North American Journal of Fisheries Management 37:189–195, 2017

ISSN: 0275-5947 print / 1548-8675 online
DOI: 10.1080/02755947.2016.1254128

MANAGEMENT BRIEF

Gear Comparison for Sampling Age-0 Mountain Whitefish in the Madison River, Montana

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Abstract
The efficacy of various sampling gears for age-0 Mountain Whitefish *Prosopium williamsoni* is largely unknown, which makes it difficult to investigate recruitment and early life history dynamics for the species. We compared four gears: seine, backpack electrofisher, minnow trap, and lighted minnow trap. Gears were tested in backwaters, large channels, and small channels in the Madison River, Montana. No age-0 Mountain Whitefish were captured in minnow traps or lighted minnow traps. Mean CPUE of age-0 Mountain Whitefish was higher for seining (0.18 fish/m^2; SD, 0.39) than for electrofishing (0.01 fish/m^2; SD, 0.03), and the CV was lower for seining. A broader length distribution was sampled by seining (17–41 mm) than with electrofishing (21–36 mm). Age-0 Mountain Whitefish CPUE in seines was highest in backwaters. In channel sites, Mountain Whitefish presence was associated with areas of still or slow water ≥2 m^2. Relative to the other sampling gears we evaluated, seining was the most efficient gear for sampling age-0 Mountain Whitefish in a lotic ecosystem.

Mountain Whitefish *Prosopium williamsoni* is a salmonid native to coldwater lakes and fourth- to seventh-order streams throughout large portions of the western United States and Canada (Brown 1971; Scott and Crossman 1973; Meyer et al. 2009). In the past decade, declines in Mountain Whitefish abundance have been reported in the Madison River, Montana, and in other rivers throughout the southern portion of their range (IDFG 2007; P. Clancey, Montana Fish, Wildlife and Parks, G. Edwards, Wyoming Fish and Game, and K. Rogers, Colorado Wildlife and Parks, personal communications). Studies on Mountain Whitefish ecology are needed to investigate these declines and identify possible limiting factors. Investigating the ecology of juvenile fish is an important component, as fish populations are often limited by bottlenecks occurring early in life (Bradford and Cabana 1997; Myers 2002).

It is difficult to investigate recruitment and early life history dynamics for Mountain Whitefish because the most efficient methods for sampling age-0 fish are not known for this species.

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Received June 19, 2016; accepted October 20, 2016

The American Fisheries Society has standardized sampling guidelines organized by water body (e.g., wadeable streams, large rivers, ponds, or lakes) and fish assemblage type (e.g., coldwater or warmwater: Bonar et al. 2009). However, the efficiency of a sampling technique also depends on factors including fish size, behavior, habitat use, and swimming ability, which can vary among species and life stages. Gear comparison studies provide information on efficiency, size selectivity, and ease of deployment of various gears and assist biologists in selecting appropriate gears for sampling a target species. Understanding the gear or gears that are most efficient (i.e., highest CPUE and lowest variability) at sampling age-0 Mountain Whitefish is necessary to design cost-effective and informative studies. Age-0 Mountain Whitefish have been sampled using seines (Brown 1952), backpack electrofishing (Stalnaker and Gresswell 1974), and dip nets (Pettit and Wallace 1975; Pierce et al. 2012). These methods successfully collected fish for growth, diet, and disease studies, but the relative efficiency of these gears has not been compared.

Understanding the habitat types that are associated with age-0 Mountain Whitefish is also necessary to design cost-effective and informative studies. Age-0 Mountain Whitefish have typically been sampled in protected habitats, including backwaters and low-velocity areas behind boulders (Brown 1952; Pettit and Wallace 1975; Davies and Thompson 1976). However, past sampling efforts for age-0 fish have neither randomly selected sampling sites nor compared CPUE among habitat types. A study comparing different gears in various habitat types would provide information on the relative efficiency of sampling gears and inform sampling designs for future studies on age-0 Mountain Whitefish.

Our primary objective was to determine the most appropriate sampling gear for age-0 Mountain Whitefish in the Madison River and similar lotic habitats. We compared four gears: seine, backpack electrofisher, minnow trap, and lighted minnow trap. Specifically, our objectives were to evaluate CPUE (fish/m^2) of age-0 Mountain Whitefish among sampling gears, assess variation in CPUE among gears, and relate habitat type to CPUE. We predicted that backpack electrofishing would have higher CPUE and lower variance for sampling age-0 Mountain Whitefish compared with seining, minnow traps, or lighted minnow traps. All selected gears can effectively sample age-0 fish (Kelso and Rutherford 1996), but electrofishing typically has high salmonid CPUE in streams with coarse substrate. Finally, we predicted that CPUE would be higher in small side channels and backwaters with lower water velocity than in main channels because age-0 Mountain Whitefish were typically found in protected habitats in other river systems (Brown 1952; Pettit and Wallace 1975; Davies and Thompson 1976).

METHODS

*Study area.—*The Madison River is formed at the confluence of the Firehole and Gibbon rivers in Yellowstone National Park, Wyoming, and flows north 195 km to Three Forks, Montana, where its confluence with the Gallatin and Jefferson rivers forms the Missouri River. The study area was between Varney Bridge and Ennis Lake, a distance of 23.5 km (Figure 1). This reach was selected because a movement study of Mountain Whitefish between Hebgen Dam and Madison Dam, a distance of 101 km, showed that during autumn spawning, the highest densities of adult Mountain Whitefish were found near Varney Bridge (Boyer 2016), and thus the reach downstream from Varney Bridge probably had the highest densities of age-0 Mountain Whitefish. Within the study site, the river is braided and has numerous side channels, backwaters, and pools. Discharge is regulated by Hebgen Dam, located approximately 73 km upstream from Varney Bridge. Mean daily discharge in this reach is 24–39 m^3/s during base flow and peaks between 60 and 175 m^3/s during spring runoff (2011–2014: USGS 2015).

*Gear comparison.—*Seining, backpack electrofishing, minnow traps, and lighted minnow traps were tested in wadeable habitat in the Madison River between Varney Bridge and Ennis Lake (Figure 1). A randomized block design, stratified by habitat type, was used to select sampling sites and assign gears to sites. We selected a blocked design that allowed us to compare CPUE among nearby sites sampled with different gears to control for possible large-scale spatial variation in age-0 Mountain Whitefish density (i.e., higher densities near spawning areas or near lake inlets). Prior to field sampling, aerial maps were used to identify three habitat strata: backwaters, large channels (≥18 m wide), and small channels (≤6 m wide). Channels that were 6–18 m wide were excluded from sampling to ensure a clear difference between large and small channel habitat types. Blocks of habitat were delineated in each habitat strata such that within a block each of the four gears could be tested at one of four sampling sites. Channel blocks were continuous reaches. Backwater blocks were four adjacent backwaters because not all sampling gears could be evaluated in a single backwater given the small size of most backwaters (Figure 2, panel A). Random sampling, stratified by habitat type, was used to select blocks (total n = 23; backwater, n = 8; large channel, n = 8; small channel, n = 7) for gear evaluation.

Four sampling sites were delineated in each selected block (Figure 2, panel B). Sampling sites were typically 50 m in length (backwater, 50 m closest to channel; large channel, 50 m of wadeable habitat along one bank; small channel, 50 m of channel) except in backwaters less than 50 m in length, where the entire backwater was sampled. Within each block, each of the four gears was randomly assigned to one of the four sites.

Gears were tested between May 15 and June 4, 2013. All sampling was conducted by the same two-person crew to control for variable sampling efficiency among crews. Seined sites were sampled using a 3 × 1.5 m beach seine with 1.6-mm bar mesh (Leslie et al. 1983; Rabeni et al. 2009). The seine was used to sample all area in the site that could be effectively seined. Electrofished sites were sampled in one continuous transect moving upstream using a backpack electrofisher (Halltech HT-2000), and fish were captured in a single pass using two dip nets with 1.6-mm bar mesh (Dunham et al. 2009). Voltage and

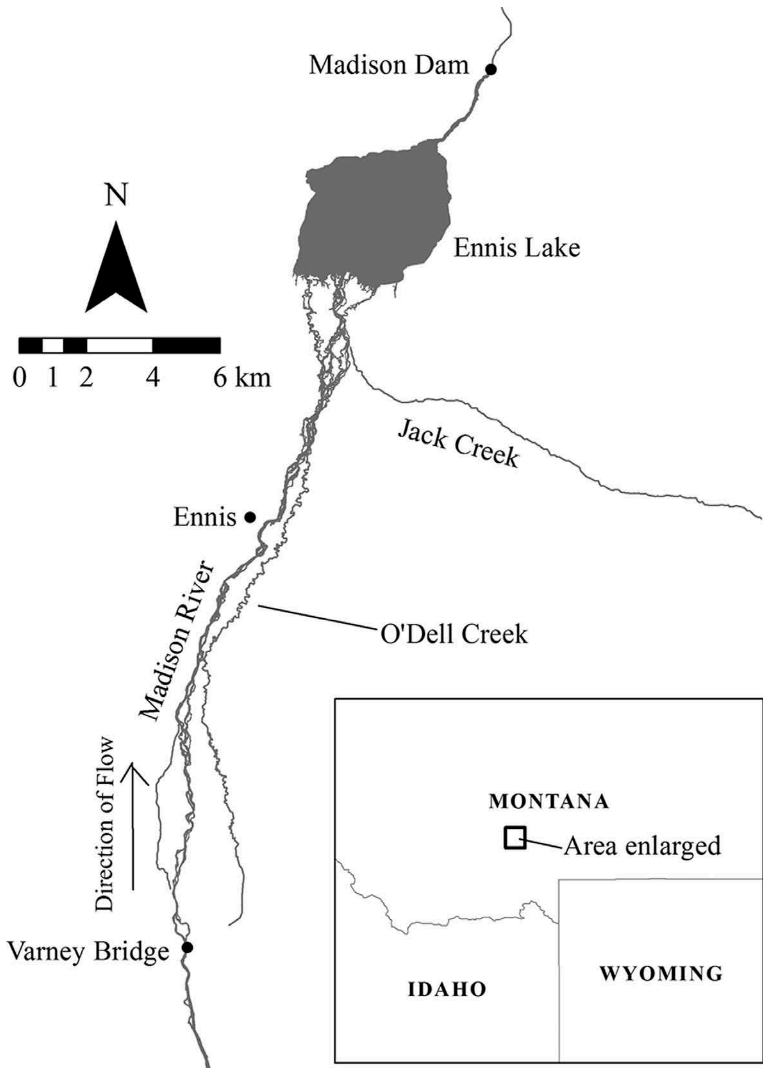

FIGURE 1. Sampling was conducted in the Madison River, Montana, between Varney Bridge and Ennis Lake, a distance of 23.5 km.

frequency were adjusted based on water conductivity and temperature to standardize power at 300–450 W (Burkhardt and Gutreuter 1995; Dunham et al. 2009). During this study, water temperature was 7.4–15.8°C and conductivity was 205–310 µS/cm; thus, voltages from 150 to 350 V and frequencies of 60 or 80 Hz were used to standardize power. We electrofished within 3 m of shore, similar to the area sampled by the seine. Sampled length (±0.5 m) and width (±0.5 m) were recorded for seined and electrofished sites, and area sampled (m^2) was calculated for each site. Minnow traps and lighted minnow traps were 46 × 25 × 25 cm (2-mm bar mesh) with two 40-mm entrances. A 24-h chemical glow stick that measured 10 × 1 cm was placed inside each lighted minnow trap. Three traps per sampling site were set and removed the following day. All fish captured were identified to species. All Mountain Whitefish were measured to the nearest millimeter TL. Start and end times of sampling (excluding fish processing) were recorded.

Water velocity (fast, >1.0 m/s; moderate, 0.6–1.0 m/s; slow, <0.6 m/s) was visually estimated at each sampled site. In blind tests paired with velocity measurements (orange float method: Gordon et al. 1997), 94% of our visual velocity estimates ($n = 66$) were correct. Presence or absence of slow water (water velocity < 0.6 m/s) areas ≥2 m^2 within a site was estimated visually in order to record the presence of small slow-water habitats, such as eddies, within channel units with predominantly moderate- or fast-velocity habitat.

Age-0 Mountain Whitefish catch was calculated for each site. All statistical comparisons were between seining and electrofishing because no Mountain Whitefish were captured in minnow traps or lighted minnow traps. We calculated CPUE to standardize catch data between gears using area sampled (m^2) as a unit of effort. Catch per unit effort is commonly used to describe the relative abundance of fish populations and can be problematic as a measure of abundance if catchability varies with density

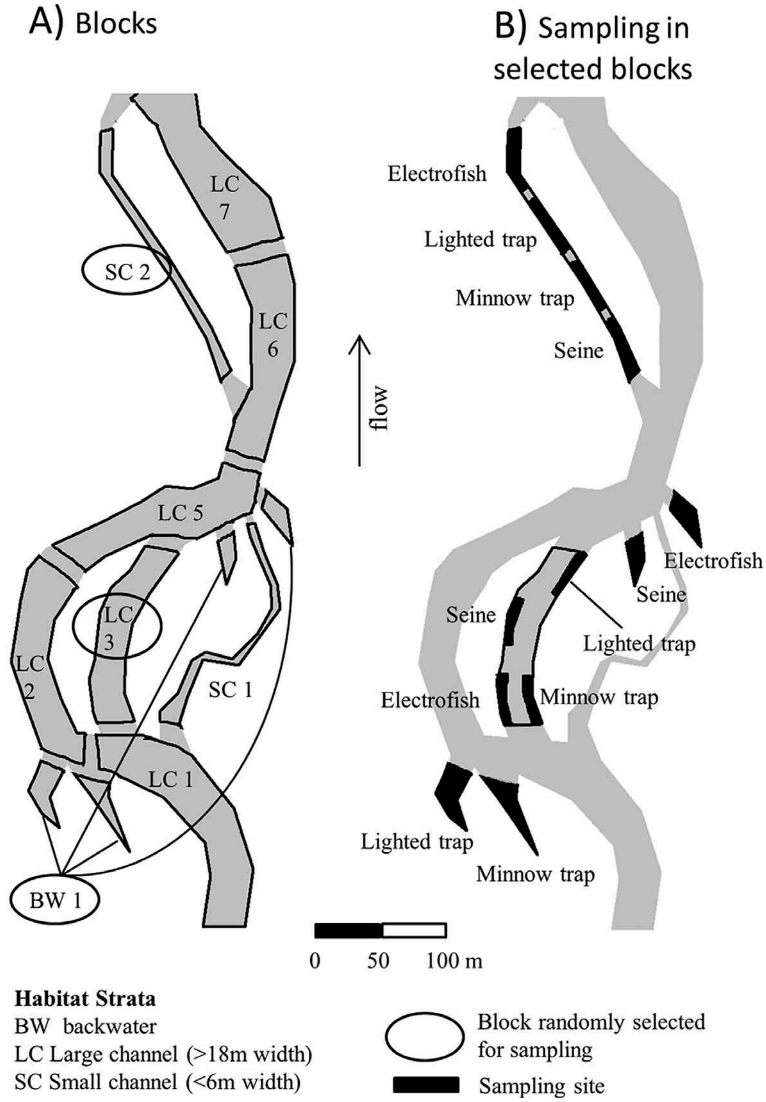

FIGURE 2. Schematic illustrating **(A)** delineation of blocks and **(B)** sampling sites within randomly selected blocks. Blocks were defined as four adjacent backwaters, 200-m reaches in large channels, and 250-m reaches in small channels. Four sampling sites were located in each block, and all four gears were tested in each block, and gear was assigned randomly to sampling site.

(Hubert and Fabrizio 2007). Nevertheless, indices such as CPUE can be useful given varying catchability (i.e., among different habitat types) if catchability varies less than the actual density (Johnson 2008). We selected CPUE because marking age-0 Mountain Whitefish for a traditional population estimate would be logistically challenging, variation in catchability is probably less than variation in density, and CPUE is a commonly used, easy metric to estimate.

Catch-per-unit-effort data for age-0 Mountain Whitefish were not normally distributed. Log and square-root transformations did not normalize the distribution of CPUE data for age-0 fish. We used a paired Wilcoxon signed-rank test, appropriate for nonparametric data, to test the null hypothesis that there was no difference in CPUE among paired (in the same block), seined, and electrofished sites. Coefficient of variation (100·SD/mean) for CPUE was calculated for seined and electrofished sites. Length distributions of age-0 Mountain Whitefish captured with seining and electrofishing were compared using a Kolmogorov–Smirnov test. Differences in sampling time between paired seined and electrofished sites were normally distributed; thus, a paired *t*-test was used to test for differences in time to sample between gears. A Kruskal–Wallis test was used to test whether age-0 Mountain Whitefish CPUE differed among backwaters, large channels, and small channels at seined sites.

TABLE 1. Descriptive statistics of age-0 Mountain Whitefish CPUE by seine and backpack electrofishing gears in the Madison River, Montana.

	CPUE (fish/m^2)	
Statistic	Seine	Electrofishing
Mean	0.18	0.01
SD	0.39	0.03
CV (%)	217	269
Median	0.00	0.00
Minimum	0.00	0.00
Maximum	1.75	0.11

RESULTS

A total of 546 age-0 Mountain Whitefish were sampled; 496 were sampled with the seine (area sampled = 3,995 m^2) and 50 with backpack electrofishing (area sampled = 4,520 m^2). No age-0 Mountain Whitefish were captured in minnow traps or lighted minnow traps. For age-0 fish, CPUE was significantly higher at seined sites (mean, 0.18 fish/m^2; SD, 0.39) than at electrofished sites (mean, 0.01 fish/m^2; SD, 0.03) (paired Wilcoxon signed rank test: V = 108, P = 0.007), and the CV was lower for seining (217%) than for electrofishing (269%; Table 1). Seining captured 0.17 additional age-0 Mountain Whitefish per square meter (95% CI, 0.00–0.36) than electrofishing in the same block. Mean TL of age-0 Mountain Whitefish was similar for both gears (seine, 31 mm; electrofishing, 29 mm). However, length-frequency distributions of captured age-0 Mountain Whitefish differed between gears (Kolmogorov—Smirnov test: D = 0.257, P = 0.005). Greater variation in length of age-0 Mountain Whitefish was observed in samples from seining (17–41 mm) compared with electrofishing (21–36 mm; Figure 3).

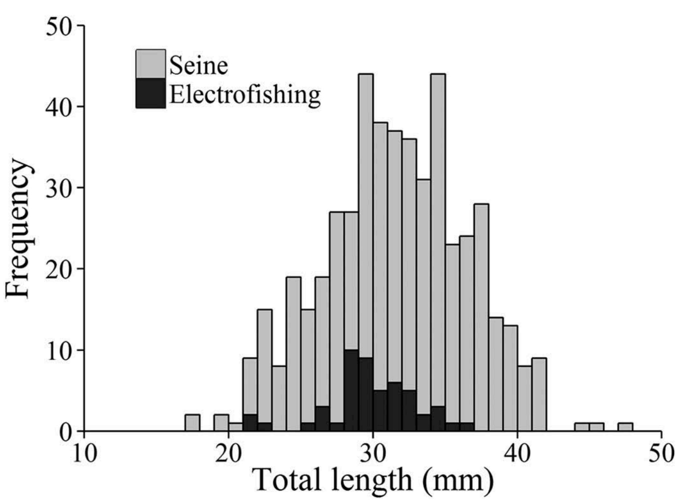

FIGURE 3. Length-frequency histogram (bin size = 1 mm) of age-0 Mountain Whitefish captured by seining and electrofishing in the Madison River, Montana, in May and June 2013.

TABLE 2. Descriptive statistics of age-0 Mountain Whitefish CPUE in the Madison River, Montana, by habitat type (backwater; large channel, ≥18 m width; small channel, ≤6 m width) and sampling gear.

Habitat type	Mean CPUE (fish/m^2)	SD	Sampling effort (m^2)
Seine			
Backwater	0.37	0.58	1,470
Large channel	0.05	0.10	1,200
Small channel	0.10	0.30	1,325
Electrofishing			
Backwater	0.01	0.04	1,770
Large channel	0.01	0.03	1,200
Small channel	0.002	0.004	1,550

Sampling a site with a seine was significantly faster than with a backpack electrofisher (paired t-test: $t = -7.56$, df = 22, P < 0.0001). Mean time required for a two-person crew to seine a site was 13 min (range, 5–28 min), and mean time to electrofish a site was 36 min (range, 12–63 min).

Mean seine CPUE was 0.37 fish/m^2 in backwaters, 0.05 fish/m^2 in large channels, and 0.10 fish/m^2 in small channels (Table 2). We did not detect differences in CPUE among habitat types (Kruskal–Wallis test: H = 4.12, df = 2, P = 0.13). However, one outlier, a small channel characterized by habitat more typically observed in backwaters (silt substrate, still water) than in other small channels (coarse substrate, higher water velocities), heavily influenced mean CPUE in small channels. When the outlier was removed small channels had lower CPUE (0.002 fish/m^2) than large channels, and there was a difference in CPUE among habitat types (Kruskal–Wallis test: H = 6.94, df = 2, P = 0.03). Age-0 Mountain Whitefish presence was associated with areas of still or slow water ≥2 m^2. All age-0 Mountain Whitefish captured by seining (n = 496) and 92% (46 of 50) of age-0 Mountain Whitefish captured with electrofishing were captured at sites with slow-water habitat. Seine CPUE was highest in backwaters, and in large and small channels, mean seine CPUE was 0.09 fish/m^2 at sites with low-velocity habitat and 0.00 fish/m^2 at sites without this habitat type. Similarly, electrofishing CPUE was 0.01 fish/m^2 at channel sites with low-velocity habitat and 0.003 fish/m^2 at sites without this habitat type (Table 3).

DISCUSSION

We recommend that seining be used for future sampling of recently hatched age-0 Mountain Whitefish (1–3 months posthatch spring sampling). Seines yielded the highest CPUE with the lowest CV of the gears tested, captured the greatest size range of age-0 Mountain Whitefish, and were the fastest sampling gear to deploy. Backpack electrofishing also captured age-0 Mountain Whitefish but required more time and yielded lower CPUE. Minnow traps and lighted minnow traps did not capture any Mountain Whitefish.

Seines probably were the most effective gear tested because age-0 Mountain Whitefish inhabited slow velocity, structurally

TABLE 3. Age-0 Mountain Whitefish CPUE in channel sites in the Madison River, Montana, by presence or absence of areas of slow water ≥2 m^2 and sampling gear.

Slow-water areas ≥2 m^2	Mean CPUE (fish/m^2)	SD
	Seine	
Present	0.09	0.20
Absent	0.00	0.00
	Electrofishing	
Present	0.01	0.03
Absent	0.003	0.005

simple areas in May and June. Capture locations for age-0 fish, as well as visual observations, demonstrated that age-0 Mountain Whitefish typically inhabited open habitats with fine substrates, limited cover, and slow water velocities. In addition, age-0 Mountain Whitefish were observed schooling in open water. Seines are highly effective at sampling schooling midwater fishes (Lyons 1986; Lapointe et al. 2006) in shallow (<1 m) areas with limited structural complexity and silt, sand, and gravel substrates (Leslie et al. 1983; Rabeni et al. 2009). Seines are less efficient in areas with cover (e.g., submerged logs, coarse substrate) or fast water velocities (Holland-Bartels and Dewey 1997), but age-0 Mountain Whitefish were rare in these areas. We rarely detected age-0 Mountain Whitefish in the above areas with electrofishing, which is effective at capturing fish in structurally complex or high-velocity habitat (Wiley and Tsai 1983; Dunham et al. 2009). Additionally, seines are effective in the variable river conditions driven by spring snowmelt that exist during the early life of Mountain Whitefish (April–June). Seines are not influenced by water conductivity, a factor that heavily influences electrofishing efficiency (Burkhardt and Gutreuter 1995). Similarly, high turbidity can decrease electrofishing catches but can increase the efficiency of seines because low light limits net avoidance behavior (Glass and Wardle 1989).

Seining captured a wider length range of age-0 Mountain Whitefish than did electrofishing, including small (16–21 mm) fish that were difficult to see and net when electrofishing, and also captured the largest age-0 Mountain Whitefish observed during this study (47 mm TL). Thus, seines are an appropriate gear for sampling age-0 Mountain Whitefish up to at least 2–3 months posthatch (June). Seine efficiency would likely decrease in late summer, as larger fish may have sufficient swimming ability to escape from a pulled net (Wiley and Tsai 1983; Hayes 1989; Van Den Avyle et al. 1995) and because of shifting habitat preferences. In late summer and autumn, age-0 Mountain Whitefish move to deep pools and channel habitats with high water velocities (Brown 1952; Davies and Thompson 1976). Thus, a different sampling gear would likely be more effective for autumn sampling targeting older age-0 fish.

Prior to this study, we predicted that electrofishing would be the most effective sampling method. Electrofishing is an efficient method for sampling age-0 trout in coldwater streams (Dunham et al. 2009), and we targeted another salmonid with a similar body shape. However, seining was more efficient at capturing age-0 Mountain Whitefish in spring because of different behavior and habitat use. Seining is a standard technique for sampling fishes in warmwater, wadeable streams (Rabeni et al. 2009), but the standard techniques used for sampling small fishes in coldwater streams are typically electrofishing and snorkel surveys (Dunham et al. 2009), methods optimized for sampling trout and salmon. This study illustrates the importance of evaluating sampling methods when little is known about a species or life stage and the habitat it occupies.

ACKNOWLEDGMENTS

We thank Patrick Luckenbill for assistance with field work. Pat Clancey, Travis Lohrenz, and Kevin Hughes of Montana Fish, Wildlife and Parks provided advice on study design and assisted with field logistics. Richard Lessner and Dave Bricker at the Madison River Foundation helped to secure funding. The Channels Ranch provided river access. Funding was provided by the Madison River Foundation, Cross Charitable Foundation, PPL Montana (now NorthWestern Energy), and Montana Fish, Wildlife and Parks. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. This study was performed under the auspices of Montana State University institutional animal care and use protocol 2012-00.

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