL than smaller-mesh net types (types 1, 2, and 3; Figure 3; Fisher's LSD).

Species richness was maximized at different numbers of species and at different levels of sampling effort among net types. For graded-mesh and small-mesh nets (types 1–3), species richness was maximized at about 25 species by 200–225 h of net time (Figure 4). In contrast, for larger-mesh nets (types 4 and 5), species richness was maximized at about 5 species by 100 h of net time.

Discussion

Variability in catch per unit effort (CPUE) among net mesh size, net length, depth of deployment, soak time, and season has been documented in a number of studies (Minns and Hurley 1988; Van den Avyle et al. 1995; Hansen et al. 1998). However, these studies (along with most of the pertinent literature) describe surveys directed at a particular species or size or age-group within the target species (Pierce et al. 1994; Van den Avyle et al. 1995) and are conducted mostly in standing waters. Assessments of large-river ichthyofauna utilizing serial gill netting, such as that of Tejerina-Garro and Merona (2001), are rare.

The influence of fish body length, girth, and encounter probability is also well documented (Reddin 1986; Spangler and Collins 1992; Paukert and Fisher 1999; Anderson and Neumann 2000). We found that fishes less than 500 mm TL were captured significantly more often in our graded-mesh (types 1 and 2) and small-mesh nets (type 3) than in our large-mesh nets (types 4 and 5), while the large-mesh nets were more efficient at capturing fishes greater than 500 mm TL (Figure 3). Minns and Hurley (1988) concluded from their study of the fish community in Bay of Quinte, Lake Ontario, that ''use of gill-net catches as indices of fish abundance must be validated species by species.''

Species richness varied with net type and sampling effort with graded-mesh and small-mesh nets, reaching higher species asymptotes over longer time periods (Figure 4). Tejerina-Garro and Merona (2001), studying fish communities of large

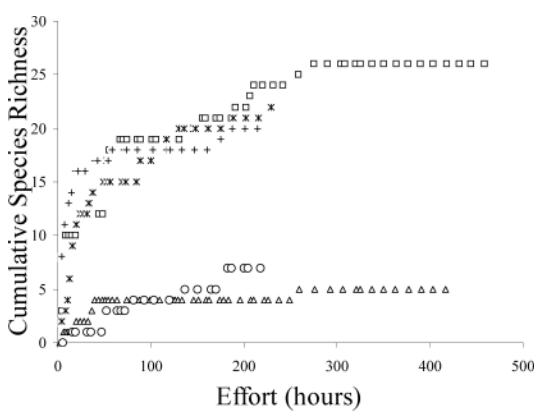

FIGURE 4.—Cumulative number of species captured in five gill-net types (Table 1) used to sample fish community structure in eight pools of the Ohio, Allegheny, and Monongahela rivers from October 2001 through November 2002. Net type 1 = square; net type 2 = asterisk; net type 3 = plus sign; net type 4 = triangle; and net type 5 = circle.

rivers in French Guiana, concluded that gill-net mesh sizes of 15–35 mm adequately sampled their target communities.

Using total species asymptotes as determinants, our results indicate that serial gill netting with a mix of mesh sizes and net lengths can adequately assess species richness of large-bodied riverine fishes. This strategy allowed us to capture the majority of species of this TFC that were expected to occur in the Ohio, Allegheny, and Monongahela rivers. Among these were 7 species recognized as ‘‘endangered or threatened’’ in Pennsylvania. Exceptions were fishes that the PFBC recognizes as ‘‘uncommon’’ in Pennsylvania (e.g., river carpsuckers) and fishes that are not vulnerable to capture in gill nets (e.g., centrarchids; R. Lorson, PFBC, personal communication). While many fish were missing scales and exhibited signs of stress upon release, survival was exceptionally high, even among alosines. Gill nets are widely used as a passive capture technique in standing waters but are selective in regard to fish size and morphology (Hamley 1975). Users can minimize selectivity by employing graded-mesh nets to capture fishes of varying lengths. However, our data suggest that nets with small-bar single-mesh panels were comparable in efficiency to graded-mesh nets for sampling the diversity of the ichthyofauna of the Allegheny, Monongahela, and Ohio rivers. These results suggest that an appropriately designed gill-net sampling strategy can be comparable to costly boat electrofishing for the characterization of this TFC.

The major weakness of this gill-net sampling approach is that some species are not vulnerable to capture in gill nets. This may be a critical issue, especially if decisions regarding fisheries management objectives require frequency of capture or proportional data. However, if the primary objective is to characterize diversity, then gill netting may offer a low-cost alternative to other more expensive and labor-intensive techniques. If the management objective demands data on those fishes that are not vulnerable to capture in gill nets, then we suggest the use of multiple sampling gears to adequately characterize the community. The results of our study suggest that graded-mesh and small-mesh nets can efficiently sample the diversity of fishes in our defined TFC (>250 mm TL).

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