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Single-Pass Electrofishing Predicts Trout Abundance in Mountain Streams with Sparse Habitat

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Abstract.—Fish abundances in mountain streams are typically estimated over a reach with multiple-pass-removal electrofishing techniques, but such estimates are time consuming and they potentially harm fish. Recent research has indicated that a single electrofishing pass can provide an index of trout abundance in some streams, but applicable circumstances were not clarified. We sampled 30 stream reaches in northwestern Wyoming to determine if the number of trout captured with a single electrofishing pass could be used to predict trout abundance as estimated by a multiple-pass-removal maximum-likelihood model. Stream width, depth, channel slope, instream cover, and substrate were also assessed to determine their possible influences on the relationship between the number of fish captured with a single pass and multiple-pass estimates. We found that trout samples from a single electrofishing pass accurately indexed the abundance of trout in small mountain streams with little instream cover and low fish densities. The relationship between the number of trout captured with a single pass and a multiple-pass estimate was highly significant ($r^2 = 0.94$) and inclusion of stream width in a multivariate model accounted for additional variance ($R^2 = 0.96$). Single pass samples in small mountain streams with little cover and low trout densities can provide accurate estimates of abundance while circumventing problems of differential capture probabilities on subsequent passes, potential harm to trout, and time in the field. Similar relationships may exist within other geographic areas with homogenous habitat, but preliminary testing is required to determine the relationship between abundance and a single-pass estimate.

The attention given to electrofishing in the scientific literature is a testament to its popularity as a stock assessment technique. Electrofishing is commonly used to assess stream fish abundance and biomass (Moore et al. 1983; Bohlin et al. 1989; Riley and Fausch 1992; Schill and Beland 1995) through either mark–recapture (Peterson and Cederholm 1984) or maximum-likelihood removal (Zippin 1956; Otis et al. 1978) approaches. Consequently, research has focused on the reliability of sampling with electrofishing to estimate population metrics (Cross and Stott 1975; Mahon 1980; Schnute 1983; Habera et al. 1992; Riley and Fausch 1992) and on the effects of electrofishing on sampled fish (Mesa and Schreck 1989; Schill and Beland 1995; Habera et al. 1996; Thompson et al. 1997).

Quantitative assessments of trout in streams are an integral part of both management and research in the Rocky Mountains. Jones and Stockwell (1995) suggested that when an abundance estimate is required and logistical constraints allow (stream size is small enough to isolate with block nets, etc.), a removal method is the most commonly applied and is probably the most appropriate technique. The basic premise of a removal estimate is that multiple electrofishing passes through a stream reach isolated with block nets will result in declining catches with each subsequent pass (until a large portion of the population has been captured) allowing fish abundance to be estimated through maximum-likelihood iterations. Certain stipulations are required for a statistically unbiased estimate, including (1) a closed population, (2) constant fishing effort on all passes, and (3) equal catchability of fish for each capture occasion (see Riley and Fausch 199; Jones and Stockwell 1995). The first two assumptions are relatively easy to accomplish, but the probability of capture may decrease with each pass due to behavioral changes in fish associated with previous exposure to an electric field (Cross and Stott 1975; Bohlin and Sundstrom 1977; Mahon 1980; Riley and Fausch 1992). A minimum of two passes are required for calculation of a removal estimate, but Otis et al. (1978) advocated at least four passes to test the equal catchability assumption.

A time-intensive sampling technique such as

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TABLE 1.—Site characteristics and trout abundant estimates for the 30 Wyoming stream reaches sampled.

Reach	Number of fish sampled on electrofishing pass: 1	2	3	Population estimate	Density (fish/m^2)	Probability of capture	Mean wetted width (m)	Mean thalweg depth (cm)	Channel slope (%)	Boulder substrate (%)	Cover (%)
Anderson	6	2	1	9	0.017	0.69	5.2	32	2.0	25	20
Brown	16	4	0	20	0.079	0.83	2.5	14	3.6	40	4
Chimney	13	1	0	14	0.043	0.93	3.2	24	4.0	10	16
Clocktower	7	3	2	12	0.022	0.62	5.4	39	7.9	26	15
Cow[a]	2	4	4	12	0.030	0.35	4.1	17	3.0	10	9
Deer	3	0	0	3	0.014	0.99	2.1	14	4.0	0	1
Dundee	1	1	0	2	0.007	0.67	2.9	18	9.9	40	30
Eleanor	14	4	0	18	0.054	0.82	3.4	18	2.4	15	5
Francs Fork	13	5	2	20	0.039	0.68	5.2	26	3.4	10	17
Goff	4	0	0	4	0.015	0.99	2.6	39	8.1	6	19
Greybull 1	21	5	4	31	0.020	0.67	15.8	40	1.0	5	20
Greybull 2	1	0	0	1	0.002	0.99	4.9	31	4.0	30	2
Gunbarrel	19	2	1	22	0.033	0.85	6.7	55	5.0	18	19
Jack	18	5	0	23	0.053	0.82	4.3	33	7.8	50	20
Kitty	10	4	0	14	0.028	0.78	5.1	47	8.3	35	27
Lodgepole	35	4	0	39	0.113	0.91	3.5	26	5.5	8	38
Marquette	44	5	1	50	0.426	0.88	1.2	42	1.4	0	20
MF Wood	11	2	1	14	0.035	0.78	4.0	33	2.0	5	5
Moss	12	1	0	13	0.037	0.93	3.5	31	5.3	11	46
Newton	5	0	0	5	0.028	0.99	1.8	15	5.1	10	12
Oliver Gulch	2	0	0	2	0.013	0.99	1.5	17	5.1	22	16
Pagoda	11	0	0	11	0.085	0.99	1.3	15	6.6	10	9
Pickett[a]	5	2	2	9	0.019	0.60	4.7	14	1.5	40	1
Piney	5	0	0	5	0.015	0.99	3.4	28	5.4	10	22
SF Wood	30	9	2	41	0.064	0.76	6.4	31	1.0	25	25
Sheep	16	2	1	19	0.073	0.83	2.6	20	5.5	8	13
Venus	7	0	0	7	0.017	0.99	4.1	49	4.0	20	7
Warhouse	14	0	1	15	0.066	0.88	2.2	18	7.8	60	17
Wood	37	13	5	57	0.049	0.66	11.5	48	2.0	30	11
WF Timber	16	7	1	24	0.082	0.73	2.9	17	2.3	5	26

[a] A fourth pass was completed because of poor depletion after three passes. In these cases, the fourth pass resulted in zero captures.

multiple-pass abundance estimation limits the ability of field personnel to assess large areas. The trade-off in time and cost between more precise multiple-pass estimates and relatively quick one-pass electrofishing samples argues for a simpler, less-costly method of enumerating stream fish populations. Strange et al. (1989) and Jones and Stockwell (1995) found that a single electrofishing pass could be used to predict three-pass abundance estimates, but accuracy varied among streams. Several conditions may influence the accuracy of one-pass samples as an index of multiple-pass abundance estimates. These conditions include the confounding effects of instream cover (Peterson and Cederholm 1984; Thompson and Rahel 1996), stream size (Habera et al. 1992), the potential for higher escapement of smaller fish on the first pass when attention is focused on larger fish (Mahon 1980), and unequal catchability of fish among passes (Riley and Fausch 1992). Thus, one-pass electrofishing samples may be unreliable in streams with complex habitat, but the benefit of such an index is obvious and warrants exploration. Potential for a simplified, one-pass electrofishing sample to index trout population abundance probably occurs in streams that are relatively small (e.g., <8 m wide) with little instream habitat and low fish densities. These features allow a large proportion of the population to be captured with a single electrofishing pass.

Our intent was to determine if a single electrofishing pass could accurately predict multiple-pass-depletion abundance estimates of cutthroat trout *Oncorhynchus clarki*, rainbow trout *O. mykiss*, brown trout *Salmo trutta*, and brook trout *Salvelinus fontinalis* in small mountain streams over a large area of northwestern Wyoming. Measures of stream size and instream cover were obtained to determine their potential influences on the relationship as well as on estimated capture probabilities.

Methods

We sampled 30 reaches on tributaries to the Greybull, Shoshone, and Clarks Fork rivers in northwestern Wyoming (see Table 1 for reach characteristics). These tributaries drain the Absaroka volcanic field, which is geologically young and highly erosive (Minshall and Brock 1991). The tributaries were generally high-elevation streams with steep longitudinal profiles and large, angular, unstable rock substrates.

Multiple-pass electrofishing depletions (Moore et al. 1983; Strange et al. 1989; Riley and Fausch 1992) were conducted with a Smith-Root model 12 backpack electrofisher (400–600 V DC). Three or four electrofishing passes were made through each 100-m stream reach enclosed with block nets (1.5-cm mesh). If the stream was narrow enough to reach bank to bank with the capture net, a single netter was deployed; otherwise two netters were used to more efficiently collect fish. After each pass, fish were counted, measured (length, mm), and released downstream of the reach. To maintain consistency between sites, age-0 fish (<60 mm) were not included in the estimates because sampling took place both before and after emergence. At least 20 min elapsed between each pass to allow suspended sediments to settle and remaining fish to return to normal activity. Stream width (nearest 0.1 m) and thalweg depth (cm) were measured at five transects equally spaced through each study reach. The proportion of the substrate composed of bedrock, boulder, rubble, gravel, or sand–silt was visually estimated at each transect, but only boulder substrate was used as a variable in the regression analysis because the substrate categories were significantly correlated. The proportion of water surface area with instream cover was measured following Binns and Eiserman (1979) and classified as dam pools, plunge pools, scour pools, large woody debris, undercut banks, and aquatic or overhanging terrestrial vegetation (Bisson et al. 1982). Channel slope (%) through each reach was estimated with a clinometer.

Maximum-likelihood estimates of trout abundance were made using model $M_{(b)}$ (Zippin estimator, Zippin 1956; Otis et al. 1978) of the program CAPTURE (White et al. 1982), which calculates (and assumes) constant capture probability for all electrofishing passes. Trout densities (age 1+) were calculated based on the estimated number of trout and water surface area in each reach. Simple-linear- and multiple-regression analyses (Neter et al. 1989) were used to assess relationships among one-pass samples and multiple-pass abundance estimates, stream habitat variables, and the probability of capture. Analyses were performed using SPSS/PC+ for Windows version 6.1 (SPSS 1994). Significance was determined at $P \leq 0.05$ for all tests.

Results

Trout population estimates in 100-m reaches ranged from 1 fish in the upper Greybull River to 57 fish in the Wood River (Table 1). Densities were lowest in the upper Greybull River (0.002/m^2) and highest in Marquette Creek (0.426/m^2). Fish were predominately cutthroat trout, rainbow trout, and hybrids of these two species; however, brown trout predominated in one reach and several others had brook trout present. The number of fish caught with a single pass was significantly related to the corresponding multiple-pass estimate ($P < 0.001$, $r^2 = 0.94$; Figure 1; Table 2). Stream width was significantly ($P = 0.015$, $r^2 = 0.19$) related to multiple-pass estimates and together with the number caught on the first pass accounted for additional variation in multiple-pass estimates ($R^2 = 0.96$). Thalweg depth and channel slope each accounted significantly for variation in estimated abundance (Table 3), but neither was significant in a multiple-regression model. Densities computed from first-pass samples were strongly related to the multiple-pass density estimates ($P < 0.001$, $r^2 = 0.99$), but other stream variables did not account for additional variation (Tables 2 and 3). Removal of the highest density observation (see Figure 1, middle panel) reduced the relationship slightly ($P < 0.001$, $r^2 = 0.93$; Table 2).

Estimated constant capture probabilities (Table 1) were high (mean = 0.82) with only one value less than 0.60. Among the measured stream attributes, only stream width had a significant (negative) relation to capture probability ($P = 0.017$, $r^2 = 0.19$; Tables 2 and 3).

Discussion

Several researchers have shown that a one-pass electrofishing sample does not provide a reliable index of fish abundance in streams due to differential catchability of length-classes among multiple passes (more large fish on first pass, Mahon 1980), changing capture probabilities among passes due to behavioral avoidance (Bohlin and Sundstrom 1977; Schnute 1983; Bohlin et al. 1989; Riley and Fausch 1992), or variation in stream size or instream cover (Kennedy and Strange 1981; Peterson and Cederholm 1984; Habera et al. 1992; Thompson and Rahel 1996). However, we observed that in small mountain streams having limited instream cover (defined as absence of undercut banks, instream vegetation, or woody debris) and

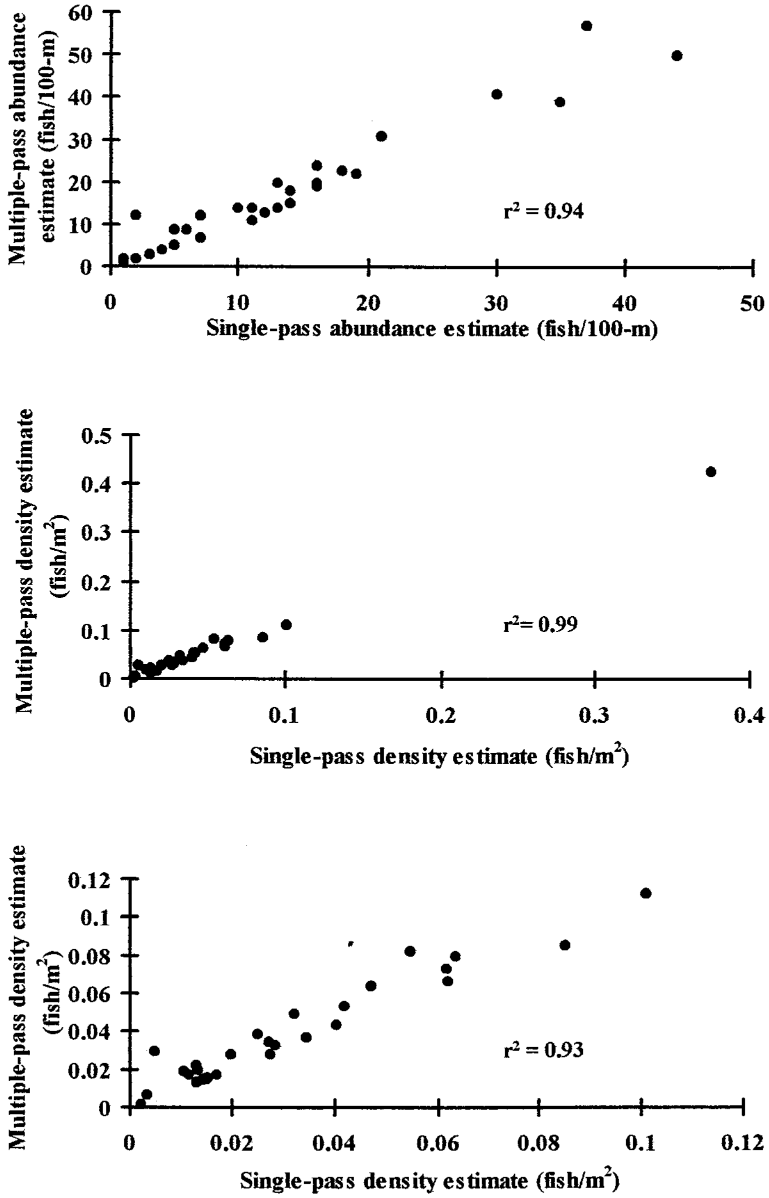

FIGURE 1.—Relationships between single-pass and multiple-pass estimates of trout abundance (upper panel) and density (middle panel) for 30 stream reaches in northwestern Wyoming. The density relationship after removal of the influential observation is shown in the lower panel (N = 29).

low trout densities (see Table 1), one electrofishing pass can provide an accurate index of trout (age 1+) abundance. The study streams were typical of those draining the Absaroka volcanic field, being relatively homogenous over each reach with cover occurring predominately as boulder pools. A major difference between this and previous studies was the lack of sampling interference from instream and streamside vegetation or woody debris in our study streams. Trout cover was predominantly boulder pools (>85% total cover), and categories expected to influence capture ability and population estimates, such as undercut banks, vegetation, and woody debris (Thompson and Rahel 1996), were limited. In fact, capture ability was enhanced by the boulder pools, which concentrated fish in

TABLE 2.—Regression equations relating one-pass abundance and density to multiple-pass estimates, including significant stream attributes, where MULTIPLE = multiple-pass abundance estimate, PASS1 = one-pass abundance estimate, WIDTH = wetted stream width, MULDENS = multiple-pass density estimate, DENS1 = one-pass density estimate, and PROBCAP = probability of capture. Regression results with the outlier (highest-density site) removed are shown in the second MULDENS equation.

Equation	SE	r^2 or R^2	P
MULTIPLE = 0.683 + 1.245·PASS1	3.613	0.94	<0.0001
MULTIPLE = −1.863 + 1.181·PASS1 + 0.797·WIDTH	2.835	0.96	<0.0001
MULDENS = 0.004 + 1.120·DENS1	0.007	0.99	<0.0001
MULDENS = 0.005 + 1.077·DENS1	0.007	0.93	<0.0001
PROBCAP = 0.920 − 0.023·WIDTH	0.146	0.19	0.017

small areas through the reaches. Strange et al. (1989; $r^2 = 0.52$ for trout and $r^2 = 0.78$ for salmon), Lobon-Cervia and Utrilla (1993; $r^2 = 0.67$ for trout), and Jones and Stockwell (1995; $r^2 = 0.76$–0.86 for trout including age-0 individuals) found significant but lower coefficients of determination for relationships between one-pass samples and multiple-pass abundance estimates of stream salmonids (age 1+) over a wide variety of stream conditions. While these one-pass assessments indicated the potential to predict abundance, none approached the predictability we observed. However, the habitat complexity and density of fish appeared to be greater in the other studies. Strange et al. (1989) and Lobon-Cervia and Utrilla (1993) may also have compromised their results by using only one netter, increasing the possibility of escapement on the initial electrofishing pass. Jones and Stockwell (1995), who had the highest correlation between single- and multiple-pass estimates, employed multiple netters.

We sampled some streams before emergence of age-0 fish, excluding them from capture and subsequent analysis. Upon emergence, age-0 fish were extremely difficult to capture in the swift water among large substrate, so capture efficiency was quite variable. Additionally, we wanted to limit exposure of these fish to electric shock and handling stress. Due to these constraints, we limited our analysis to age-1+ fish and made comparisons to values in the previous literature only where age-0 fish were excluded.

We hypothesized that stream size and instream cover would affect the ability to predict multiple-pass estimates of abundance from single-pass electrofishing data, but the single-pass data predicted abundance and density so well that stream attributes were not necessary to strengthen the relationship. Similar to Riley and Fausch (1992) but contrary to Peterson and Cederholm (1984), instream cover did not negatively affect our abundance estimates, probably because instream cover and habitat complexity in our study streams were low and actually enhanced capture efficiency. Stream attributes (width, depth, channel slope) were univariately related to estimated fish abundance, and stream width significantly explained additional variation when combined with the one-pass index in a multiple-regression equation. However, no stream attribute was significantly related to fish density. This metric includes stream width in its computation, thus we would not expect width to provide more explanatory power in a multivariate setting. Indeed, the abundance equation containing both the one-pass sample and stream width variables predicted abundance with a coefficient of determination of 0.96, whereas the equation predicting estimated density with only the one-pass density index had a coefficient of determination of 0.99—very similar levels of prediction.

TABLE 3.—Correlations between stream attributes and capture probability, abundance, and density estimates.

	Probability of capture		Multiple-pass population estimate		Multiple-pass density estimate	
Variable	r	P	r	P	r	P
Width (m)	−0.43	0.017	0.44	0.015	−0.24	0.200
Depth (cm)	−0.01	0.954	0.37	0.043	0.11	0.572
Slope (%)	0.26	0.174	−0.43	0.017	−0.24	0.198
Boulder (%)	−0.18	0.356	−0.07	0.700	−0.23	0.228
Cover (%)	0.02	0.912	0.24	0.203	0.14	0.475

The model we used to estimate trout abundance ($M_{(b)}$) calculated a constant capture probability for all passes, thus we could not test for differences in capture probability among passes. However, our mean probability of capture was 0.82, indicating high capture efficiency. Riley and Fausch (1992) mentioned that with high capture probabilities (approaching 0.90) field biologists can become falsely confident in the precision of depletion estimates because high capture probabilities may be the result of reduced catchability on second or third passes due to behavioral avoidance, not depletion of the stock. Because time was allowed between passes and many depletions resulted in zero captures on the second or third passes, we believe our capture probabilities were not inflated by behavioral avoidance. However, as would be expected, our capture probabilities were influenced by stream width (similar to Habera et al. 1992). No other stream variable seemed to affect catch efficiency, probably due to the low habitat complexity among the study streams.

In our study streams with limited cover and low densities of trout, a one-pass sample provided a precise index of trout (age-1+) abundance. Consequently, one pass electrofishing in such streams allows reduced field effort while limiting potential harmful impacts of electrofishing and handling on the trout. We recommend this approach for watershed-scale assessments of trout populations but caution its use if rigorous comparisons are needed to detect small changes in trout abundance. This approach has potential for other watershed or geographic areas with simple habitat structure, but a preliminary analysis may be required to assess the relationship between single- and multiple-pass abundance estimates.

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