Evaluation of a New Sediment Sampling Device

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Abstract: A two-part sediment sampler (stationary base and removable trap) was designed for a long-term study of stream sedimentation associated with highway construction. Before the long-term study, a laboratory study in an experimental flume examined efficacies of our sampler and two other sediment samplers: a modified core sampler and Whitlock-Vibert boxes. Based on the flume experiment, the efficacy of our sediment sampler was consistent with that of core and Whitlock-Vibert samplers. The advantage of our two-part sediment sampler design is that it allows for repeated removal of sediment samples without continual disturbance of the streambed. It also minimizes labor necessary to collect sediment samples. Our sampler is designed for long term monitoring of streams impacted by sedimentation and not for characterization of stream substrate composition.

Key words: flume experiment, rivers, streams, sediment, sediment traps, Whitlock-Vibert box

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Sediments are one of the most common and geographically-widespread pollutants of stream systems (Judy et al. 1984, U.S. EPA 1990, Richter et al. 1997). Although sedimentation is a natural process, stream systems are often negatively affected by anthropogenic sediment inputs from gravel mining (Brown et al. 1998), agriculture (Crawford and Lenat 1989, Dennehy et al. 1998, Wasler and Bart 1999), forestry practices (Beschta 1978, Scrivener and Brownlee 1989, Eaglin and Hubert 1993), and construction of roads (King and Ball 1965, Beschta 1978, Platts et al. 1989). Excessive stream sedimentation from anthropogenic land disturbances alters community composition and decreases survival, population size, and reproductive success of fishes (Scrivener and Brownlee 1989, Rabeni and Smale 1995, Jones et al. 1999), amphibians (Corn and Bury 1989, Welsh and Ollivier 1998), and benthic invertebrates (King and Ball 1965, Cline et al. 1982, Henley et al. 2000). Quantitative measures of stream sedimentation are useful to monitor and study anthropogenic impacts on stream biota; however, efficacies of sampling methods are not fully understood.

Stream sedimentation is measurable with multiple sampling methods. Traditional techniques for characterizing sediment composition in streams include core sampling (McNeil and Ahnell 1964, Platts et al. 1989, Wellman et al. 2000), the shovel method (Grost et al. 1991, Hames et al. 1996), and visual estimation along transects (Platts et al. 1989, Eaglin and Hubert 1993). Core sampling disturbs a portion of the streambed during each use (Berkman and Rabeni 1987, Platts et al.1989), and is usually used for single or annual measurements of sediment as it is not effective for repeated sampling over long time intervals (e.g., monthly sampling) due to labor intensiveness and cost. The shovel method costs less than core sampling (Grost et al. 1991), but also results in heavy samples, and disturbs the substrate during each sampling event. To reduce labor and cost, several techniques for trapping sediment hav been developed (Wesche et al 1989, Lachance and Dube 2004, Hedrick et al. 2005), but relatively few studies have addressed sampling efficacies among traditional and trap samplers (see Wesche et al. 1989).

We developed a sediment trap sampler with a two-part design, a stationary base and removable trap (Hedrick et al. 2005). Initially, we ran trial field tests with our sediment sampler and Whitlock-Vibert (W-V) boxes during a six-week period (Hedrick et al. 2005). However, due to the unique design of our sampler and the limited scope of the comparison trial, more information was needed to determine the effectiveness of our sediment sampler and how it compares to other methods of sediment trapping. The objective of this study was to use a laboratory flume to test for differences in the amount of deposited sediment collected in our sediment sampler compared to a gear that samples the stream substrate (corer) and one that traps sediment (W-V boxes).

Methods

Sampler Design

Our sediment sampler consisted of two parts, a base and a trap. The base was constructed from 10.16-cm schedule 40 PVC cou-

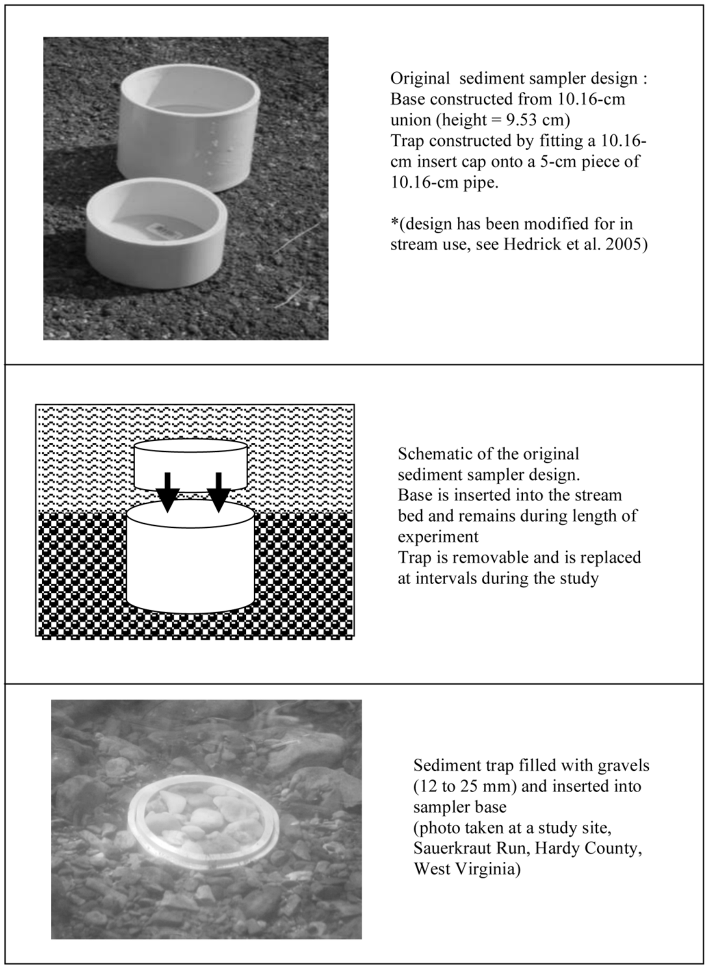

Figure 1. Original sediment sampler design consisting of a stationary base and removable trap (for details on manufacturing see Hedrick et al. 2005).

pling with a height of 9.53 cm. The top half of the coupling was ground out to allow the trap to slide freely in and out of the base. The trap was constructed by fitting a 10.16-cm insert cap onto a 5-cm piece of 10.16-cm schedule 40 PVC pipe (Figure 1; for details on sampler design see Hedrick et al. 2005). During sampler deployment in a stream, we embedded the base in the substrate with the base top flush with the substrate, and then inserted the trap into the base. At subsequent sampling events, we removed and replaced the trap but left the base embedded in the streambed. The two-part design allowed us to disturb the streambed only once at the onset of deployment, and it prevented accidental addition or loss of sediment during deployment or retrieval. We also found that its stationary base and removable trap minimized labor necessary to collect sediment samples.

Flume experiments

We ran two experiments (each with three trials) to test differences between the amount of fine material (sand particles < 0.85 mm in diameter) accumulated in our sediment sampler versus core samplers (experiment 1) and our sediment sampler versus W-V boxes (experiment 2). The wooden experimental flume measured 2.4 x 0.6 x 0.6 m. For each experiment, we filled the flume to a depth of 12.7 cm with gravel (Figure 2) and filled all traps with 12- to 25-mm diameter gravels. Two water recirculating pumps created flows that averaged 0.51 m per second (range 0.45 to 0.55 m per second).

The flume was visually divided into six blocks. For the first experiment, each section consisted of two rows and each row was assigned a random number. We embedded 18 of our sediment samplers into the gravel of the flume bed: six rows of three samplers each in the lowest numbered row of each block. We added 1.89 liters of fine material at the head of the flume over the top panel covering the water outflow, and the sand dispersed into the water column. Once all sand had been added, the pumps were left on for three additional minutes to allow sufficient flow to transport added material the length of the flume. After three minutes, pumps were turned off, and we removed the sampler traps, sieved rocks from the contents of the sampler traps, and placed the remaining sand in watertight containers for further processing. We collected 12 core samples using a modified core sampler, 10.16 cm in diameter and 15 cm in length (constructed out of thin-walled 10.16-cm PVC pipe). Two core samples were taken in the highest numbered row of each block. The core sampler was placed flush with the bottom of the flume, creating a seal. Rocks were removed and rinsed, and the remaining water and sand was siphoned out of

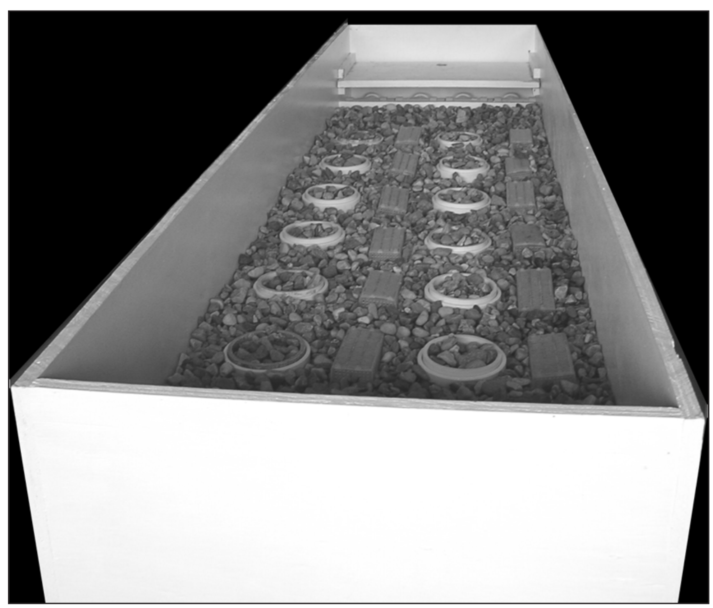

Figure 2. Wooden flume designed for sediment sampler experiments. Water source is located below the panel. Sediment was added to the panel and water was allowed to wash the sediment into the flume.

the pipe and placed in a watertight container for further processing. After the sand settled, clear water was removed with a siphon. Samples were dried at 75 C for 36 to 48 h until a constant weight. We weighed the amount of sand from each sample to the nearest 0.0001 g (Sargent-Welch, SWA 200-DR). After each trial, we removed the gravel bed from the flume, and washed out the sand. Clean gravel was returned to the flume, and sediment sampler bases were repositioned in the same place as the previous trial. The three trials took place on 9 July, 18 July, and 2 August 2004.

For the second experiment, we placed 12 sediment samplers and 12 W-V boxes (for detailed methods see Wesche et al. 1989) side by side in the gravel flume bed. Each of the six blocks was assigned four slots. Two sediment samplers and two W-V boxes were randomly assigned a slot in each block. Following methods detailed above, fine material was added to the flume. At the end of each experiment, we removed traps and W-V boxes from the flume, rinsed the gravels, and placed the sand from each sampler in a watertight container for further processing. Drying and weighing of material was the same for the sediment sampler and core sampler experiment. To begin subsequent experimental trials, we replaced the traps into sampler bases and dug the W-V boxes back into the gravel bed in the flume. The trials comparing the sediment samplers to W-V boxes were conducted on 14, 18, and 23 August 2004.

A randomized complete block (RCB) design with the block effect for experimental trial was used to compare differences in the mean amount of fine material accumulated within each type of samples during the three trials (alpha = 0.05). If no block effect was detected, then data from the three experimental trials were combined to determine differences in the amount of sediment accumulated between gear types within rows. Analysis of variance was used to compare sediment samplers in each row ($n = 3$ per trial) with the surrounding core samples taken ($n = 4$ per trial), and to compare sediment samplers and W-V boxes from rows 1 through 6 ($n = 2$ of each gear type per row per trial).

Results

The RCB design for the three trials comparing the sediment samplers to core samples indicated no significant block effect for experimental trial ($P = 0.79$) and no significant difference between sampling gear type ($P = 0.22$). The trials comparing sediment samplers to W-V boxes indicated the same results, with no significant block effect for experimental trial ($P = 0.92$) and no difference in the amount of material accumulated by gear type ($P = 0.43$). As expected, deposition decreased with distance from the sediment source for all samplers (our sediment samplers, core samplers, and W-V boxes); hence, large variances resulted from differences between rows (Figure 3). The amount of fine material did not differ significantly between our sediment samplers and surrounding core samplers ($P > 0.05$; Figure 4). For combined trials comparing sediment samplers to W-V boxes, W-V boxes had a significantly greater amount of fine material accumulated in row 2 ($P = 0.007$), however, in all other rows there were no significant differences ($P > 0.05$; Figure 4).

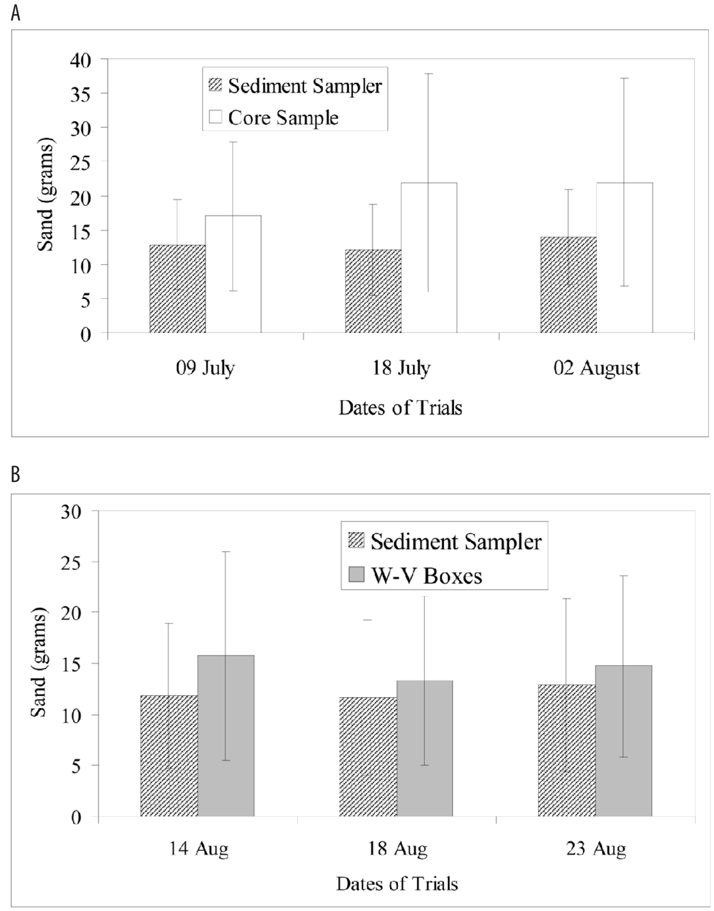

Figure 3. Mean amount of (A) sand accumulated in sediment samplers ($n = 18$) and removed with core samples ($n = 12$) and (B) sand accumulated in sediment samplers ($n = 12$) and W-V boxes ($n = 12$) from three trials in an experimental flume. Error bars indicate 95% confidence intervals.

Discussion

Our results indicate that our sediment sampling device can be used in place of core sampling and W-V boxes in studies monitoring fine sediment accumulation. Based on experimental flume study of fine sediments less than 0.85 mm in diameter, the three methods were similar in measurements of sedimentation. Wesche et al. (1989) found that accumulation of fine sediment less than 0.85 mm did not differ significantly between W-V boxes and McNeil core samples ($P < 0.05$) in an experimental flume. Garrett and

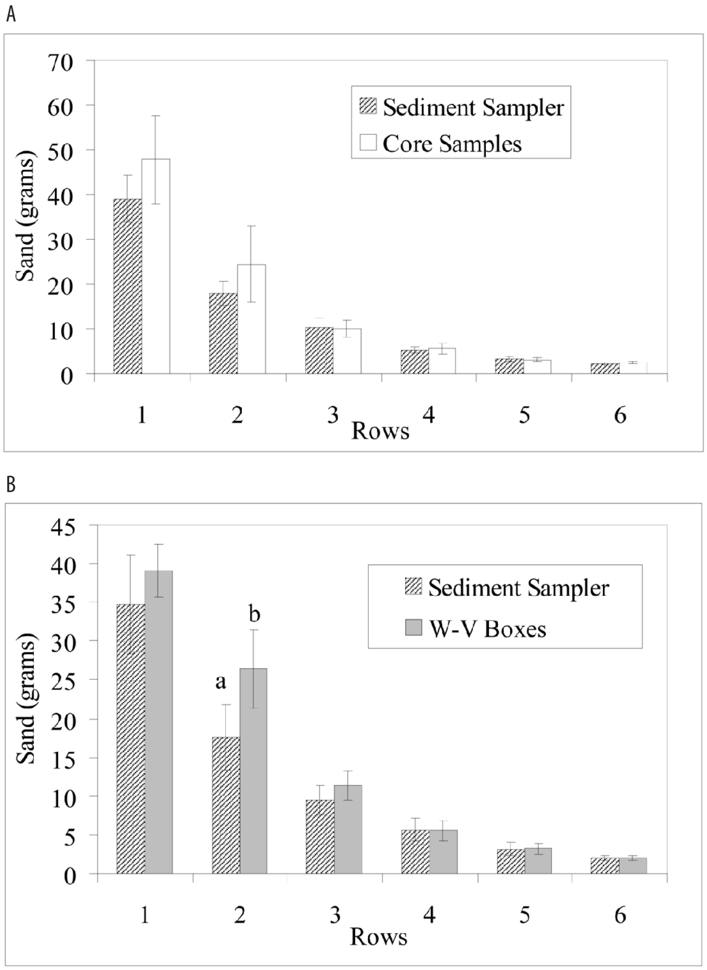

Figure 4. Mean amount of sand accumulated in (A) sediment samplers ($n = 9$) per row and surrounding core samples ($n = 12$) and (B) sediment samplers ($n = 6$) and W-V boxes ($n = 6$) per row from three combined trials in an experimental flume. Error bars indicate 95% confidence intervals.

Bennett (1996) also found intrusion of fine sediment smaller than 0.83 mm to be similar in spawning gravel and W-V boxes in a study on the North Fork of the Payette River near McCall, Idaho.

The sediment sampling device was designed for long term monitoring of sites impacted by highway construction. We plan to take repeated measures of sediment accumulation at paired sites upstream and downstream from construction and ultimately correlate these with changes in the benthic macroinvertebrate community. Our design allows users to monitor temporal changes in sediment, disturbing the streambed only once during initial deployment and limiting impacts on other aspects of a study. Core sampling and the W-V box methods disturb the streambed when retrieving or replacing samplers.

Our sampling design includes installation of a rigid structure (without openings at depth within the portion of the trap embedded in the substrate) into the streambed. This does not appear to change the effectiveness of the sampler. We chose not to have openings at depth because during initial testing of various designs, we visually noticed sediment infiltrating into the trap during deployment. Whitlock-Vibert boxes have openings at depth, and we visually noticed sediment being lost through these openings as the boxes were pulled from the substrate and through the water column in the experimental flume. Garret and Bennet (1996) found no significant difference in the amount of fines (< 0.83 mm) collected between W-V boxes wrapped in plastic screening and surrounding gravels, or between unwrapped W-V boxes and surrounding gravels. Unwrapped boxes accumulated more fines than wrapped boxes, and the authors attributed this to a sand seal (sand particles bridging the openings of the mesh and preventing infiltration of fines). The open top design of our sampler prevents formation of a sand seal.

Our sediment sampling device was designed specifically to monitor impacts from highway construction on small streams in the Appalachian region. It is useful for collection of sediment data in long-term studies, and to quantify sediment for time periods before, during, and after construction (or other anthropogenic contributors of stream sedimentation). In addition to monitoring sediment intrusion, long-term data from our sediment samplers will prove useful as covariates in models of sediment accumulation and changes in aquatic communities.

Sediment trapping is useful in determining the amount of fine material accumulated in a streambed over a time period. However, sediment trapping methods do not characterize the current substrate, nor do they document changes in coarser substrate over time. Repeated measures using core samples and the shovel method would be more beneficial for these latter uses, and proven useful in studies assessing the effects of substrate composition in redds on the survival and emergence of fishes, particularly salmonids (Grost 1991, Platts et al. 1989).

Alterations to our sediment sampler design can be made to adjust for local conditions. We were using the sampler in small first and second order streams in the Appalachians. Conditions in these streams did not require us to anchor the devices. Anchors could be added if samplers were used in streams with higher flows. The open top design does allow infiltration of multiple sizes of material. If the user was interested in a particular sediment size, screening could be placed over the top of the sampler. Screening may also prevent scouring of the samplers during high flow events. In our study area, stream beds have limited interstitial spaces in the substrate. Sediment deposition most often results from fines being transported across the surface of the substrate. Therefore, we do not believe that our sampler underestimated sediment infiltration by not having openings at depth. The closed design also prevented addition of material to the sampler during deployment of the device and loss of material during its retrieval.

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