A sampler for stream macroinvertebrates and organic matter occurring on boulders and bedrock in pools

E. A. Greathouse and C. M. Pringle

Introduction

Among the wide variety of benthic sampling methods and devices, none to our knowledge has been described for quantitatively sampling the benthos associated with large boulders and bedrock in still-water pools. Benthic samplers for stream pools, such as the stovepipe core, are designed for fine substrates (Merritt et al. 1996). However, still-water pools dominated by boulders/bedrock, with cobble, gravel, leaves and sticks in the crevices between boulders, are often a major habitat. In our studies of mountain streams in Puerto Rico, an average of 47% (range: 15–77%) of pool substrate measurements are boulder or bedrock (diameter ≥ 256 mm). Thus, we developed a benthic sampler for use on boulder/bedrock habitats in still-water pools where use of traditional samplers is not tractable due to the lack of flow and large substrate sizes. The sampler, which we call the "benthic block net," can be used for sampling quantitatively (abundance/biomass per unit area) or semi-quantitatively (relative abundances/biomass). Because still-water boulder/bedrock pools are important habitats in various high-gradient streams throughout the world, our sampler may be useful in a variety of benthological studies.

Key words: benthic, sampling, boulders, bedrock

Sampler description and operation

The benthic block net (Fig. 1) consists of an enclosed tube made from water-resistant cloth (we used a cloth shower curtain) with a chain sewn into the bottom, metal rods (we used curtain rods) sewn approximately two-thirds of the way down the cloth and a removable, adjustable Styrofoam float with a 0.25 m^2 square opening. Two operators set the block net by holding the chain up against the Styrofoam float, placing the device on the water, and then simultaneously releasing the chain to sink to the bottom and seal against the substrate (Fig. 1). One operator then holds the float in place while the second ensures that the chain seal is secure and conducts sampling within the block net. When necessary, the first operator can maintain the chain position on steeply sloped boulders/bedrock by using two poles placed in the block net corners. The metal rods help maintain a square shape in the cloth tube, providing a standardized sampling area of 0.25 m^2. The block net can be tied to the Styrofoam float approximately halfway down the cloth for sampling at shallower depths, or at the top for sampling at depths up to approximately waist level (Fig. 1 displays the float tied to the top of the block net).

We developed the benthic block net to obtain quantitative estimates of non-decapod invertebrate (hereafter referred to simply as "invertebrate") biomass and standing stocks of organic and inorganic matter as part of a larger study of the Mameyes River, which drains the Caribbean National Forest in Puerto Rico. In 7 of 9 sites sampled in a longitudinal survey, still-water pools were boulder/bedrock-dominated: from 16–660 m above sea level, 55–78% of rock measurements in pools were boulder or bedrock. In each of the 7 sites, we took 3 block net samples.

Sampling within the block net consisted of four steps: (1) a "pre-pass" removed by hand all snails and large organic matter (e.g. leaves, sticks) for preservation in a labelled plastic bag; (2) in each of three 3-minute passes, the substrate was thoroughly scrub-brushed and a clean 210-µm hand net was passed through the water column using vigorous stirring. For the 3 passes, we used identical but separate hand nets labeled "A," "B" and "C", and the contents of each were washed into separate plastic bags, preserved and labeled; (3) to estimate standing stocks of very fine (<250 µm) benthic organic and inorganic matter, the second operator agitated the water in the block net, took a sub-sample of known volume and measured 5 depths within the block net (Lugthart & Wallace 1992); and (4) both operators conducted a "post-pass", pushing the chain inward while maintaining contact with the stream bottom until the block net could be lifted out of the water with invertebrates trapped inside, letting the water strain out through the

0368-0770/05/0029-0975 $ 1.00
©2005 E. Schweizerbart'sche Verlagsbuchhandlung, D-70176 Stuttgart

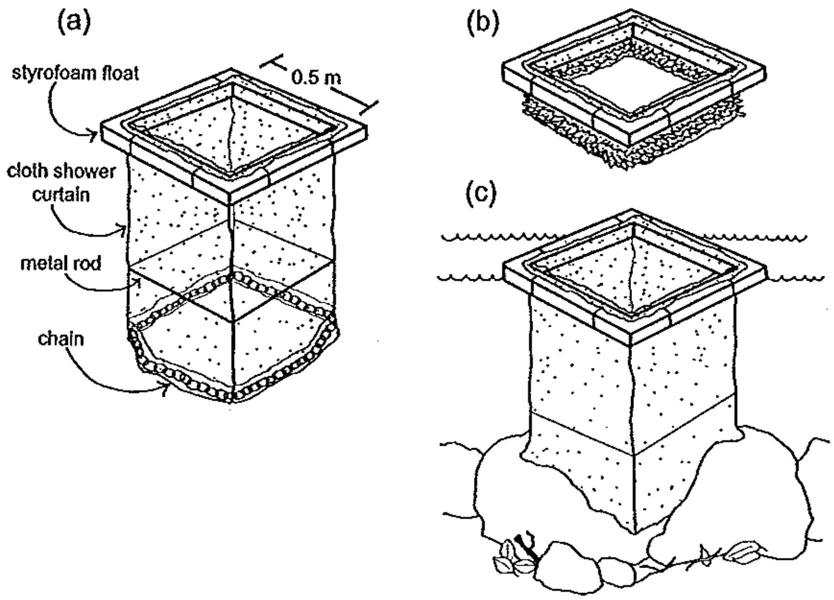

Fig. 1. Diagram of (a) the benthic block net design showing the enclosed cloth shower curtain tube, with a Styrofoam float tied at the top, metal curtain rods sewn approximately two-thirds of the way down, and a chain sewn into the bottom; (b) the initial position on the water surface; and (c) the position after releasing the chain to seal against the substrate.

cloth. Visible invertebrates on the cloth were removed and placed in a labeled plastic bag.

Laboratory processing of the contents of each plastic bag followed methods modified from LUGTHART & WALLACE (1992). For each block net sample we used removal-sampling calculations on the timed passes to estimate densities of each invertebrate taxon captured. These estimates represented densities that were in the block net after conducting the prepass. Removal estimates were calculated in the program CAPTURE using the generalized removal estimator (WHITE et al. 1982). When CAPTURE calculations were not feasible, we used two alternate methods to estimate densities. If the third pass contained no captures, or if captures increased with each pass, our density estimate was based on the total number captured over 3 passes. If captures in pass 3 were greater than or equal to those in pass 1, but depletion occurred between passes 2 and 3 (this occurred in 6 cases), we calculated the maximum likelihood approximation for passes 2 and 3 (WHITE et al. 1982) and added this number to the number captured in pass 1 (FIEVET et al. 1999). To estimate biomass for each taxon, we multiplied density by the average biomass per captured individual. Adding the invertebrate biomasses in the pre-pass samples to these estimates then gave us biomass estimates prior to setting the block net. Post-pass data were used for 3 samples in which the post-pass contained individuals that represented size classes or taxa not found in the 3 passes; biomasses of these individuals were added to the estimates obtained from the timed passes and pre-passes.

Our sampling method is partially based on previously described removal sampling for estimating invertebrate densities (MARCHANT & HEHIR 1999) and a sampler in which releasing a metal sink unfolded an enclosed block net (HENRIKSON & OSCARSON 1978). The benthic block net functioned similarly to a stovepipe core: during sampling, water inside the block net became turbid and brown while water immediately outside of the block net was clear.

Results and discussion

Captures declined over 3 sequential passes, and thus allowed calculation of CAPTURE estimates, for only 89 of 256 estimates. An additional 10 of these 256 estimates were absolute counts of snails enclosed in the block net. Although CAPTURE estimates and absolute counts of snails represented only 39% of the estimates, they represented, on average, 82% and

78% of the total invertebrate abundance and biomass, respectively. In 54 of the 256 estimates, captures increased with each pass; however, using the total mass sampled as an estimate of their biomass, these invertebrates represented, on average, only 4% of the total invertebrate biomass. For 28 CAPTURE estimates, goodness of fit tests indicated the capture data did not fit the model assumption of constant capture probability (chi-square p-value < 0.1; WHITE et al. 1982). Average capture probability for CAPTURE estimates was 0.61. Non-snail estimates for which CAPTURE calculations were not able to be computed tended to be for estimates of low density (mean abundance per block net sample = 2.6, SE = 0.3). Mean abundance per block net sample for CAPTURE estimates was 36 (SE = 10).

Our results indicate that removal sampling was not highly effective for uncommon taxa, and ~1/3 of our CAPTURE estimates did not fit the removal model we used. However, for purposes of estimating biomass per unit area in our longitudinal survey of the Mameyes River, estimates based on the most common taxa and total captures of uncommon taxa were sufficient. This is because, based on our biomass estimates and our familiarity with the system, biomass of shrimps, crabs and snails is more than two orders of magnitude higher than biomass of other macroinvertebrates in boulder/bedrock pools of the Mameyes. Shrimp and crab biomass was sampled using electroshocking, not the benthic block net, and the benthic block net provided absolute counts for snails. Our benthic sampler allowed additional estimation of non-decapod, non-snail taxa. The performance of our removal calculations is comparable to other published applications of removal estimates to real data (CARLE & STRUB 1978, FIEVET et al. 1999), and we suspect that the performance of our sampler is at least as effective as methods commonly considered quantitative for sampling other benthic habitats (e.g. Surber net).

Conducting > 3 passes and/or combining the benthic block net with suction methods, such as those described by BROOKS (1994), could improve estimates for those studies requiring highly accurate and quantitative biomass estimates for rare invertebrates. Alternative calculation methods (CARLE & STRUB 1978, POLLOCK & OTTO 1983) may similarly provide a better fit to benthic block net data. The method can also be modified to obtain semi-quantitative estimates of invertebrate biomass and standing stocks of organic matter (i.e. relative abundance/catch per unit effort) by conducting a pre-pass, a single 3-minute pass and a post-pass. We have successfully used the benthic block net for examining relative abundances of invertebrates in mountain streams across the island of Puerto Rico, where on average, 40% of rock measurements in pools were boulder or bedrock (range: 15–70%).

Our benthic block net technique has several advantages over other methods that we considered for quantitatively sampling boulder/bedrock pools. A core or suction sampler, with foam rubber to seal against the surface of a single boulder or bedrock area, would have excluded organic matter and associated invertebrates that accumulate in crevices between boulders. Foam rubber would also be incapable of creating a seal with many of the irregular substrate contours that the block net chain was able to seal. Compared to other methods, the block net is also more effective for sampling mobile taxa, such as baetid and leptophlebiid mayflies and dragonfly larvae, which will swim short distances in response to disturbance. This swimming behavior makes attempts to adapt methods traditionally associated with flowing water problematic for still-water pools. For example, placing an individual stone (GRUBAUGH et al. 1996) or artificial substrate (MARCH et al. 2002) into a nearby net does not work well for mobile taxa. During a study of still-water pools in a catchment neighboring the Mameyes River, the number of mayflies sitting on tiles prior to sampling by flipping the tiles into a net were 4 times higher than the number captured in the net (E. GREATHOUSE, unpubl. data), and mayflies were observed to swim a few inches away from the tiles during sampling. Because of the block net's relatively large sampling area (0.25 m^2), any invertebrate movement due to our shadows or release of the chain was probably largely within the area the block net subsequently enclosed. Thus, we think our technique is superior to other methods we considered. However, if the advantages of the block net (large sampling area and superior sealing abilities) were to be combined with the advantages of suction methods (e.g. efficiency and probable collection of all invertebrates within the enclosed area), the resultant sampling method would likely be the best possible for boulder/bedrock in still-water pools.

The published literature in both fluvial geomorphology and stream ecology reflects the dominant view that stream pools have finer substrates than do riffles and those that do have significant representation of boulder/bedrock are flowing-water pools (ALLAN 1995, KNIGHTON 1998, CHIN 1989). Thus, boulder and bedrock habitats in still-water pools have largely been ignored. Our sampler may be useful in studying this habitat in tropical and temperate streams throughout the world. Streams that contain boulder or bedrock habitat in still-water pools occur in bedrock streams of Indiana (KELLER & MELHORN 1978) and mountainous regions of other Caribbean islands (F. SCATENA, University of Pennsylvania, personal communication), Panama (S. CONNELLY, University of Georgia, pers. comm.), Costa Rica (ANDERSON-OLIVAS 2004), Ecuador (T. THOM, US Fish and Wildlife Service, pers. comm.) and California (HEMPHILL & COOPER 1984).

Acknowledgments

We thank L. ERICKSON for assistance with sampler design/construction; C. SANDERS, E. STEIN, K. STEPP, S. MEYERS, C. FRANKLIN and L. MELDA for field and lab assistance; and A. COVICH, M. FREEMAN, M. HUNTER and the Pringle lab for comments on manuscript drafts. Support was provided by the National Science Foundation Luquillo LTER program (DEB#00805238), a U.S. Department of Agriculture grant to C. PRINGLE (#10-21-RR551-141) and a National Science Foundation Graduate Fellowship to E. GREATHOUSE.

References

ALLAN, J.D., 1995: Stream ecology: structure and function of running waters. – Chapman and Hall, London, 388 pp.

ANDERSON-OLIVAS, E., 2004: Ecological and social implications of hydropower development on a neotropical river system, Costa Rica. – Ph. D. Diss., Institute of Ecology, Univ. of Georgia, Athens, Athens.

BROOKS, S., 1994: An efficient and quantitative aquatic benthos sampler for use in diverse habitats with variable flow regimes. – Hydrobiologia **281**: 123–128.

CARLE, F.L. & STRUB, M.R., 1978: A new method for estimating population size from removal data. – Biometrics **34**: 621–630.

CHIN, A., 1989: Step pools in stream channels. – Progress in Phys. Geogr. **13**: 391–407.

FIEVET, E., BONNET-ARNAUD, P. & MALLET, J.P., 1999: Efficiency and sampling bias of electrofishing for freshwater shrimp and fish in two Caribbean streams, Guadeloupe Island. – Fish. Res. **44**: 149–166.

GRUBAUGH, J.W., WALLACE, J.B. & HOUSTON, E.S., 1996: Longitudinal changes of macroinvertebrate communities along an Appalachian stream continuum. – Can. J. Fish. Aquat. Sci. **53**: 896–909.

HEMPHILL, N. & COOPER, S.D., 1984: Differences in the community structure of stream pools containing or lacking trout. – Verh. Internat. Verein. Limnol. **22**: 1858–1864.

HENRIKSON, L. & OSCARSON, H., 1978: A quantitative sampler for air-breathing aquatic insects. – Freshw. Biol. **8**: 73–77.

KELLER, E.A. & MELHORN, W.N., 1978: Rhythmic spacing and origin of pools and riffles. – Geological Soc. of America Bull. **89**: 723–730.

KNIGHTON, D., 1998: Fluvial forms and processes: A new perspective. – Arnold, London, 383 pp.

LUGTHART, G.J. & WALLACE, J.B., 1992: Effects of disturbance on benthic functional structure and production in mountain streams. – J. North Am. Benthol. Soc. **11**: 138–164.

MARCH, J.G., PRINGLE, C.M., TOWNSEND, M.J. & WILSON, A.I., 2002: Effects of freshwater shrimp assemblages on benthic communities along an altitudinal gradient of a tropical Island stream. – Freshw. Biol. **47**: 377–390.

MARCHANT, R. & HEHIR, G., 1999: A method for quantifying hand-net samples of stream invertebrates. – Mar. Freshw. Res. **50**: 179–182.

MERRITT, R.W., CUMMINS, K.W. & RESH, V.H., 1996: Design of aquatic insect studies: collecting, sampling and rearing procedures. – In: MERRITT, R.W. & CUMMINS, K.W. (Eds.): An introduction to the aquatic insects of North America: 12–28. Kendall/Hunt Publishing Company, Dubuque, Iowa.

POLLOCK, K.H. & OTTO, M.C., 1983: Robust estimation of population size in closed animal populations from capture-recapture experiments. – Biometrics **39**: 1035–1049.

WHITE, G.C., ANDERSON, D.R., BURNHAM, K.P. & OTIS, D.L., 1982: Capture-recapture and removal methods for sampling closed populations. – Los Alamos National Laboratory, Los Alamos, New Mexico.

Authors' address:
E.A. GREATHOUSE, C.M. PRINGLE, Institute of Ecology, University of Georgia, Athens, GA, 30602, USA.
E-mail: effieg@gmail.com