METHODS FOR ASSESSING THE IMPACTS OF SEDIMENT DEPOSITION ON THE SURVIVAL TO EMERGENCE OF COLORADO RIVER CUTTHROAT TROUT AND BROWN TROUT

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Several tools have been developed to evaluate the survival of salmonid eggs and alevins during incubation in the streambed relative to the proportion of fine sediment in the stream (Chapman 1988). Models, such as the one by Stowell et al. (1983) for Idaho batholith watersheds, have been linked with sediment-yield models (Cline et al. 1987) to predict survival from egg deposition to emergence in response to sediment yield within the basin.

Our work focused on the development of assessment tools for use in southeastern Wyoming on relatively small streams in forested watersheds with populations of small- to moderate-sized resident trout. We developed field-sampling techniques and strategies, as well as relations between substrate composition and survival to emergence of trout. We believe that our work has produced useful insight as to when, where, and how to sample substrate in streambeds, as well as a reasonable set of assessment tools for evaluating the impact of sediment on survival to emergence of resident trout.

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Purpose

The purpose of this field guide is to summarize the findings of Grost (1989) and Young (1989) into a set of usable tools for fishery management purposes. The techniques can be used to assess the potential impact of sediment on survival of the eggs and alevins of Colorado River cutthroat trout (Oncorhynchus clarki pleuriticus) and brown trout (Salmo trutta) while they inhabit redds. Techniques for detecting changes in the substrate composition of streambeds are also discussed. This field guide includes five sections that describe:

1. Field sampling -- a description of where, when and how to sample the streambed;
2. Laboratory procedures -- a description of the way in which the composition of substrate samples is determined;
3. Descriptive statistics -- a description of the computation of statistics used to describe substrate composition;
4. Assessment tools -- a description of the models developed through laboratory studies that describe relations between substrate composition and survival to emergence of trout; and
5. Determination of differences in streambed composition -- a description of field, laboratory, and statistical procedures useful in monitoring sediment concentration in streambeds.

Field Sampling

Our field studies indicated that eggs can occur throughout a redd, but most frequently occur in the upstream half of the tailspill. During redd construction, trout alter the substrate at the locations where eggs are deposited (egg pockets) by reducing the amount of fine sediment. Substrate composition around eggs and in the tailspill is substantially different from that outside of redds. As a result, substrate samples from spawning riffles or other areas outside of redds DO NOT provide an accurate measure of the sediment surrounding incubating eggs and alevins. However, such samples can provide a measure of relative ambient sediment levels that may be useful for comparisons among streams. Also, we found that fine sediment accumulates in egg pockets as incubation progresses. With these observations in mind, we believe that the ideal substrate sample from which to assess sediment impacts on eggs and alevins is one collected late in the incubation period and that includes an egg pocket.

However, the ideal sample is not easy to obtain. First, egg pockets are difficult to locate in individual redds. Second, eggs and alevins are often destroyed by substrate sampling directly in the egg pocket. And finally, redds may be difficult to identify or relocate late in the incubation period due to ice and snow cover, freshets, or substrate changes. Substrate samples collected in the upstream half of the tailspill soon after spawning may provide accurate estimates of egg pocket composition late in the incubation period. In brown trout redds, we found that the substrate composition of tailspills just after spawning was nearly identical to that of egg pockets late in the incubation period.

Brown trout build redds that are easily recognized by clean gravel and the pit-tailspill configuration. Eggs are generally found 4-5 inches deep (Figure 1). Other fall spawning species, such as brook trout (Salvelinus fontinalis) construct redds that are similar to those of brown trout. Therefore, in sympatric populations, redds should be identified as to species by direct observation of spawning fish or hatching of eggs retrieved from redds.

Colorado River cutthroat trout construct small redds that are frequently difficult to identify. We found that when this fish spawns in the spring the gravels of streams have been cleaned of silt and algae due to spring runoff; therefore, the characteristic area of clean gravel used to identify brown trout redds cannot be used for Colorado River cutthroat trout. Also, because Colorado River cutthroat are small (<8 inches), they rarely construct redds with readily identifiable pits and tailspills. We found that redds of this species could only be confirmed through excavation of possible locations (based on hydraulics, gravel size, and patterns of surface gravel morphology) with a shovel and observation of eggs and alevins. Unfortunately, all sampling methods are destructive and impractical in streams where a potentially endangered species is being managed.

We found that the McNeil core sampler (McNeil and Ahnell 1964) was the best tool for obtaining a representative substrate sample from redds (Figure 2). However, the large size of the McNeil sampler makes it cumbersome to carry into remote areas. We observed that a shovel with a pointed blade (6.5 x 8.0 inches) produced samples that were very similar to those of a McNeil sampler with a 6-inch diameter core. The average weight of substrate samples taken with a McNeil sampler was 10 pounds, while shovel samples averaged 7 pounds.

We feel that a shovel may be an adequate substrate-sampling tool for most management applications in small streams. The technique for using the shovel is simple. The blade is worked vertically into the upstream half of the tailspill to the full length of the blade. The blade is then levered to the horizontal position and lifted from the water. The substrate on the shovel is placed directly into a heavy-duty plastic bag and stored in a bucket or backpack for transport to the laboratory.

Laboratory Procedures

Substrate samples are analyzed using soil analysis techniques. Each sample is oven dried for 3 days at 140°F, weighed, and shaken on a mechanical shaker for 3-5 minutes through a set of 10 Tyler USA standard testing 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 (2.0, 1.0, 0.5, 0.37, 0.25, 0.13, 0.07, 0.03, 0.017, and 0.008 inches, respectively). However, no more than six sieves should be used at one time. Each fraction is weighed to the nearest 0.1 gram on an analytical balance. Because the size fraction held by the 50-mm sieve was not present in most of our samples, we omitted this fraction from the total sample in our computations (other investigators have chosen to include them). If the shovel or McNeil corer is used, we recommend that the 50-mm particles be excluded to standardize the computations of substrate compositions.

Descriptive Statistics

The amount of sediment in substrate samples is generally defined as the percentage of fine material, but the sizes considered as fine material have varied from particles of <0.25 inches in diameter down to <0.03 inches. If the percentage of fine material is used as a descriptive statistic, both the size of particles defined as fine material and the size range of particles included in the computation must be stated. We recommend that particles <0.85 mm (<0.03 inches) be considered as fine material and that only particles <50 mm in diameter be included in the computations.

Investigators have found other descriptive statistics to be useful, especially ones that consider all of the sizes of particles in their computation, such as the geometric mean particle size. Geometric mean is computed by the formula:

$$Dg = Da^{Pa} \times Db^{Pb} \times \ldots Di^{Pi}$$

where Dg = geometric mean (mm),

D*i* = mean diameter (mm) of material retained on sieve *i*, and

P*i* = the proportion of the entire sample made up of material retained on sieve *i*.

We found that survival to emergence of both Colorado River cutthroat trout and brown trout fry was most highly correlated with geometric mean particle size in our laboratory studies. The percentage of fine particles and Fredle Index were much less effective predictors of survival to emergence.

Assessment Tools

Our laboratory studies defined the relation between geometric mean particle size (mm) of the substrate and survival to emergence of Colorado River cutthroat trout and of brown trout (Figure 3). We believe that the regression equations provide an index as to the possible impacts of alteration in substrate composition on naturally incubating trout eggs and alevins in the field. The predicted survival at a given geometric mean is the average for that geometric mean under laboratory conditions where only the substrate composition is believed to impact upon survival. Additional factors, such as predation, water quality, dewatering, freezing, or upwelling can occur in natural redds to further reduce or enhance survival to emergence.

Despite the strong sediment-survival relationship in laboratory experiments, field tests of the Colorado River cutthroat trout model in 1988 and 1989 produced little or no relation between predicted and observed survival to emergence of fry among a range of substrate compositions. We believe that other variables, such as dissolved oxygen concentration of the intragravel water and intragravel water velocity, also affected survival. The brown trout model has not been field tested.

Use of the predictions of survival to emergence from our regression models probably yields an overestimate of natural survival and cannot be regarded as accurate. Managers are advised not to utilize the predictions of our regression equations in modeling efforts that attempt to quantify survival to emergence within a watershed from knowledge of sediment yield (See Stowell et al. 1983). Inflated estimates of survival to emergence will be obtained from such efforts.

Instead, we believe that the predictions from our regression models provide an index that can be used to assess relative differences among streams or changes over time within a stream. The estimates must be viewed as an approximation of survival to emergence with no other biotic or abiotic forces impacting upon survival.

Determination of Differences in Streambed Composition

In many management situations, biologists are faced with the problem of determining if changes in sediment accumulation are occurring in streams. Our work has yielded a set of tools that can be used to monitor sediment levels.

Field sampling can be conducted in specified stream reaches following a random or systematic sampling regime. The exact nature of the sampling scheme will depend on the objective of the work. However, either a McNeil sampler or shovel can be considered as an effective sampling tool in small streams. Laboratory procedures used to assess redds can also be used to assess non-redd samples with computations again based on size fractions <50 mm in diameter. Modified Whitlock-Vibert boxes can also be used to compare streams and assess trends in sediment deposition (Wesche et al. 1989). Whatever sampling tool is used, when comparing different streams the samples should be taken in reaches of hydraulic similarity at the same time of the year. Variation in sediment can be quite pronounced seasonally and among years.

When we assessed descriptive measures of substrate composition for the purpose of evaluating differences in substrate composition in streams over time or between watersheds, we found that the percentage of fine sediment <0.85 mm in diameter was the most sensitive measure of sediment differences. This statistic identified differences when geometric mean particle size did not (also see Beschta 1982). Because substrate composition is rarely distributed normally, we suggest that non-parametric analyses be used to evaluate samples. Statistical comparisons of samples between years or locations can be made for one location with a Wilcoxon signed-rank test or for several locations with a Mann-Whitney U-test (Sokal and Rohlf 1981).

We believe that a systematic sampling scheme using a shovel will be adequate for most management purposes. The recommended sample statistic, the percentage of fine sediment less than a given size, is the best measure for detecting possible differences. However, this statistic is sensitive to the size of sediment being added to the stream by land management. Consequently, the size chosen, e.g., <0.85 mm, should reflect the sediment size that is expected to change.

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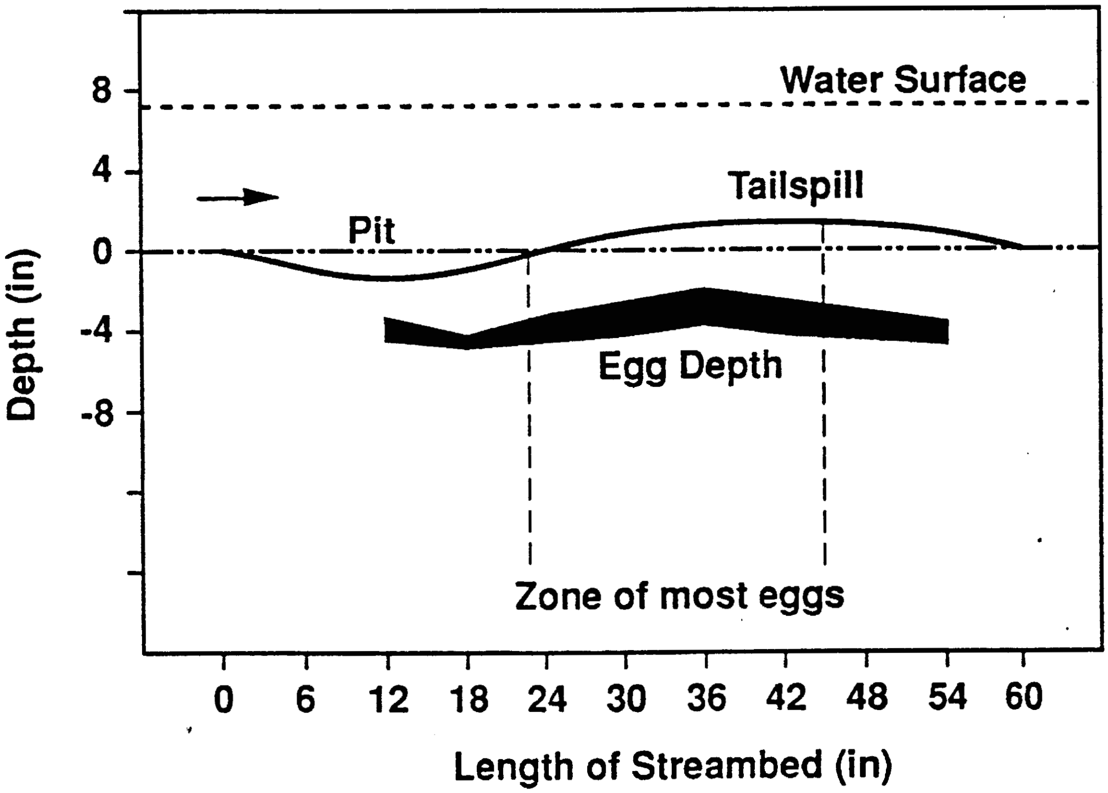

Figure 1. Section view of a typical brown trout redd showing average egg depths relative to surface contour.

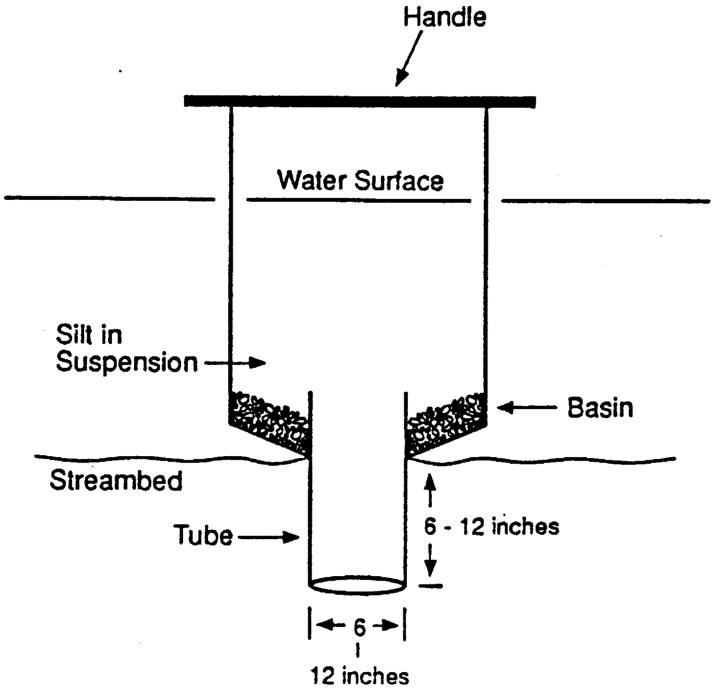

Figure 2. Drawing of a McNeil core sampler.

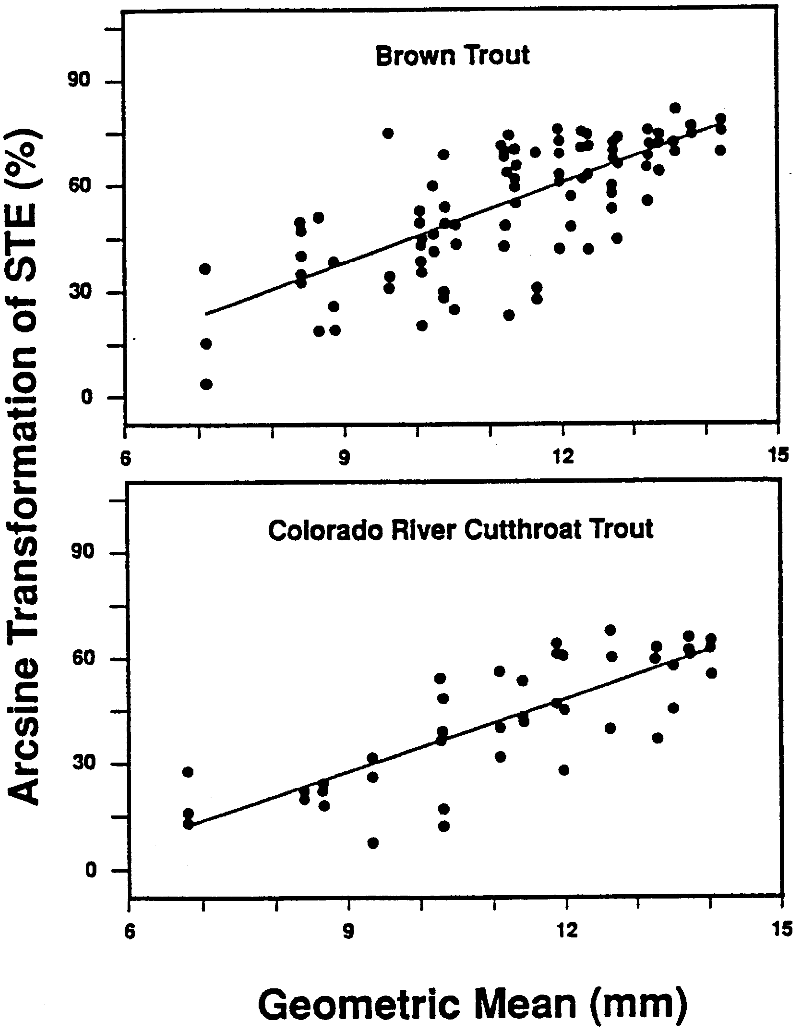

Figure 3. Relations between survival to emergence (STE) and geometric mean particle size (mm) in laboratory tests. For brown trout the equation is Arcsine (STE) = 7.75 (Geometric Mean) - 32.5 (r^2 = 0.54, $\underline{P}$ < 0.0001, N = 99). For Colorado River cutthroat trout the equation is Arcsine (STE) = 7.01 (Geometric Mean) - 36.9 (r^2 = 0.65, $\underline{P}$ < 0.0001, N = 45).