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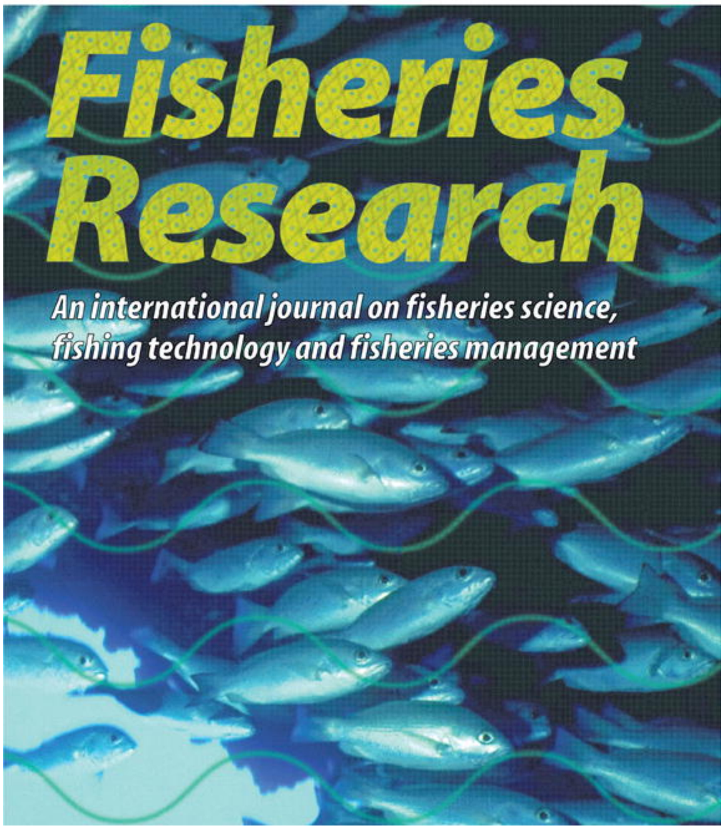

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Efficacy of two-pass electrofishing employing multiple units to assess stream fish species richness

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Abstract

We utilized two-pass, multiple unit backpack electrofishing data to assess stream fish species richness. Twenty-six streams in the Monongahela River basin of Pennsylvania were sampled over 200 m standard reaches. Effort, as measured by the number of electrofishers employed, was increased as a function of increasing mean stream width (<30 m) to a maximum of three operated abreast across the stream. We calculated proportional fish species richness ($\hat{s}$) and the probability of detection ($\hat{p}_{s_1}$) for each species. Values of $\hat{s}$ ranged from 1 to 27, whereas values of $\hat{p}_{s_1}$ ranged from 67 to 100 across all streams. Median $\hat{p}_{s_1}$ values did not differ significantly among effort categories nor did the probability of capturing a new species on pass two ($P > 0.05$). Narrow 95% confidence intervals around $\hat{s}$ values attest to the validity of this approach in estimating species richness. Small percids (e.g., darters) and schooling (e.g., cyprinids) fishes evaded capture on the first pass more frequently than centrarchids, ictalurids, or catastomids. Our results indicate that increasing effort (as measured by number of electrofishing units employed incrementally over a standardized length of the sampling reach) provides a practical and efficient alternative to increasing sampling reach length with increasing stream width when sampling for species richness.

Keywords: Backpack electrofishing; Species richness; Multiple-pass; Stream width

1. Introduction

Characterization of fish community composition is an important aspect of conservation plans and water quality assessments in flowing waters. Fish community diversity and abundance are sensitive to a variety of environmental perturbations. Efforts to quantify these parameters involve creation of appropriate sampling paradigms which themselves are often heavily influenced by considerations of manpower and budget.

Basin-wide water quality assessments often require locally tailored strategies, which address the multiple stream orders present. The National Water Quality Assessment Program (NAWQA) implemented by the U.S. Geological Survey (USGS) is testament to the importance of integrating fish community structure along with other factors in evaluating the nation's water quality (Meador et al., 1993). The need to maximize the amount and quality of data collected while minimizing time and expenditure has spawned a variety of sampling strategies focusing on selecting the minimum area of stream to be sampled to yield the maximum results. A number of authors have investigated this issue (Simonson et al., 1994; Paller, 1995; Peterson and Rabeni, 1995) and provided means to estimate appropriate sampling reach length or area. Various multiples of length/width (*L*/*W* ratio) scenarios have been proposed (Angermeier and Smogor, 1995; Paller, 1995; Dauwalter and Pert, 2003); whereas others have suggested ranges for standard reach lengths based on stream size (Ohio EPA, 1987; Plafkin et al., 1989). In wadeable streams, backpack electrofishing is typically employed (Meador et al., 2003) with increasing width and depth giving way to towed shockers (Meador, 2005) and ultimately in non-wadeable streams to boat electrofishing (Ohio EPA, 1987; Plafkin et al., 1989).

A number of techniques for estimating species richness of stream fish assemblages utilizing variants of established depletion methodology have been reported (Seber and Le Cren, 1967; Meador et al., 2003). However, Meador et al. (2003) suggested the efficiency of single-unit backpack electrofishing may decrease with increasing stream width. For example, as stream width increases, this approach requires the operator to adopt a zig-zag pattern across the thalweg to cover the increased area.

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As a result, the arc-reach of the probe, would not subject fishes to a constant electrical field likely increasing escape. Our objective was to assess the efficacy of a multi-unit backpack electrofishing strategy for assessing species richness in a selected set of wadeable Monongahela River tributaries of varying sizes employing a standardized sampling reach of 200 m.

2. Methods

2.1. Study region

The Monongahela River arises from the juncture of the West Fork and Tygart rivers in Fairmont, West Virginia and flows 200 km north to its confluence with the Allegheny to form the Ohio River in Pittsburgh, Pennsylvania. The Monongahela River drains a 19,166 km^2 area, of which 5252 km^2 are located in Pennsylvania. This study focused on those tributaries that join the Monongahela River along its 130 km course from the West Virginia/Pennsylvania border to Pittsburgh, Pennsylvania. During low-flow summer periods of 2003 and 2004, we surveyed fish species richness in 40 of the 51 tributaries named on USGS quadrangle maps of the Monongahela River basin in Pennsylvania (Kimmel and Argent, 2006) using two-pass backpack electrofishing (Heimbuch et al., 1997; Meador et al., 2003). The remaining 11 streams were dry at the time of sampling.

2.2. Study design and general procedure

Of the 40 streams surveyed, we eliminated 14 from consideration for this study because they either contained barriers to fish passage prohibiting a survey of the appropriate length, they were too large to effectively sample with backpack electrofishing gear, or they contained so few fish (<10) in the first pass that comparisons between passes could not be made. The remaining wadeable streams (Table 1) were used to assess the efficacy of double-pass electrofishing employing multiple electrofishers to estimate species richness.

At each station, we took five measurements at equidistant locations to determine mean stream width (m) over a 200 m standard reach length. Streams were then divided into three effort categories based on multiples of 6 m width increments for sampling. A 6 m width increment approximates the arc-reach (i.e., circumference about an operator) of our hand-held electrofishing probes while in operation. Streams with an average width ≤6 m were sampled with one electrofisher, whereas those between 6 and 12 m were sampled with two units and those greater than 12 m were sampled with three units. In order to ensure constancy of effort in the third width category (Table 1), operators maintained contact across their respective arc-reaches.

At each site, we employed pulsed-dc backpack electrofishers set with frequencies of 60 pulses/s. Voltage was adjusted according to ambient conductivity in order to maximize capture efficiency and minimize mortality. Each unit contained one 28 cm diameter round anode attached to a 1.82 m fiberglass long pole and one trailing cathode. Each crew consisted of an operator equipped with a 33 cm × 33 cm × 25 cm diamond-shaped dip net, one additional netter, and a person to carry captured fish.

Table 1
Summary of sampling reach dimensions

Stream name	Length (m)	Mean width (m)	L/W	Area (m^2)	Effort category
Sunfish	200	1.6	125.0	320	
Lobbs	200	2.2	90.9	440	
Meadow	200	3.1	64.5	620	
Fallen timber	200	3.4	58.8	680	
Fishpot	200	4.2	47.6	840	
Streets	200	4.5	44.4	900	1-Backpack electrofisher
Neel	200	4.5	44.4	900	
Middle	200	5.0	40.0	1000	
Rush	200	5.1	39.2	1020	
Little redstone	200	5.4	37.0	1080	
Barney's	200	5.6	35.7	1120	
Maple	200	6.1	32.7	1220	
Wallace	200	6.2	32.3	1240	
Sandy	200	6.8	29.4	1360	
Dunlap	200	7.3	27.4	1460	
Mingo	200	7.9	25.3	1580	2-Backpack electrofishers
Muddy	200	8.3	24.1	1660	
Pike	200	8.5	23.5	1700	
Pigeon	200	10.8	18.5	2160	
Whiteley	200	11.6	17.2	2320	
Peters	200	11.9	16.8	2380	
Turtle	200	13.3	15.0	2660	
Georges	200	19.3	10.4	3860	
Tenmile	200	20.7	9.7	4140	3-Backpack electrofishers
Redstone	200	24.7	8.1	4940	
Dunkard	200	25.7	7.8	5140	

Note effort category represents the number of backpack electrofishing units used to sample each stream as determined by stream width.

All electrofishing was conducted in an upstream manner at or near the mouth to the nearest natural break to the 200-m endpoint. Blocking nets, ineffective in improving catch rates (Paller, 1995) or species richness estimates (Simonson and Lyons, 1995) were not utilized. When multiple electrofishing units were employed, operators moved abreast at the same pace through the water to minimize disturbance. Upon completion of each pass, large specimens (>250-mm TL) and gamefish were identified in the field and released. All others were fixed in 10% formalin and identified in the laboratory. Retained specimens were separated by pass for comparison.

We used equations derived by Seber and Le Cren (1967) for removal method population estimates, modified to assess species richness (Nichols and Conroy, 1996) as described in Meador et al. (2003). Total species richness was estimated according to: $\hat{s} = (s_1)^2/(s_1 - s_2)$; where s_1 is species richness collected in the first pass, s_2 is the number of additional species collected in the second pass, and $\hat{s}$ is the total estimated species richness. Percent total species richness estimated on the first pass was determined from $\hat{p}_{s_1} = (s_1/\hat{s})\,100$ (Nichols and Conroy, 1996). To derive 95% confidence intervals for each richness estimate, we modified Seber and LeCren's (1967) formula for computing abundance variance to species richness by replacing catch (c)

with richness (s):

$$\mathrm{var}(\hat{s}) = \frac{s_1^2 \times s_2^2 \times (s_1 + s_2)}{(s_1 - s_2)^4}$$

We compared the frequency of capture of new species on pass two by unit effort to determine if any trends existed among species or families at large. We evaluated our results by comparing data from pass one with pass two to determine if the second pass added an appreciable number of new species to the sample. We used a Mann–Whitney *U*-test to determine if species richness differed between passes one and two and a Kruskal–Wallis test to determine if differences existed in $\hat{s}$ and $\hat{p}_{s_1}$ as a function of increasing stream width (as measured by effort category). Spearman's rank correlation was used to examine relationships between $\hat{p}_{s_1}$ and mean channel width for each stream assessed. We established $\alpha = 0.05$ as our level of statistical significance for all tests.

3. Results

Mean stream widths varied from 1.6 to 25.7 m, which yielded effective sampling areas of 320–5140 m^2 (Table 1). Eleven streams in this watershed were sampled with one backpack shocker; 10 required two; three units were employed on five (Table 1). *L/W* ratio values ranged from 35.7 to 125 in streams sampled with one shocker; 16.8–33.3 with two shockers; 7.8–15 with three shockers (Table 1).

A total of 6150 fishes representing 40 species or hybrids and eight families were collected across the 26 stream subset, representing 95% of the documented ichthyofaunal complement (Cooper, 1983). Values of $\hat{s}$ ranged from 1 to 27 across all streams (Table 2). Median $\hat{p}_{s_1}$ values were not significantly different among effort categories ($P > 0.05$; Fig. 1), indicating the relative efficiency of capture on pass one did not change with stream size. We found no significant relationship between mean channel width and $\hat{p}_{s_1}$ values ($P > 0.05$; Fig. 2). The majority of our effort category one streams yielded $\hat{p}_{s_1}$ values of 100 (Table 2).

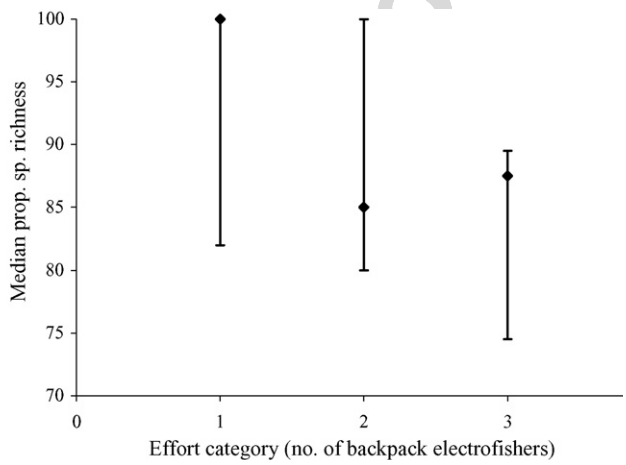

Fig. 1. Median proportional species richness on the first pass ($\hat{p}_{s_1}$) by effort category and 95% confidence interval. Median for effort category one is 100.

Table 2
Percent total stream species richness estimated on the first pass ($\hat{p}_{s_1}$) and estimated total species richness summarized by effort category

Stream name	$\hat{p}_{s_1}$	$\hat{s}$	(±) 95% CI $\hat{s}$	Effort category
Sunfish	89	10	0.89	
Lobbs	100	5	0.00	
Meadow	100	1	0.00	
Fallen timber	70	14	4.41	
Fishpot	83	14	1.80	
Streets	100	1	0.00	1-Backpack electrofisher
Neel	100	14	0.00	
Middle	100	6	0.00	
Rush	67	9	4.24	
Little redstone	100	11	0.00	
Barney's	100	7	0.00	
Maple	89	10	0.00	
Wallace	83	7	1.27	
Sandy	100	3	0.00	
Dunlap	79	18	2.86	
Mingo	100	21	0.00	2-Backpack electrofishers
Muddy	100	25	0.00	
Pike	67	27	7.35	
Pigeon	82	13	1.96	
Whiteley	93	15	0.64	
Peters	80	6	1.53	
Turtle	88	9	0.98	
Georges	86	8	1.10	3-Backpack electrofishers
Tenmile	90	23	1.12	
Redstone	89	21	1.21	
Dunkard	75	16	6.00	

We added at least one new fish species during pass two in 15 of the 26 streams we sampled. Median number of new fish species added in pass two did not vary significantly among effort categories ($P > 0.05$; Fig. 3), suggesting that richness at large was effectively sampled during pass one. Further analysis of those fishes added across all streams yielded 22 species representing five families that were not collected during the first pass (Table 3). Among these fishes, darters and minnows were the most frequently missed on the first pass; however, no species was more likely to be captured in one effort category than another (Table 3).

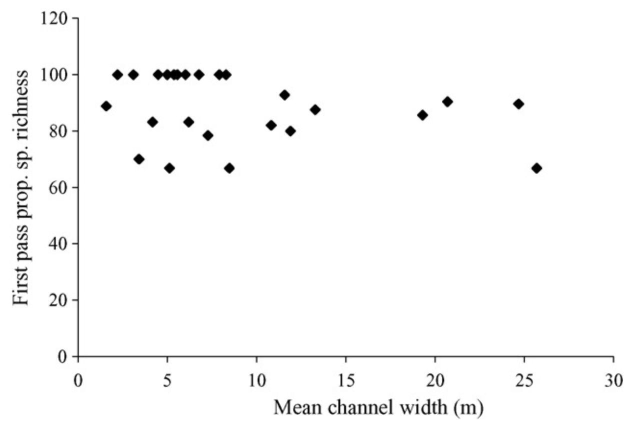

Fig. 2. Scatter plot relating mean channel width (m) and proportional species richness on the first pass ($\hat{p}_{s_1}$).

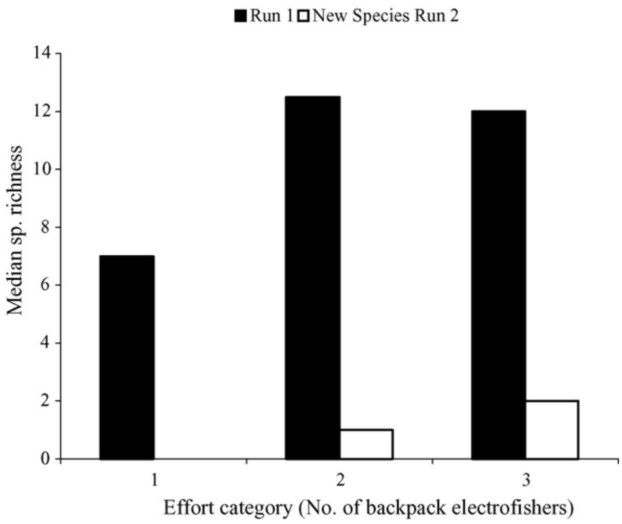

Fig. 3. Median species richness by effort category on pass one and median number of new species added on pass two. Median species richness of pass two in effort category one is 0.

Table 3
Frequency of occurrence of new species on pass two by effort category

Family	Species	Occurrence by effort category		
		1	2	3
Catastomidae	Silver redhorse	1	1	0
Catastomidae	White sucker	0	2	1
Centrarchidae	Bluegill	0	0	1
Centrarchidae	Green sunfish	0	1	0
Centrarchidae	Sunfish hybrid	0	1	0
Cyprinidae	Blacknose dace	0	1	0
Cyprinidae	Bluntnose minnow	0	0	1
Cyprinidae	Common carp	0	1	0
Cyprinidae	Emerald shiner	0	0	1
Cyprinidae	Mimic shiner	0	1	0
Cyprinidae	Spotfin shiner	0	1	0
Cyprinidae	Channel shiner	1	1	0
Cyprinidae	Common shiner	1	1	0
Cyprinidae	Creek chub	1	0	1
Cyprinidae	Striped shiner	2	0	0
Cyprinidae	Rosyface shiner	1	0	2
Ictaluridae	Yellow bullhead	0	1	0
Percidae	Banded darter	0	0	1
Percidae	Fantail darter	1	0	0
Percidae	Johnny darter	0	0	1
Percidae	Logperch	0	1	0
Percidae	Variegate darter	0	0	1
Total		8	13	10

4. Discussion

Assessments of stream fish species richness utilizing depletion methodology typically involve the selection of an effort strategy based on either a standard reach length or one defined by a selected multiple of *L*/*W* ratios. Numerous authors have described the issue of effort required to effectively sample fish species richness within a stream. Some focus on issues of linear sampling distance (Lyons, 1992; Hughes et al., 2002), whereas others focus on issues of sampling frequency or number of passes (Pusey et al., 1998).

Meador et al. (2003) evaluated the efficacy of double-pass electrofishing for estimating species richness in 80 wadeable streams surveyed as part of the U.S. Geological Survey's NAQWA Program. Its protocol (Meador et al., 1993) defined the minimum sampling reach as 150 m with a maximum of 300 m for the collection of a representative sample to determine fish community structure. However, in streams greater than 30 m wide, the protocol calls for consideration of a maximum reach of 500 m. We selected 200 m, the maximum sampling reach length for wadeable streams proposed by the Ohio EPA (1987) and Plafkin et al. (1989) as our standard for this survey in order to optimize species richness estimates. The streams surveyed by electrofishing in Meador et al's (2003) analysis varied in mean width from 7.0 to 15.3 m and in sampling reach length from 159.8 to 253.3 m and were sampled with one-backpack unit. We utilized multiple-backpack electrofishers to sample Monongahela Basin tributaries over a range of mean widths from 1.6 to 25.7 m (Table 1) and a standard reach length of 200 m by incrementally increasing numbers of backpack units with increasing reach mean width.

Meador et al. (2003) reported a detection rate of 40–100% of estimated species richness on the first pass ($\hat{p}_{s_1}$) for streams averaging 11.4 m in width. For the nine streams in our survey that fell within Meador et al.'s (2003) sampling reach range of 7.0–15.3 m ($\bar{X} = 8.1$ m), $\hat{p}_{s_1}$ values ranged from 67 to 100 (Table 2). Overall, our $\hat{p}_{s_1}$ values by effort category averaged 91.7 for our >6 m and 87.0 and 85.6 for our 6–12 and >12 m categories, respectively (Table 2). Our lowest individual species richness first pass estimate of 67% occurred only twice—once in effort category one and again in category two (Table 2). Others report high first pass richness estimates in narrow streams (up to about 10 m) (Simonson and Lyons, 1995; Pusey et al., 1998; Patton et al., 2000). We found no significant difference in first pass sampling efficiency with increasing stream width ($P > 0.05$; Fig. 2). Our estimates of species richness on the basis of two-pass electrofishing across all effort categories as evidenced by narrow 95% confidence intervals indicate the high efficiency of this approach (Table 2).

Median $\hat{p}_{s_1}$ and the median number of new fish species added on pass two (Fig. 3) did not change significantly by effort category indicating constancy of effort and efficiency across categories ($P > 0.05$; Fig. 1). New species of cyprinids and darters rather than cyprinids and centrarchids noted by Meador et al. (2003) were most likely to be initially captured on pass two, but their frequency of capture did not differ among effort categories (Table 3). Our data suggests that fishery managers planning surveys of species richness utilizing depletion methodology consider the merits of adding electrofishing units over a standard reach length versus multiples of *L*/*W* ratios or other measures to accommodate increasing stream size. Adding additional backpack electrofishing units incrementally concomitant with increasing reach width may prove an efficient strategy to accurately assess stream fish species richness.

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