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[Management Brief]

Development and Efficacy of an Electrified Benthic Trawl for Sampling Large-River Fish Assemblages

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Abstract.—Sampling small benthic and lithophilic fish species in large rivers and lakes presents challenges not adequately addressed by conventional survey methods such as boat electrofishing and gill netting. The development of the Missouri trawl has helped to address these issues; however, our observations by scuba diving when using the Missouri trawl have revealed avoidance of the trawl by benthic fishes, especially in rocky substrates. Therefore, we equipped a Missouri trawl with a cathode–anode electrical array to facilitate capture by attracting and immobilizing fish. In 40 paired comparisons with a standard Missouri trawl in the upper Ohio River drainage of Pennsylvania, this electrified PSU trawl captured significantly more fish and species as well as more large fish. The PSU trawl also captured more species and more fish across habitats and rivers within the drainage. The PSU trawl is therefore a useful new device for sampling large-river benthic fish communities.

Sampling small benthic and lithophilic fishes in large rivers is challenging because they are not vulnerable to nets (e.g., trap and gill nets) or to electrofishing gear when they inhabit deep water. Small fish may be captured with beach seines, minnow or Windermere traps, or electrofishing, but these methods are most effective close to shore (Murphy and Willis 1996). The use of these methods results in samples that are biased against small-bodied benthic and deeper-water fish species. Since presence/absence and abundance data are often used to make inferences about species-specific habitat use, incorrect conclusions could be drawn from data obtained by such survey methods.

The Missouri trawl (Herzog et al. 2005), in which a fine-mesh net is attached to the exterior of a benthic trawl, was designed to remedy this situation. The Missouri trawl has proven to be effective in sampling small benthic fishes in rivers throughout North America, thereby extending the distribution and abundance estimates for many species (Stewart et al. 2005; Argent et al. 2007; Koryak et al. 2008; Freedman et al. 2009) and supplementing other gear types (Argent et al. 2007; Koryak et al. 2008). However, our observations by scuba diving of the Missouri trawl in action have revealed avoidance of the trawl by some species, especially in gravel–cobble substrates where fish can easily seek refuge in the interstitial spaces. During our trawling of the Allegheny and Ohio rivers of Pennsylvania, we have observed a bias toward capturing the juveniles of many darter (Percidae) and minnow (Cyprinidae) species. However, larger individuals and adults seldom are captured. Some species also seem to be abundant during scuba surveys but rare or absent in the trawls. In short, it seemed that while the Missouri trawl is relatively effective in capturing these small-bodied fishes, improvements were possible.

Electric currents have been used to capture fish for several decades (Reynolds 1996). While electrofishing gear (including electrified seines) has been successfully used in wadeable streams (Bayley et al. 1989; Peterson and Rabeni 2001), its utility has been limited by not being able to sample fish from deeper water (depths greater than 1.2 m). An exception is the capture of sea lamprey *Petromyzon marinus* ammocoetes by deepwater electrofishing (McLain and Dahl 1968; Bergstedt and Genovese 1994; Moser et al. 2007). While most of these deepwater methods have used a combination of electric currents and suction to capture ammocoetes, McLain and Dahl (1968) modified a sled-mounted benthic trawl by electrifying it and pulling it along the lake bottom. Although it was considered to be effective in capturing ammocoetes, it also had a high bycatch rate for 23 species representing 19 genera. This technology was seldom used through the intervening years; however, Peterson (1996) used an electrified benthic trawl for sampling fish in nonwadable reaches of Ozark streams, where it proved effective.

Since electric currents have the ability both to attract and to incapacitate fish, we electrified a Missouri trawl. We hypothesized that an electrified trawl would be more efficient than a nonelectrified one, capturing greater numbers of both species and fish as well as

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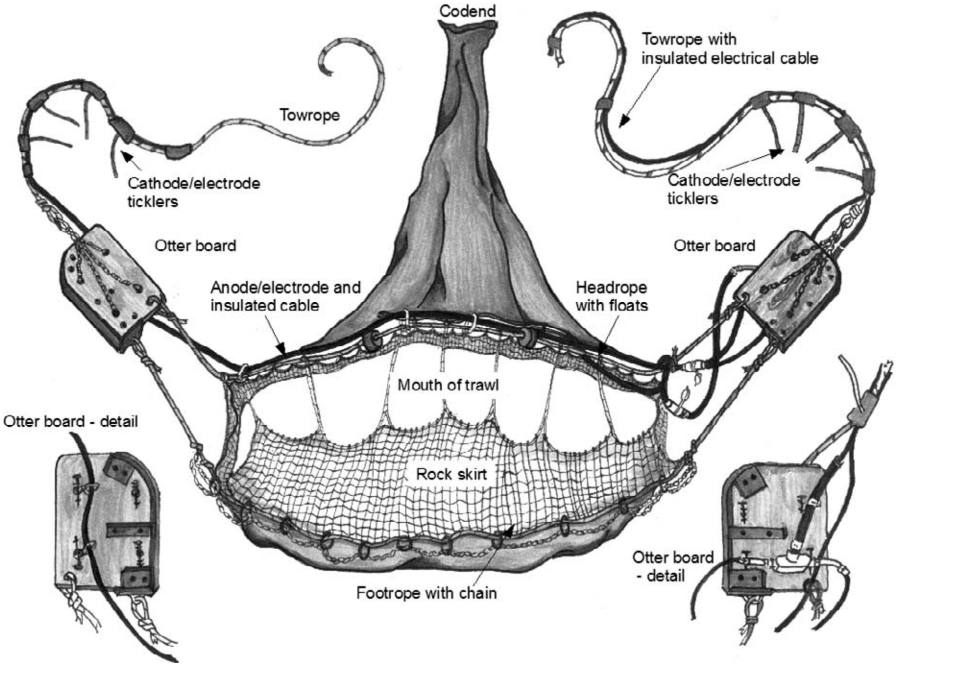

FIGURE 1.—Diagram of a PSU trawl showing the modifications made to electrify it. The insulated electric cable attached to the towrope contains separate leads for the cathodes and the anode, which in turn are attached to an electrofishing controller unit using standard amphenol connectors (not to scale).

larger individuals. We tested the trawl in the Ohio, Allegheny, and Monongahela rivers in Pennsylvania. The substrate of the Allegheny River is primarily glacial alluvial gravel and rocks, while that of the Monongahela River is primarily sand and mud. The Ohio River forms at the confluence of the Allegheny and Monongahela rivers in Pittsburgh and has a substrate intermediate between those of its two tributaries. These three bodies of water thus allowed us to test the trawls in a variety of riverine habitats.

Methods

We modified a Missouri trawl consisting of a 19.05-mm-stretch inner mesh bag and a 4.76-mm-stretch outer mesh bag with a 2.44-m headrope (Herzog et al. 2005) manufactured by Innovative Net Systems (Milton, Louisiana). The trawl was modified by adding 15-cm-stretch mesh across the opening of the net as a rock exclusion device or rock skirt. To electrify the trawl, we added five 30-cm-long wire "ticklers" (called cathodes in DC mode and electrodes in AC mode) to each of the tow ropes above the otter boards and a wire along the headrope (anode in DC mode and electrode in AC mode) (Figure 1). The electrodes were connected to a Smith-Root VI-A electrofishing controller unit connected to a Honda 3,500-W generator. The modified trawl was called the PSU trawl. Trawling was conducted with a 5.3-m johnboat powered by a 25-hp (1 hp = 746 W) outboard motor.

We sampled a total of 40 sites in the Allegheny (28 sites), Ohio (4), and Monongahela (8) rivers in Pennsylvania, using paired trials to compare the trawls. The sampling sites were selected randomly from a group of sites that we were sampling as part of a larger study. At each site, we randomly selected either the PSU or the Missouri trawl to be tested first and randomly selected the location within the river (bank or midchannel). We then conducted a 2-min trawl with each device at the same speed and in close parallel transects. Trials were conducted during October and November 2007 and from May to August 2008.

We used the same trawl for all comparisons to eliminate potential bias due to trawl differences (i.e., the trawl was electrified for the PSU trawl replicates and not electrified for the Missouri trawl replicates). These trawls were conducted 3–8 m apart so as to sample the same or similar habitats while minimizing any effects that the previous trawl may have had in attracting or repelling fish along its transect. In addition, the trawls were conducted 30–60 min apart to minimize the effects of disturbances to the fish. The trawls were conducted with and slightly faster than the current. Trawl depth ranged from 2 to 10 m, with mean depths of 4.37 m for the PSU trawls and 4.53 m for the Missouri trawls. Secchi depth ranged from 60 to 160 cm. Fish were identified to species in the field, photo vouchers were recorded, and representative specimens were placed in permanent storage at the Pennsylvania State University Fish Museum. Most shiners (*Notropis* spp.) were too small to identify reliably; hence, all were conservatively grouped together as "shiner species."

We used a paired-sample Wilcoxon signed-ranks test with continuity correction to test whether the PSU trawl captured more fish and more species than the Missouri trawl. Statistical analyses were performed in R 2.5.1 (R Development Core Team 2008).

Results and Discussion

In 40 paired trials, we caught significantly more fish using the PSU trawl than using the Missouri trawl ($P = 0.0001628$; Table 1; Figure 2). The PSU trawl caught more fish in 80% of the trials, compared with 12.5% for the Missouri trawl. We also caught significantly more species with the PSU trawl than with the Missouri trawl ($P = 0.0002281$; Table 1; Figure 2). With the PSU trawl we caught more species in 62.5% of the trials as well as eight species not caught with the Missouri trawl; the Missouri trawl was more successful in 12.5% of the trials and caught only one species not caught by the PSU trawl (Table 1). While the Missouri trawl failed to catch any fish in 30% of the trials, the PSU trawl failed to do so in only 2.5% of the trawls. These trends held across all three rivers, that is, we caught more individuals and species with the PSU trawl in each river as well as cumulatively. The PSU trawl was tested first in 53% of the trials, while on average the first trawl to be tested in each trial caught more fish 46% of the time, suggesting that trawl order had no influence on catch rate.

While we did not measure every fish that we caught, we did classify all of the ones that exceeded 20 cm (total length) as "large." Although the rock skirt probably acted as a barrier to large fish, we caught seven such fish in our trawls (six in the PSU trawl and one in the Missouri trawl). We have observed that the rock skirt is very effective in reducing snags and wear and tear induced by dragging rocks in the trawl, and it is therefore recommended for trawling rocky substrates. Herzog et al. (2005) regularly captured larger-bodied fishes in the Mississippi River using the Missouri trawl. Their relative success in capturing larger species is probably due to the higher turbidity and softer substrate of the Mississippi River in addition to the absence of a rock skirt. The Secchi depths in the Mississippi River ranged from 2 to 61 cm and averaged 28 cm, while those in our study ranged from 60 to 160 cm and averaged approximately 100 cm. Higher turbidity may make trawls less noticeable to fish by either sight or sound. Softer substrate may reduce the possibility of avoiding trawls by hiding in the interstitial spaces among rocks. In the Monongahela River, however, which has a softer substrate than the Allegheny and Ohio rivers, we caught more individuals in six of the eight comparisons performed and only caught more species with the Missouri trawl in one comparison. However, since the sampling-area footprint of the PSU trawl is intrinsically limited by the width of the trawl, this is probably the limiting factor in capturing larger fish, rather than habitat-specific differences or the rock skirt.

Benthic trawls have been modified with anode–cathode electrical arrays for sampling deep lakes

TABLE 1.—Total abundance of fishes caught in 40 paired comparisons of the PSU and Missouri trawls in the Ohio, Allegheny, and Monongahela rivers, Pennsylvania.

Species	Trawl type	
	Missouri	PSU
Catostomidae		
Northern hog sucker *Hypentelium nigricans*	1	0
Smallmouth buffalo *Ictiobus bubalus*	0	1
Golden redhorse *Moxostoma erythrurum*	1	1
Smallmouth redhorse *Moxostoma breviceps*	0	2
Cyprinidae		
Streamline chub *Erimystax dissimilis*	44	11
Shiner species *Notropis* spp.	20	32
Bluntnose minnow *Pimephales notatus*	4	2
Ictaluridae		
Channel catfish *Ictalurus punctatus*	3	27
Centrarchidae		
Rock bass *Ambloplites rupestris*	0	1
Smallmouth bass *Micropterus dolomieu*	1	3
Percidae		
Greenside darter *Etheostoma blennioides*	9	33
Rainbow darter *Etheostoma caeruleum*	1	17
Bluebreast darter *Etheostoma camurum*	11	81
Fantail darter *Etheostoma flabellare*	0	6
Spotted darter *Etheostoma maculatum*	0	6
Johnny darter *Etheostoma nigrum*	1	5
Tippecanoe darter *Etheostoma tippecanoe*	6	31
Banded darter *Etheostoma zonale*	1	1
Logperch *Percina caprodes*	21	57
Channel darter *Percina copelandi*	283	601
Gilt darter *Percina evides*	17	17
Longhead darter *Percina macrocephala*	11	11
River darter *Percina shumardi*	10	16
Sauger *Sander canadensis*	0	2
Walleye *Sander vitreus*	1	1
Sciaenidae		
Freshwater drum *Aplodinotus grunniens*	0	4
Cottidae		
Mottled sculpin *Cottus bairdii*	0	9
Number of individuals	448	988
Mean (SD)	11.2 (23.0)	24.7 (35.4)
Median (SD)	2.5 (23.0)	7.5 (35.4)
Number of species	19	26
Mean (SD)	1.9 (1.9)	3.2 (2.4)
Median (SD)	1.0 (1.9)	2.0 (2.4)

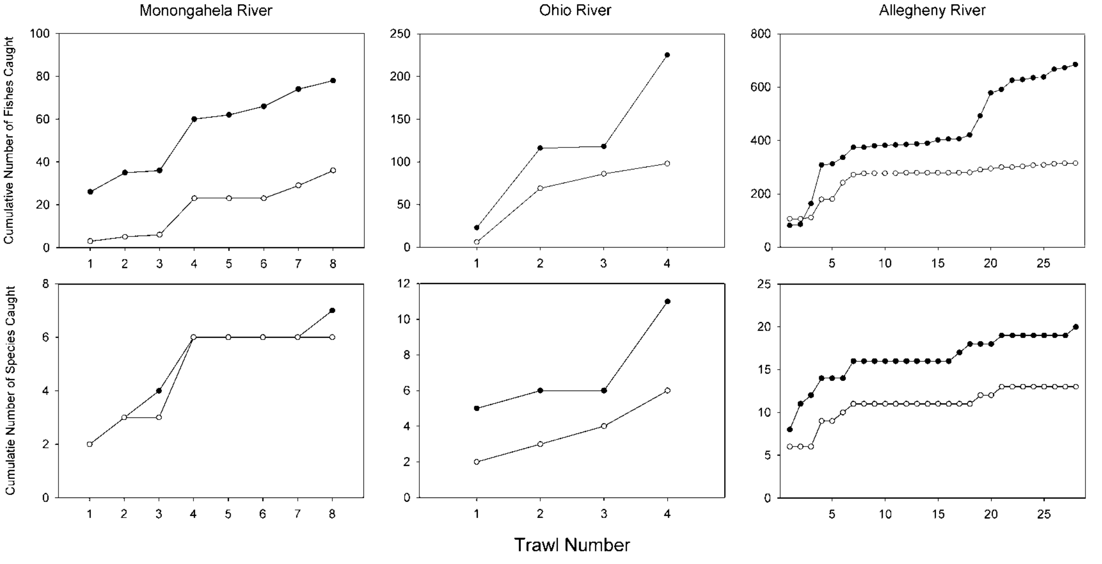

FIGURE 2.—Cumulative number of fish (upper row) and number of species (lower row) caught with the PSU (filled circles) and Missouri trawls (open circles) in paired comparisons in the Monongahela, Ohio, and Allegheny rivers.

(McLain and Dahl 1968) and nonwadable stream reaches (Peterson 1996). McLain and Dahl's (1968) sled-based trawl was effective in capturing a variety of benthic fishes as well as the targeted sea lamprey ammocoetes. Such a sled, however, may prove unwieldy and difficult to bring into the boat on repeated trawls. Peterson's (1996) electrified trawl was smaller than the Missouri trawls used in our study (1 m across compared with 2.44 m) and therefore may have been less efficient in sampling large rivers. Herzog et al. (2005) used Missouri trawls with headropes of 4.87 m, which have proved to be very successful in sampling the Mississippi River. While we used the smaller trawl primarily to minimize snags in the rocky substrates of the Allegheny and Ohio rivers, we expect that it would be possible to electrify the larger trawl and obtain similar results. The electricity did not appear to cause mortality among the fish or bycatch (e.g., turtles, amphibians, and crayfishes).

In conclusion, we caught more than twice as many fish and eight more species using the PSU trawl than using the Missouri trawl, as well as more large individuals. Further testing in different watersheds and under different water conditions (e.g., depth, turbidity, conductivity, temperature, and substrate) will probably support our results. Further research will also determine the effectiveness of the PSU trawl in capturing specific species, sizes, and life history stages of fish in comparison with other sampling methods and perhaps reveal differences in relative susceptibility to capture between otherwise similar species. The rock skirt is effective in preventing snags and excluding rocks from the trawl, but it will be important to examine the degree to which it excludes larger fish from the samples. Further testing should compare AC and DC and seek to determine the ideal electric settings for these trawls. As there are inherent risks associated with any sampling conducted with electricity, we recommend observing the safety guidelines in Reynolds (1996) to minimize potential hazards.

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References

Argent, D. G., W. G. Kimmel, R. Lorson, and E. Emery. 2007. Ichthyofauna of the Monongahela River basin in Pennsylvania: a contemporary evaluation. Journal of Freshwater Ecology 22(4):617–628.

Bayley, P. B., R. W. Larimore, and D. C. Dowling. 1989. Electric seine as a fish sampling gear in streams. Transactions of the American Fisheries Society 118:447–453.

Bergstedt, R. A., and J. H. Genovese. 1994. New technique for sampling sea lamprey larvae in deepwater habitats. North American Journal of Fisheries Management 12:449–452.

Freedman, J. A., T. D. Stecko, R. W. Criswell, and J. R. Stauffer, Jr. 2009. Extensions of the known ranges of *Percina shumardi* Girard and three species of *Etheostoma* (subgenus *Nothonotus*) in Pennsylvania. Journal of the Pennsylvania Academy of Science 83:42–44.

Herzog, D. P., V. A. Barko, J. S. Scheibe, R. A. Hrabik, and D. E. Ostendorf. 2005. Efficacy of a benthic trawl for sampling small-bodied fishes in large-river systems. North American Journal of Fisheries Management 25:594–603.

Koryak, M., P. Bonislawsky, D. Locy, and B. A. Porter. 2008. Use of benthic trawling to supplement electrofishing in characterizing the fish community of the Allegheny River navigation channel in Pennsylvania, USA. Journal of Freshwater Ecology 23(3):491–494.

McLain, A. L., and F. H. Dahl. 1968. An electric beam trawl for capture of larval lampreys. Transactions of the American Fisheries Society 97:289–293.

Moser, M. L., J. M. Butzerin, and D. B. Dey. 2007. Capture and collection of lampreys: the state of the science. Reviews in Fish Biology and Fisheries 17(1):45–56.

Murphy, B. R., and D. W. Willis, editors. 1996. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Peterson, J. T. 1996. The evaluation of a hydraulic-unit-based habitat classification system. Doctoral dissertation. University of Missouri, Columbia.

Peterson, J. T., and C. F. Rabeni. 2001. The relation of fish assemblages to channel units in an Ozark stream. Transactions of the American Fisheries Society 130:911–926.

R Development Core Team. 2008. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available: www.R-project.org. (October 2007).

Reynolds, J. B. 1996. Electrofishing. Page 221–253 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2 edition. American Fisheries Society, Bethesda, Maryland.

Stewart, J. G., V. A. Barko, D. B. Henry, D. P. Herzog, J. W. Ridings, A. F. Kelley, and J. E. Wallace. 2005. New records of the crystal darter (*Crystallaria asprella*) in the middle Mississippi River. American Midland Naturalist 154(2):471–473.