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1991
Journal Article WWRC-91-03

In

North American Journal of Fisheries Management

Volume 11

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North American Journal of Fisheries Management 11:347–351, 1991

Field Comparison of Three Devices Used to Sample Substrate in Small Streams

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Abstract.—We conducted a field study to compare the composition of substrate samples collected from small streams with three types of samplers: an excavated-core sampler, a single-probe freeze-core sampler, and a shovel. Large particles (>50 mm in diameter) occurred most frequently in excavated-core samples (76%) and least frequently in freeze-core samples (52%), but they had the greatest influence on overall sample composition when they occurred in freeze-core samples. Excavated-core and shoveled samples did not differ significantly in composition, but freeze-core samples differed significantly from both excavated-core and shoveled samples for some particle sizes. When freeze-core samples were divided into halves, the lower portion contained significantly more fine particles than the upper portion. We concluded that the freeze-core sampler does not produce samples similar to excavated-core samples and is too expensive and cumbersome for routine management applications. Conversely, the shovel produces substrate samples similar to those obtained with an excavated-core sampler, and it is the least expensive and least cumbersome of the samplers. Field biologists should consider the shovel a viable alternative to an excavated-core sampler when sampling streams similar to the ones we studied.

Many studies have been conducted to assess the effect of substrate composition in redds on survival to emergence of salmonid fry (Chapman 1988). Comparison of results among these studies is difficult because of the variety of methods used to sample streambed substrate. Most workers have used some form of excavated-core sampler (McNeil and Ahnell 1964; Reiser and Wesche 1977; Avery 1980; Anderson 1983; Witzel and MacCrimmon 1983), but others have used freeze-core devices (Walkotten 1976; Everest et al. 1980; Platts and Penton 1980; Ottaway et al. 1981; Young et al. 1989) or simply shovels (Hausle and Coble 1976). Although each type of sampling device functions uniquely, it has been assumed that the composition of substrate samples does not differ among devices (Shirazi and Seim 1979). Our objective was to compare three different substrate samplers in terms of sample composition, cost, and field efficiency. The samplers were an excavated-core (EC) sampler, a freeze-core (FC) sampler, and a shovel.

Methods

Five study sites in southeastern Wyoming were sampled during August 1988: (1) Pioneer Canal near Sodergreen Lake, (2) Douglas Creek near Medicine Bow National Forest road 512-F, (3) Douglas Creek downstream from Rob Roy Dam, (4) Douglas Creek upstream from Rob Roy Reservoir, and (5) Muddy Creek near Medicine Bow National Forest road 543. The study sites were intended to represent typical spawning habitats for brook trout *Salvelinus fontinalis* and brown trout *Salmo trutta*. Their substrates consisted primarily of materials smaller than 10 cm in diameter, and the dominant substrate sizes ranged from 0.5 to 5.0 cm in diameter. Study sites had wetted widths of 3–10 m, maximum water depths from 6 to 40 cm, and mean water velocities of 20–80 cm/s. At each site, five transects were selected perpendicular to the flow. Along each transect, three evenly spaced points (0.5 m apart) with similar water depth, velocity, and substrate were identified. Each such point was sampled with a different sampler so that each transect provided a set of samples for paired comparisons. During sampling, notes were

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[2] The Unit is jointly supported by the University of Wyoming, Wyoming Game and Fish Department, and U.S. Fish and Wildlife Service.

made for each sampler on time and labor required, sampling problems, and apparent biases. Sampling depth varied for each sampler and with the occurrence of large rocks in the streambed.

The excavated-core sampler was based on the design of McNeil and Ahnell (1964). The tube (15 cm in diameter, 22 cm long) was worked into the substrate to a target depth of 22 cm. Substrate was scooped by hand from the streambed inside the tube to the holding chamber within the sampler. Samples were poured from the sampler into a 5-L pail and then into a 3.8-L polyethylene bag. After the fine particles had settled for 5–10 min, the surface water was decanted from the bag.

The freeze-core sampler was modified from the design of Walkotten (1976) and Everest et al. (1980). We used a single probe constructed of steel conduit (2.2-cm in outside diameter, 76 cm long) with a solid conical point at the bottom end. The probe was driven into the substrate with a dead-blow hammer to a target depth of 26 cm. A steel ring (15 cm in inside diameter, 8 cm high) was lowered over the probe to the streambed to slow the water velocity at the substrate surface. Carbon dioxide was injected into the probe for 2 min from a 9-kg pressurized cylinder with a hose and manifold assembly similar to that used by Walkotten (1976). The probe and attached frozen substrate were then lifted vertically from the streambed. The substrate sample was thawed in the field with a propane torch and divided into approximately equal upper and lower halves. Each half of the sample was transferred to a 3.8-L polyethylene bag for transport.

The shovel blade (20 cm wide, 24 cm long) was worked vertically into the streambed to a target depth of 20 cm, levered until parallel to the water surface, and gently lifted from the stream. The sample was allowed to drain for a few seconds before it was placed into a 3.8-L polyethylene bag.

In the laboratory, all substrate samples were oven-dried for 3 d at 60°C and then mechanically shaken through a series of 10 Tyler USA standard sieves with mesh openings of 50, 25, 12.5, 9.5, 6.3, 3.4, 1.7, 0.85, 0.42, and 0.21 mm. Each size-fraction retained by a given sieve was weighed to the nearest 0.1 g and reported as a percentage of the total weight of the sample.

The Wilcoxon signed-rank test was used to test the null hypothesis of no difference in substrate composition between paired samples (Zar 1984). We used the Bonferroni procedure to maintain an experiment-wise alpha of 0.10; the alpha for individual comparisons was 0.009 when 11 size-fractions were compared and 0.010 when 10 size-fractions were compared (Neter et al. 1985).

Results

We collected samples with each sampler from five transects at five sites, which yielded 25 samples for paired comparisons. Substrate samples were inconsistent in the occurrence of particles larger than 50 mm, but they nearly always contained the next-smaller size. Particles larger than 50 mm were found in 76% of EC samples, 56% of shovel samples, and 52% of FC samples, as well as in 36% of both upper FC and lower FC samples. In contrast, particles in the 25-mm size-fraction occurred in 100% of EC and shovel samples, 96% of FC samples, and 84% of both upper FC and lower FC samples. To assess the possible bias caused by the inconsistent occurrence of particles over 50 mm in diameter, statistical comparisons were conducted with and without the 50-mm size-class included in the samples.

When 50-mm particles were included, seven sets of paired comparisons between sampler types yielded 12 significant differences (Table 1). Overall, no differences were observed between EC and shovel samples for any size-fraction of particles. However, FC samples differed from EC and shovel samples for two and three size-fractions, respectively. The upper half of FC samples were not different from EC samples, but they differed from shovel and FC samples for four size-fractions and one size-fraction, respectively. Finally, upper FC samples differed from lower FC samples for the two smallest size-fractions. Overall, significant differences occurred in 8 of 11 size-fractions.

When the 50-mm particles were excluded, the seven sets of paired comparisons between sampler types yielded 18 significant differences (Table 1). Again, there was no difference in the composition of EC and shovel samples. Freeze-core samples differed from EC and shovel samples for two size-fractions each. The upper FC samples differed from EC, shovel, and FC samples for one, three, and five size-fractions, respectively. Finally, upper FC samples differed from lower FC samples for five size-fractions. Among all the significant differences observed, only one involved particles larger than 3.4 mm in diameter.

Freeze-core samples were most influenced by the presence of particles in the 50-mm size-fraction; consequently, they showed the greatest response to omission of these particles (Figure 1). When present, 50-mm particles constituted an average of 36% (by weight) of FC samples, 30% of

TABLE 1.—Paired comparisons of the composition of substrate samples taken with an excavated-core sampler (EC), a freeze-core sampler (FC), and a shovel (S). Freeze-core samples were further divided into upper (FCU) and lower (FCL) halves. Inequality signs indicate the direction of significant differences (i.e., they substitute for "versus"); for samples with 50-mm particles included, $P \leq 0.009$; for samples with 50-mm particles omitted, $P \leq 0.010$.

Samplers compared	Particle size-fraction (mm)									
	25	12	9.5	6.3	3.4	1.7	0.85	0.42	0.21	<0.21
50-mm particles included										
EC versus S										
FC versus S					<		<	<		
FC versus EC		<	<							
FCU versus S					<	<	<	<		
FCU versus EC										
FCU versus FC										<
FCU versus FCL									<	<
50-mm particles omitted										
EC versus S										
FC versus S							<			>
FC versus EC			<							>
FCU versus S						<	<	<		
FCU versus EC							<			
FCU versus FC						<	<	<	<	<
FCU versus FCL						<	<	<	<	<

upper FC samples, and 43% of lower FC samples. In contrast, 50-mm particles constituted an average of only 18% of EC and 16% of shovel samples. Excavated-core and shovel samples tended to be similar whether or not 50-mm particles were included in the particle-size distributions. Omission of 50-mm particles generally enhanced the similarity between samples taken with the FC and the other types of samplers (Figure 1).

There was considerable variation in the cost and efficiency of the three samplers. The EC sampler produced the largest sample (mean weight, 4.8 kg), and it tended to collect a greater proportion of large particles (>50 mm), than the other two samplers. The EC sampler was cumbersome to carry and use; it weighed 15 kg, and small adults had difficulty reaching the bottom of the tube. It was often difficult to work the EC sampler into the substrate to the full length of the tube. Fabrication of an EC sampler with stainless steel, similar to the one described by McNeil and Ahnell (1964), cost about US$900.

The FC sampler yielded the smallest samples (mean weight, 1.4 kg) and was the most complex of the three samplers. It required a custom-built hose and manifold assembly, steel probes, carbon dioxide in pressurized tanks, and an assortment of peripheral equipment such as dead-blow hammer, propane torch, wrenches, and tank fittings. Each 9-kg-capacity carbon dioxide tank weighed about 20 kg when full and produced enough gas to collect four or five samples. The peripheral equipment and probes weighed another 20 kg. Collection and thawing required 15–20 min for each sample. The FC sampler with six probes cost about $1,500 to construct; each tank cost $75, and carbon dioxide was $2 per sample.

The shovel produced moderate-size samples (mean weight, 3.0 kg). It was the quickest sampling tool to use: each sample took about 1 min to dig, drain, and bag for transport. It was also the least cumbersome (weight, 2 kg) and least expensive (cost, about $25) of the three samples.

Discussion

We found no differences in the substrate composition of samples collected with the EC sampler and shovel, but differences were detected between FC samples and those obtained with both the EC sampler and shovel (Table 1). In a laboratory test of substrate samplers, Young et al. (in press) also found that FC samples differed from EC and shovel samples, and that samples taken with an EC sampler or a shovel were similar in composition. Ringler (1970) also reported differences in the composition of samples from FC and EC samplers, but others have suggested that such samples are similar (Everest et al. 1980; Lotspeich and Reid 1980; Shirazi et al. 1981).

The FC samples contained more of the finest particles (<0.212 mm) than EC of shovel samples, but this relationship was only significant when large

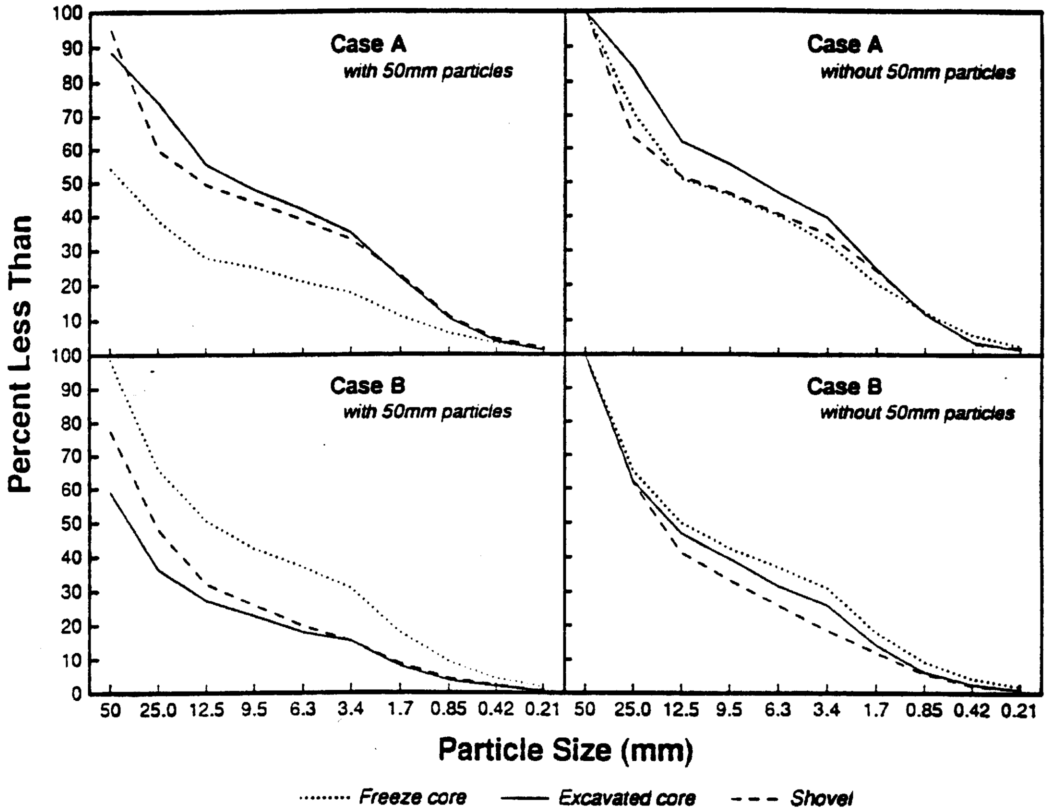

FIGURE 1.—Cumulative particle-size distributions (dry-weight percentage of particles less than a given diameter) for substrate samples collected along two stream transects, A and B. Case A shows the influence of 50-mm and larger particles on the composition of samples taken with a freeze-core sampler, excavated-core sampler, and shovel. Case B illustrates the influence of 50-mm particles when present in EC and shovel samples but missing from FC samples.

particles were omitted from the samples. When FC samples were split, we found more fine particles in the lower halves, as have others (Everest et al. 1982; Young et al. 1989). This may be an artifact of streambed composition, or it may be a sampler bias produced as the probe shakes or drives fine particles deeper into the streambed. Other workers have questioned the accuracy of FC samplers because of variation within samples (Adams and Beschta 1980) and failure to detect anticipated differences (Crisp and Carling 1989), but the entire sample was included in our analyses. When we used only the upper half of FC samples, they were similar in composition to samples taken with an EC sampler. However, FC samplers are an unnecessary burden except when specific depth strata need to be isolated (Grost 1989; Young et al. 1989).

Because the actual streambed composition was unknown, we could not determine which of the samplers yielded the most representative samples. However, in a laboratory experiment with constructed test substrates of known composition, Young et al. (in press) found significant differences between test substrates and samples collected by the three samplers. The EC and shovel samples differed least from the actual composition, whereas FC samples differed most.

Samples taken with an EC sampler and a shovel were similar in composition even though the weights of shovel samples were smaller. Reduced sample weight can be an advantage at remote sites; also, less time is needed to sieve smaller samples. A shovel has other advantages over an EC sampler: it is light and easy to carry, inexpensive, and can take samples more quickly. However, a shovel may be more prone to difficulties in use and to sample bias when used in fast water (>80 cm/s). Overall, our results indicate that a shovel is a viable alternative to an EC sampler for sampling in streams less than 40 cm deep with water velocities less than 80 cm/s and a streambed consisting primarily of material smaller than 10 cm in diameter. A shovel is especially useful for sampling in remote areas or when sampling budgets are limited.

Acknowledgments

We thank P. Anderson, D. Lanning, and M. Young for help in field sampling, laboratory analysis, and statistical analysis; and V. Hasfurther, R. Marston, D. Reiser, R. Schmal, and R. Wiley for guidance and critical comments. The project was supported by the U.S. Forest Service, Wyoming Game and Fish Department, Wyoming Water Research Center, and the Department of Range Management at the University of Wyoming.

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