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Case Study: McNeil Sampling in North Coast Watersheds

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McNeil sediment samples (McNeil and Ahnell 1964) have been used at 35 – 40 specific monitoring sites throughout the Hawthorne Timber Company (HTC) ownership since 1993 for the purpose of estimating particle size distribution and percentages of fine sediments in the stream systems throughout the property. The sediment monitoring program was initiated by the previous owner, Georgia-Pacific (GP), and was continued by Campbell Timberland Management (CTM) staff when they acquired the property in 1999. McNeil samples were taken by CTM staff from 1999 through 2002 at most of the same monitoring locations as those sampled by GP. McNeil samples were utilized to calculate particle size distribution of instream substrate and corresponding values of geometric mean diameter and Fredle index. These three measurements have been used by others to calculate survival to emergence ratios (STE) of salmonids, to link stream conditions to land management activities, and percentages of finer material in potential salmonid redds (Hines and Ambrose 1996).

Three coastal watersheds in Mendocino County (Big River, the Noyo River, and The Ten Mile River) have been identified as sediment impaired and are proposed for 303d listing status partially based on the reported results of these surveys. Particle size distribution, specifically the percentage of fine particles (< .85 mm), within the stream substrate has been selected by regional agency staff as a metric for both evaluating gravel quality and as a target for the TMDL Action Plan. Our experience to date suggests metrics of this nature are not well suited for use as targets in the dynamic coastal watersheds of North Coast California. The primary issues of concern can be broadly characterized into three categories:

- The difficulty in estimating fine sediment values within spawned substrate from measurements taken in un-spawned substrate
- The seasonal variation in fine sediment distribution observed between summer and winter
- The differential between wet sieved, volumetric samples and dry sieved, gravimetric samples

The "Winnowing" Problem

The threshold for impairment determination of less than 14% fine sediment in stream substrate adopted by the Regional Water Quality Control Board is a mean value in a range observed by various researchers investigating the effects of fine sediment on salmonid embryo survival. These investigations measured the effects of interstitial fine sediment within redds on STE. However, a problem arises from a monitoring perspective regarding how investigators should estimate fine sediment within redds when logistic and ethical considerations prevent them 1) from sampling during the period when salmonids spawn and 2) from sampling within redds. In his paper on assessing the quality of spawning gravel, Kondolf (2000) partially addresses the problem of estimating fine sediment within the redd by establishing a localized correction factor based on empirical values within redds plotted against fine sediment values found in adjacent potential spawning gravel. The correction factor addresses the winnowing effect on fine sediment within the redd caused by the caudal scouring of the egg pocket by the female. In his case study regarding Rainbow Trout in a Colorado River Tributary, he established a correction factor of .67X, recognizing that fine sediment values within the redd will always be lower than those observed in the surrounding substrate. The use of Kondolf's correction coefficient would change a reported fine sediment value of 20% to 13%, effectively transforming an impaired value to one considered suitable for optimal STE. The GP staff never applied this correction or addressed this differential other than to report that fine sediment distribution was probably lower in spawned substrate.

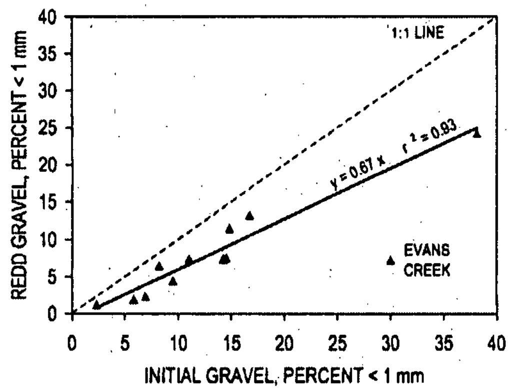
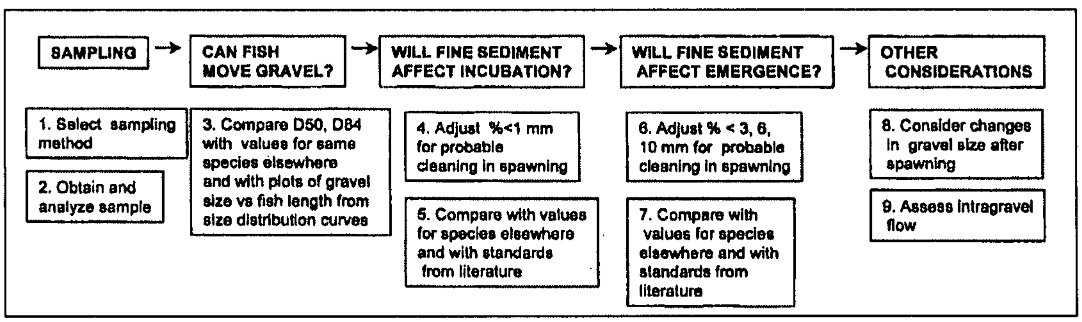


FIGURE 6.—Percentage of sediment finer than 1 mm in redds and potential (comparable, unspawned) gravels. The data point for Evans Creek is excluded from the regression. (See Kondolf et al. 1993 for sources of data.)

From Kondolf (2000): Correction factor for unspawned gravels.



From Kondolf (2000): GP and CTM staff never implemented steps 4, 5, and 6.

Seasonal Variation in Fine Sediment

Kondolf, however, does not address the issue of seasonal variation of fine sediment levels, which may be greater than the variation between spawned and unspawned areas. This is likely because he was not investigating anadromous fish. The problem with the present threshold is that it was determined by rates of embryo survival within redds during the spawning period. However, the measure of fine sediment from potential spawning areas during the non-spawning season is not equivalent to within redd measurements during spawning season – the basis of the threshold.

There is evidence suggesting that percent fines are generally lower in unspawned substrate during winter than during summer, before the Kondolf corrections would be applied.

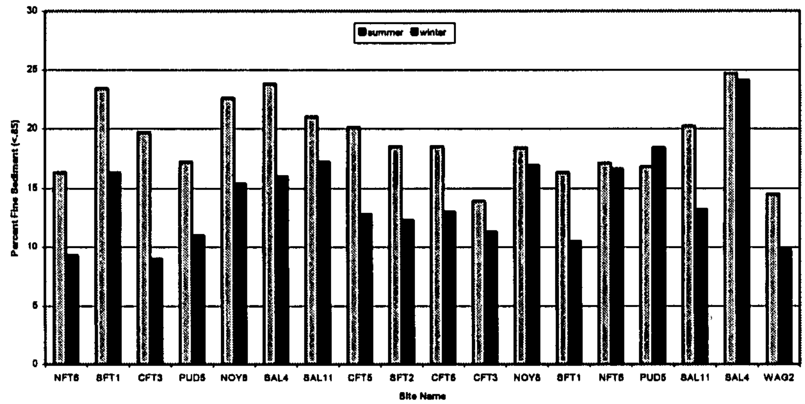


Figure 2: The differential in percent fines found in 18 sampling sites between the summers of 2001, 2002 and the winters of 2002, 2003.

During the winter periods of 2002 and 2003, CTM staff conducted McNeil surveys at 18 locations that had been sampled during the previous summers. At all but a single site, the winter fine sediment values were found to be lower than summer. The magnitude of the difference varied considerably between sites, indicated by the low correlation coefficient of the linear regression of these data. However, analysis of the data suggests a correction factor of .74X. Using this correction factor, a stated value of 20% would transform the value to approximately 15%. The GP staff applied no correction for seasonal variation, so sampling is biased to indicate higher fine sediment distribution.

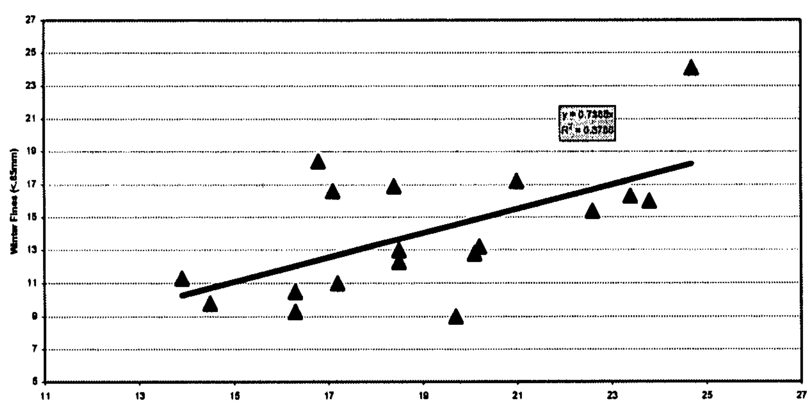


Figure 3: The linear regression of the plotted summer-winter sampling sites, which might be used as a correction factor. The low R^2 value reflects the high variation between sites. However, all sites but one were lower in winter.

Challenges Associated with Wet / Dry Sieving Methodologies

Shirazi (1978) addressed another issue when determining particle size distribution within stream substrate – the differential between wet and dry sieved methodologies. There are two methods of evaluating particle size distribution:

1. Gravimetric based dry sieving, which requires the sediment sample to be dried, then sieved and weighed for determining particle size distribution.
2. Volumetric based wet sieving, which requires the sample to be processed wet. The volume of water displaced by each size class determines particle size distribution.

When a collection of McNeil samples is dry sieved, the samples are dried either in the sun or in a kiln at a lab facility. This method is generally considered to be more accurate than wet sieving, but it is also more resource intensive. It requires staff to transport bulky samples back to a lab for processing, which is problematic when it's necessary to sample many sites, as is the case on this ownership.

Wet sieving offers a convenient alternative to the dry method, allowing the samples to be processed on site. However, there is bias associated with the method: As the displacements of progressively smaller particle sizes are measured, the volume of water contained within the interstitial space between particles is also measured. As the particle size decreases, the ratio of withheld water increases. In order to compensate for this discrepancy, Shirazi determined a correction factor for each particle size ranging from .96X (64 mm) to .72X (.79 mm). For the purposes of estimating the approximate reduction in reported fine distribution, we apply the mean value of .87X, which would transform a value of 20% fines to 17.4 %. All samples processed by GP and CTM staff were wet sieved and the correction issue was never addressed, so all samples were biased to show higher levels of fine distribution.

Additional Sampling Biases

There are a number of minor issues that contribute to sampling bias, in addition to the main issues noted above. The following list of issues all skew results towards higher fine distribution.

- Sharazi (1978) states that the minimum diameter of the substrate sampler should be three times the size of the largest particle sampled, otherwise results will be skewed towards higher fine distribution. GP or CTM staff never applied this protocol, thus removing larger framework stones from the samples.
- The sampling locations within the pool riffle crests are arbitrary and subject to observer bias. In many cases, when the substrate contained a high percentage of large particles, the observer would be forced to sample in areas with higher fines because it was impossible to insert the device into the rocky portion of the substrate. This sampling error is partially the result of the limited diameter of the device.
- Although not strictly a sampling bias, locations for sediment sampling were never evaluated for their importance within the watershed. For logistical convenience, only one site was sampled at the lower end of the stream in many of the smaller sub-basins thereby characterizing the entire sub-basin by the results of one sampling site.

Discussion

The purpose of this document is not to re-analyze the reported fine sediment distribution in stream networks across the Hawthorne ownership, but to provide additional context for the evaluation of existing and future data sets. Table 1 shows the range of fine sediment values reported by GP / CTM staff and how they may be transformed by the application of the discussed correction factors.

Stated Value: These are the range of values for percent fine sediment in substrate as reported by GP and CTM (1993-2001)	Kondolf Correction (.67X): The correction factor to allow for the observed differential in fine sediment between spawned and unspawned substrate. The "winnowing" correctional coefficient suggested by Kondolf (Kondolf 2000).	Shirazi Correction (.87X): The mean of the correction factors established by Sharazi to account for the differential between wet and dry sieved samples. (Sharazi, 1978)	CTM Correction (.74X): The correction to account for the differential in empirical values between summer and winter fines at established sampling locations (CTM, unpublished)
30	20.10	26.10	22.20
29	19.43	25.23	21.46
28	18.76	24.36	20.72
27	18.09	23.49	19.98
26	17.42	22.62	19.24
25	16.75	21.75	18.50
24	16.08	20.88	17.76
23	15.41	20.01	17.02
22	14.74	19.14	16.28
21	14.07	18.27	15.54
20	13.40	17.40	14.80
19	12.73	16.53	14.06
18	12.06	15.66	13.32
17	11.39	14.79	12.58
16	10.72	13.92	11.84
15	10.05	13.05	11.10
14	9.38	12.18	10.36
13	8.71	11.31	9.62
12	8.04	10.44	8.88
11	7.37	9.57	8.14
10	6.70	8.70	7.40

Table 1: The range of fine sediment values reported for the ownership now managed by CTM and the correction coefficients that may reasonably be applied.

When considering the stated correction factors that may be applied to the McNeil or Valentine protocols for spawning gravel assessment, an additional question arises: If an investigator is sampling gravel in this region (Coastal Northern California) during the summer non-spawning season using the wet sieve method, which corrections should be applied to the results in order to gauge STE? One might reason that all the correction factors should apply: Initially, the sample must be corrected for the seasonal differential, then corrected for the differential between spawned and un-spawned substrate, and finally for the measuring bias inherent in the wet sieve method. If all three corrections were applied, the stated results would be considerably lower than those reported.

These questions must be addressed if this method of gravel assessment is used as a water quality single statistic target, as proposed in the TMDL Action Plan Scoping information. Special consideration is also required to ensure samples are collected in accordance with a statistically sound sampling strategy that effectively characterize gravel quality within a watershed over time.