Development of biological criteria for sediment TMDLs: the relation of sediment deposition to benthic invertebrate communities of streams exposed to varied land use disturbances in the Sierra Nevada and Coast Range mountains of California

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Report 3 of 4

INTRODUCTION

Among the water quality indicators that may be used in developing sediment TMDLs for streams, physical habitat descriptions of particle size distribution specify the quantity of sediment deposition, but the ecological consequences of sedimentation require information on responses of stream life to evaluate limitations on biological integrity and beneficial uses. Benthic (i.e., bottom-dwelling) aquatic invertebrates are directly exposed to sediment deposition, and play a central in the function of stream ecosystems as consumers of organic matter (wood and leaf debris) and algae, and as food sources to higher trophic levels (e.g. fish and riparian birds). These organisms are ubiquitous in streams and rivers, comprising diverse communities of taxa with varied ecological function and a range of morphological and physiological sensitivity to disturbance and pollution including that related to sedimentation. Because benthic invertebrates often have life cycles on the order of months to years, they also integrate the influence of changes in hydrological and water quality conditions over all seasons. Quantitative collections of benthic invertebrates may be used to evaluate diversity and relative abundance of taxa, feeding guilds, and pollution tolerance, as measures of the ecological integrity of a stream. Use of quantitative data on the structure of biological communities in evaluating stream habitat quality is known as bioassessment (US EPA 1999). Bioassessment surveys of baseline conditions can provide an evaluation of the existing status of target watersheds in contrast to reference watersheds that have been selected to reflect the natural spatial and temporal variability expected for similar stream types in minimally disturbed habitats. Differences between reference and target conditions among sediment-impaired streams may be used to evaluate the extent of sediment effects on biological integrity and provide a baseline and goal for monitoring ecological restoration. The use of bioassessment data can contribute to developing sediment TMDLs by providing indicators of changing ecological health as altered over gradients of sediment deposition, and in setting target values for attaining a restored ecological condition. These data can also provide objective criteria for Clean Water Act section 303(d) decisions on listings or de-listings of polluted water bodies.

Sediment as a pollutant may be particularly harmful to benthic aquatic life because fine particles (clay, silt) and sand cause physical disturbance during both transport and deposition (Minshall 1984, Waters 1995). During suspended sediment transport, benthic invertebrates may be impacted through abrasive action of particles, interference in food gathering, and clogging of respiratory surfaces, all of which may induce organisms to drift downstream. The overall effect of sediment deposition is often most extensive as the sediment coats, embeds, or buries benthic habitat. Species type, richness, and diversity may change as excess sediment inputs convert the dominant substrate from larger sizes (pebbles, cobble) to small particles (sand, silt, clay). The classic change is from a community dominated by mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa (collectively referred to as EPT), to one dominated by burrowing invertebrates such as segmented worms (Oligochaeta) and midges (Chironomidae). These changes do not necessarily proceed in a linear fashion and may depend on size fractions, timing and duration, habitats affected, organic content of the small particles that may be an initial subsidy to growth, and other covariates. The conceptual syndrome of change is that with additions of small amounts of sediment, invertebrate abundance may decrease, but community structure and species richness not change, but as greater amounts of sediment, sufficient to change the substrate type to dominance by sand-silt, the community will be altered in terms of number and type of taxa, involving a shift to increased proportions of tolerant forms, and fewer sensitive taxa (Waters 1995). Finally, deposition may leave a lasting legacy of impacted habitat and a depleted community that may only be recovered slowly by so-called flushing flows and control of sediment inputs.

Recent studies of biological responses to sediments have produced inconclusive results and been hindered by data sets that are difficult to compare (Table 1). Studies have used varied definitions of what particle size limits constitute sediment, from fines (clay-silt) through sand and gravel fractions. In some cases the sediment is measured as surface cover, in others as bulk weight or volume. Response variables and methods of detecting effect levels have also been inconsistent, some using total density and diversity measures, others emphasizing the most sensitive taxa, with results that vary from none detected, to gradual losses in abundance and richness, to very low limits for response of selected indicators. Other problems include small sample sizes of streams surveyed or experimental treatments compared, limited range of sediments examined, or wide gaps in the levels tested.

Field observations have shown declines of taxa richness, density and composite biological integrity with increased sediment deposition across regional stream surveys, but there is considerable scatter in comparing reach-scale measures of sediment with invertebrates not collected at the same scale or locations as the bed substrata (Mebane 2001, Ode et al. 2005). Larsen et al. (2009) reported that patch-scale distribution of fine particles was closely related to declines in benthic invertebrates but that little association was found between reach-scale fine substrates and invertebrates. Experiments have suggested that particle size, duration of sediment exposure, and in some cases particle heterogeneity may control invertebrate responses (Williams 1980, Erman and Erman 1984, Shaw and Richardson 2001, Molinos and Donohue 2009). Some studies have used differing responses among taxa to develop an index of tolerance specific to deposited sediments (Relyea et al. 2000, Zweig and Rabeni 2001).

The integrative objectives of our study was to use different scales of resolution and size fractions of sediments to examine effects of sediment in relation to invertebrate communities from field surveys of a large sample of streams from different geographic regions – the Sierra Nevada and central coast region of California. Reference streams were used to develop numeric criteria, and responses over gradients of sediment used to identify potential thresholds of change, with the goal of guidance for sediment TMDLs.

METHODS

Study Design, Site Selection and Habitat Surveys

For complete descriptions of research design, distribution of survey locations, selection and grouping of reference and test sites, and physical habitat survey methodologies and protocols, refer to Report 1. Suffice it that streams of similar geomorphic type were partitioned into reference groups for each region based on a least-disturbed criterion of low levels of roadedness and combined land use coverages. Stream surveys involved detailed documentation of channel physical environment and patterns of sediment deposition at various spatial scales within the reach. This report will cover only methods related to the sampling and analysis of benthic invertebrate collections.

Invertebrate field sampling

Reach-wide multi-habitat sampling

In order to collect an integrated profile of the invertebrate community in each study reach we used the reach-wide sampling protocol that combines microhabitat patches from a series of samples taken in proportion to habitat conditions occurring within the reach. Proceeding upstream from the lower end of a 150 m reach, a 500 µm D-net (30 cm wide) was used to collect a total of eleven samples at 5, 20, 35, 50, 65, 75, 85, 100, 115, 130, and 145 m along the reach length. The lateral cross-section position sampled alternated between left, center and right (at approximately one-quarter, one-half, and three-quarters the distance across the wetted channel width at each transect). Typically samples were collected by rolling, rubbing and gently digging around the substrates by hand within a 30 x 30 cm area above the sample net, as invertebrates, organic matter and substrates were carried into the net by the current or swept in by hand. This was done for a fixed-effort of approximately 30 seconds for each locale sampled. Samples were combined into a single collection bucket for processing. Larger organic and inorganic debris was first removed and cleaned of all invertebrates, followed by repeated elutriation of all floatable material that could be suspended and collected in a fine mesh (100 µm) aquarium net, and then searching all remnant sand and gravel for heavier cased caddis and mollusks that were not collected by elutriation. The processed sample was then labeled by stream, site and date and preserved in 80-90% ethanol and stained with a few drops of 3 mg/L Rose Bengal solution.

Depositional bar sampling

Invertebrate samples were also collected from depositional bar formations in each study reach within a fixed depth range of 5 to 20 cm. This was done at five locations selected to cover a range of low to high levels of deposition of fines and sand particles. Prior to sample collection, a 20 x 20 cm grid frame (5x5 crossing lines) was gently placed over the selected location and counts made at the 25 intersecting grid points of fines or sand present. Once the number of fine and sand intersects were counted, the grid was gently removed to avoid disturbance. A modified Surber sampler (100 µm mesh nitex screen upstream and on sides) covering the 400 cm^2 area was then placed over the same location and a 20 cm wide aquarium net (100 µm mesh) placed at the downstream side and the sample area swept into the net by hand. All material collected, including the fine and coarse particulate organic matter (FPOM and CPOM), was then preserved in 80-90% ethanol and a few drops of Rose Bengal solution added. Along with these five bar samples, an additional 20 grid-patches were selected at random using a random number table for points corresponding to the mapped bar formations along the reach length. This then provided an index of the extent of FS deposition on the bars, and the associated patch-scale invertebrates present. Refer to the physical habitat methods for further description of the mapping and fine/sand grid counts from depositional bar formations.

Laboratory Analysis

Whole field samples were sub-sampled using a Folsom (rotating drum) Plankton splitter to achieve a minimum count of 550 animals for reach-wide multi-habitat sample and 250 animals for depositional bar samples. Additional split fractions were processed as necessary to achieve the minimum count. Once the minimum was achieved, the remaining unprocessed remnant was inspected for large and rare individuals which were identified separately and added as single counts. Invertebrates were counted and identified to the lowest taxonomic unit possible, typically genus or species (including midges and mites) where reliable keys were available (Wiggins, 1996, Larson et al 2000, Thorp and Covich 2001, Stewart and Stark 2002, Merritt et al. 2008). Only oligochaetes and ostracods were not identified at greater taxonomic resolution.

Depositional bar sample quadrats were usually processed in entirety, sometimes subsampled as above. In addition to the invertebrates removed and identified, all FPOM and CPOM present was separated (1 mm mesh) after invertebrates were removed, dried to constant weight (at 50-60°C), and ashed in a muffle furnace at 500°C to obtain estimates of ash-free dry mass organic matter content.

Data Analysis

As a preliminary step to more detailed analysis, this report contains descriptive statistics for density and taxa richness of the depositional bar patch-scale samples from all 98 streams (490 grid-frame samples), and the multi-habitat reach-wide samples from the central coast range.

Depositional bar quadrats were separated into bins at intervals of 8% combined counts of fines and sand (FS) of 25 possible grid intersects within each sample quadrat, keeping the zero count or complete cover (25) as separate groups. As samples were collected selectively from a range of FS counts within each site, these bins combine quadrats from across many sites, and from both the Sierra Nevada and central coast region. These samples were examined in terms of total richness and EPT richness to determine at what level there might be change from the zero FS cover samples in terms of 95% confidence interval overlap with the mean of successive bin increases in FS cover (this is an approximate test of significance at $p = 0.05$).

The reach-wide benthos data from 74 Sierra Nevada streams, and 24 central coast range streams was divided into reference and test groups in order to compare differences in selected indicator metrics of total richness, EPT richness, percent EPT, biotic index (sum product of relative abundance and tolerance value of all taxa in a sample, signifying composite community tolerance), percent tolerant individuals (of taxa with tolerance values, TV = 7-10), and richness of sensitive taxa (TV = 0-2). The 10th and 25th metric percentiles was used as a criterion level for the lowest range of metric performance (90th or 75th for metrics increasing with impaired condition) as a means of designating streams not supporting a reference standard, where reduced biological integrity exists. This is consistent with regional assessments of western streams (Stoddard et al. 2005). We also examined changes in representative indicator metrics over the sediment range measured in reach-scale stream surveys, using the deviance reduction method to identify thresholds or changepoints in responses over environmental stressor gradients (Qian et al. 2003).

For Sierra Nevada streams, community ordination using nonmetric multi-dimensional scaling (NMDS) was used to contrast dissimilarity in overall community structure between reference and test groups and the relationship of separations to environmental gradients of disturbance and sediment content. This analysis was also conducted for an expanded set of coastal streams supplementing the sites surveyed in this study that include more reference sites (Herbst et al. 2011c, project summary).

Weighted averaging of FS and abundance associations were also conducted to develop taxa-specific sediment tolerance rankings (after method of Yuan 2006).

RESULTS

To place results of this study in context, samples taken from extensive (n = 134) bioassessment surveys in the eastern Sierra Nevada (Herbst and Silldorff 2009) have examined overall trends in the relation of sediments to a multimetric index of biological integrity (Figure 1). In relation to combined fine, sand and gravel fractions, IBI scores based on 10 equally scaled metrics show considerable scatter, but there is a clear loss of biological integrity with increased FSG, much of this above the level of about 50% cover (gravel usually contributes about 10-20% cover on average in these samples (as in Figure 7 of report 1), so FS level would be equivalent to about 30-40% cover).

Setting biological expectations for what constitutes an unimpaired stream can be based on the distribution of reference streams, and here the criterion levels for impaired condition is the exceedance of the lowest-performing quartile, and the lowest-performing 10%, for 3 or more of 6 indicator metrics (Appendix A, listing reference and test streams). Using these criterion levels allows making distinctions between the worst cases (<10th %), and those that are somewhat better but still under-performing (<25th %). Setting the limit for impaired condition at this lower quartile level incorporates a margin of safety in protecting the best conditions of biological integrity. This same approach was taken in examining the distribution of sediments in reference sites (report 1 of this series), so both sets of indicators can be evaluated to enhance certainty regarding determinations of impairment. Appendix A shows that 2 references were in the worst class of loss of biological integrity, but neither was in the worst class of sediment impairment. Among test sites, 17 (of 46) suffered worst case biological degradation, and these agreed in 9 of those cases with worst sediment impairment. Both sources of information should be considered in making assessments. Such a listing was also prepared for coastal streams (Herbst 2011b), and using the more conservative 75th percentile, these showed 1 reference stream with both biological and sediment impairment, and 12 of 45 test streams with both.

Changepoints in total richness response to FS sediment indicates a threshold in the Sierra at 35% FS (Figure 14), and on the coast starts at 25, changes most at 30-40% FS and above 50% where few very low richness values differ most from lower %FS (Figure 15). In contrast to this type of threshold for diversity measures (Fig.s 2-6), proportional tolerance measures typically show more gradual change over the sediment gradient (Fig.s 8-13). The tolerance measures show for example declining upper limits on the percent of EPT with sediment level (Fig.s 8-9), or that fewer numbers of tolerant indicator organisms occur below 30-40% FS , so the biotic index is lower (Fig.s 10-13). Changepoints for EPT richness vs. %EPT in the Sierra show this difference in response with more abrupt break and threshold at 35% for richness, and graded change over a broader range for the fraction of EPT present but still greatest at 35% FS (Fig.s 16-17).

Samples collected at the small 20×20 cm patch-scale in grid quadrats taken on bars also support the reach-scale conclusions (Figure 18). In the range of 25-40% FS, total and EPT richness means of dropped below the 95% confidence interval of samples where no FS was present, indicating significant and persistent loss of biological integrity above this range. This scale showed less scatter than seen for reach-scale samples.

NMDS analysis (using PC-Ord, MjM software) was conducted for Sierra Nevada reachwide benthos (RWB) samples by first eliminating rare taxa (only those taxa occurring in at least 20% of sites, 15 of 74 sites) and converting counts to log (x+1), and these numbers relativized prior to running ordination analysis using Sorenson (Bray-Curtis) distances. This analysis yielded a 3-dimensional solution, final stress = 17.8, 73 iterations, using minimum r^2 for environment vectors of 0.25. Test sites separated from references along a gradient correlated with riparian roads and road crossings, corresponding to higher FS sediment levels, showing that differences in community composition can be related to the disturbance factors that distinguish R from T, and produce increased sediment (Figures 19 and 20). Similar analysis was done with the combined coast region samples, with results also showing R/T separation related to roads and FS sediments (refer to Herbst et al. 2011b).

The development of taxa-specific tolerance values from these data sets was accomplished by calculating weighted-averages of the sum product of relative abundance and %FS levels at each of the collection sites where taxa were found. Doing this for both the bar samples and for the reachwide samples provided a large sample size, and to obtain the weighted averages we set a minimum of 15 samples for either type in order to provide a reasonable estimate of tolerance. For each sample type we first ranked these weighted scores from minimum to maximum, then re-scaled 0 to 1. For each sample type these values were added (or duplicated if the taxon was present only in either bars or reachwide samples), and again re-scale 0-1, then multiplied by 10 and rounded to the nearest integer (including 0) to obtain a tolerance value from 0 to 10, so it scaled the same as conventional tolerance values (Appendix B). We also examined the fraction of all chironomidae midges as a sediment indicator, in response to FS cover present on bar grid-quadrat samples (Figures 21 and 22). For both regions, this proportion increases with FS cover. Some midge taxa become more common as sensitive taxa such as EPT are lost, and midges dominate the tolerant end of the TV list (Appendix B), but some have moderate to low TVs (e.g. *Cricotopus_Nostococladius*, *Eukiefferiella devonica* and *brehmi* groups, *Polypedilum aviceps*, *Rheotanytarsus*, etc).

DISCUSSION

The spatial scale at which ecological interactions occur is important in considering how resources and environmental limits shape the distribution and abundance of different life forms. The scale of observations will be an important influence on the patterns that can be discerned. Bioassessment sampling and habitat surveys takes place within study units defined as stream reaches – usually >100 meters in length. This may lead to difficulty in finding a clear correspondence between reach-scale measurements of stream bed substrates and deposition with reach-wide collections of invertebrates because they typically are not taken from the same specific locations. Even though this may result in “fuzzy” relationships between benthic invertebrates or other stream life used as indicators, as sediment coverage increases, limits or boundaries often appear in biological capacities (diversity, types and traits of taxa) that can be achieved within a stream reach. In streams of the Sierra Nevada we have observed this for the composite or multimetric index of biological integrity (Figure 1). In streams of both the Sierra and central coast region we observed a similar pattern of decreased total, EPT, and sensitive taxa richness as the FS fraction increased above a threshold of around 30-40%. In contrast, The percent of total density that are EPT taxa (Fig.s 8-9) covers a comparable range among reference and test sites, but shows that as FS cover increases, the upper limit on this indicator gradually becomes lower and lower. Increases in biotic index and percent tolerant taxa suggest a similar proportional shift in more tolerant taxa (higher TVs) and fewer sensitive taxa (lower TVs) with increased sedimentation. This indicates that while increases in FS have a gradual effect on the proportions of individuals surviving, the more sensitive taxa eventually reach limits on their ability to persist, and they disappear (by mortality and or drift) or fail to recruit. Apparently additional tolerant taxa do not appear to replace these losses, but the proportions of those already there increase. Below 30% FS there are substantially fewer tolerant forms, evident in lower biotic index and % tolerant.

Many test sites had limited habitat quality as sediment deposition features in this group were consistently more extensive, and biological indicators showing more degradation of biological integrity. Greater richness and more intolerant taxa in reference than test groups demonstrated higher biological integrity, and the distribution of these metrics can form the basis for establishing numeric criteria that can be used to identify sediment impairment. The limiting threshold of 30-40% for richness measures shown by deviance reduction analysis also corresponds to numeric criteria.

NMDS community ordination showed that communities differed between reference and test sites that were distinguished based on road and land use disturbance. These groups became more dissimilar over gradients that corresponded to FS levels, supporting the univariate metric responses and showing that sediment is a primary driver of overall change in community structure. Road and land use exposure, separating reference and test groups, linked to elevated levels of sedimentation, can thereby be tied to degraded biological integrity. So landscape disturbances that produce a probability distribution of sediments that show high risk of exceeding threshold criteria may be used to guide regulation and management of problem areas.

Microhabitat preferences among aquatic insects are well-established as integral to the dynamics of environmental heterogeneity that accounts for much of the diversity observed at the reach and larger scales in streams (Townsend 1989). Sediments can eliminate patch-scale habitat heterogeneity and reduce diversity. This was clearly seen in the patch-scale samples of grid quadrats taken on bars, where again limits were exceeded in the range of 30-40% FS (Figure 22). Biological degradation at the patch-scale on bars suggests that where bars comprise an increased area of the bankfull channel, and are composed of greater fractions of FS, there will be reduction in the biological integrity of these sites. The clear dose-response relation to FS at the patch scale suggests that assessment and sampling at more localized spatial scales may improve ability to detect the effects of sedimentation pollution. Placing quadrats for FS counts at each of the reachwide benthic sample points would be a simple way to accomplish this.

Although the data presented here are used to develop a set of numeric criteria, the reference data sets are somewhat limited, so it would be advisable to include other reference-condition streams, conforming the selection criteria used here, to supplement these criteria and improve the representation of stream types and geographic range with each of the regions considered. Nonetheless, these studies demonstrate the linkage between the limiting influence of land use and sedimentation on the biological integrity of benthic invertebrate communities, and application of numeric criteria indicators.

Table 1. Selected Recent Studies of Biological Responses to Fine Sediments – varied definitions, methods, and findings

Reference	Biological Indicator	Sediment Measure	Location & Study Type	Sediment Effect & Limits on Response Indicator
Angradi 1999	BMIs	FS bulk weight <2 mm	WV Experiment	Declines in density / biomass with sediment increase, but otherwise weak metric responses if any. Range 0-30% at 5% increments, n=240 trays in 3 reaches of one stream.
Relyea et al 2000	BMIs	FS cover <2 mm	ID OR WA WY Field	Fine sediment tolerance index developed for common taxa based on max range of occurrence (n=562 surveys). Graded responses found for %EPT (n=270 stream surveys).
Mebane 2001	BMIs	FSG cover <6 mm	ID Field	Continuous declines over range for many metrics but esp. pronounced change at >30-40% cover for n=279 streams.
Zweig-Rabeni 2001	BMIs	FS visual cover <2mm and embeddedness	MO Field	Total and EPT richness and density decline with sediment increase. FS cover recorded at 5% intervals visual estimate for 4 streams and n=85 samples.
Suttle et al 2004	Fish & BMIs	FS cover <2 mm	CA Experiment	Juvenile steelhead growth decline over range, with most decline at >40%FS. BMI burrowers increase & clinger-types decrease. Only one river, of n=24 trays at 20% increments.
Kaller-Hartman 2004	BMIs	F bulk weight <0.25 mm or <0.125 mm	WV Field	Above 0.8-0.9% F by weight showed ↓ in %EPT but not other metrics. Variable results across 2 seasons and 7 streams (inconsistent F size and samples analyzed).
Braccia-Voshell 2006	BMIs	FS bulk weight <2 mm	VA Field	Some but not all group metrics respond in patch-scale samples, and FS taxa index calculated (6 streams n=230).
Cover et al 2008	BMIs	FS cover <4 mm	CA Field	No correlations of sediment with community metrics, and only a few taxa found with predicted negative responses. For 6 streams, n=4 riffle samples/stream. Limited range of sediment (just 4-16% cover).
Bryce et al 2008	Fish	F cover <0.06 mm	West US Field	Fish IBI declines about 5% for each 10% increase in F. 75th percentile of reference =5%F critical level (n=169 mountain ecoregion sites)
Bryce et al. 2010	BMIs & Fish	F cover <0.06 mm FS cover <2 mm	West US Field	Minimum effect level for fish was 5% F and 13% FS, and for macroinvertebrates, optimum was 3% F and 10% FS for the <u>most</u> sensitive BMIs in mountain streams (n=557 surveys)

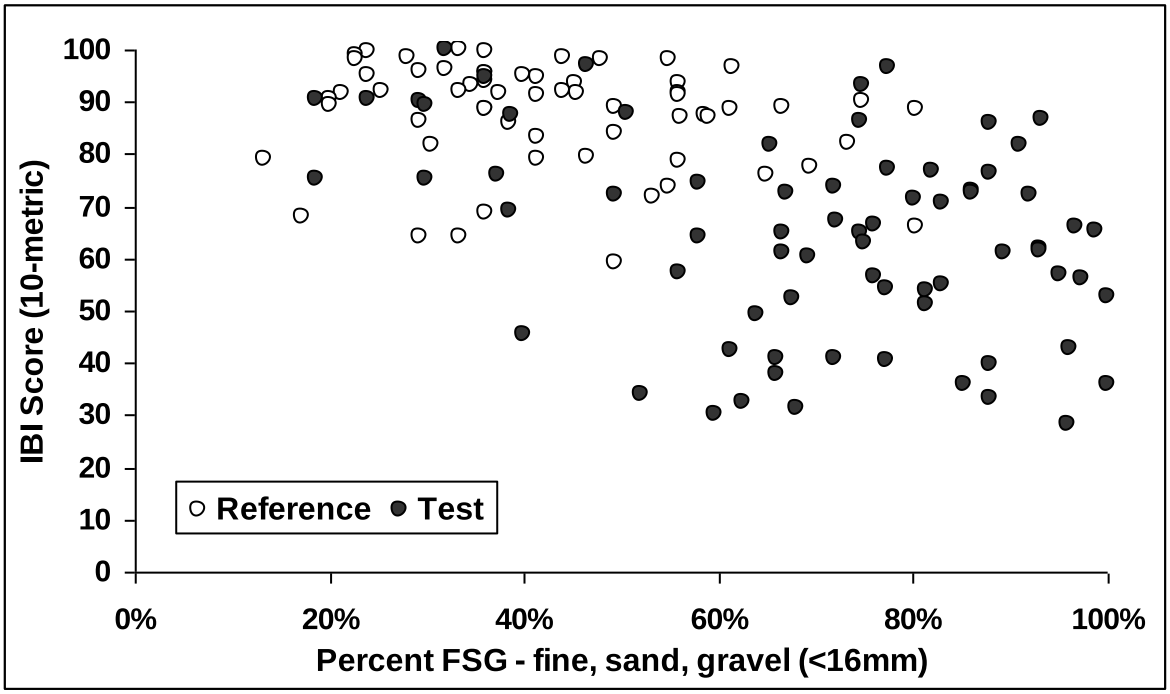
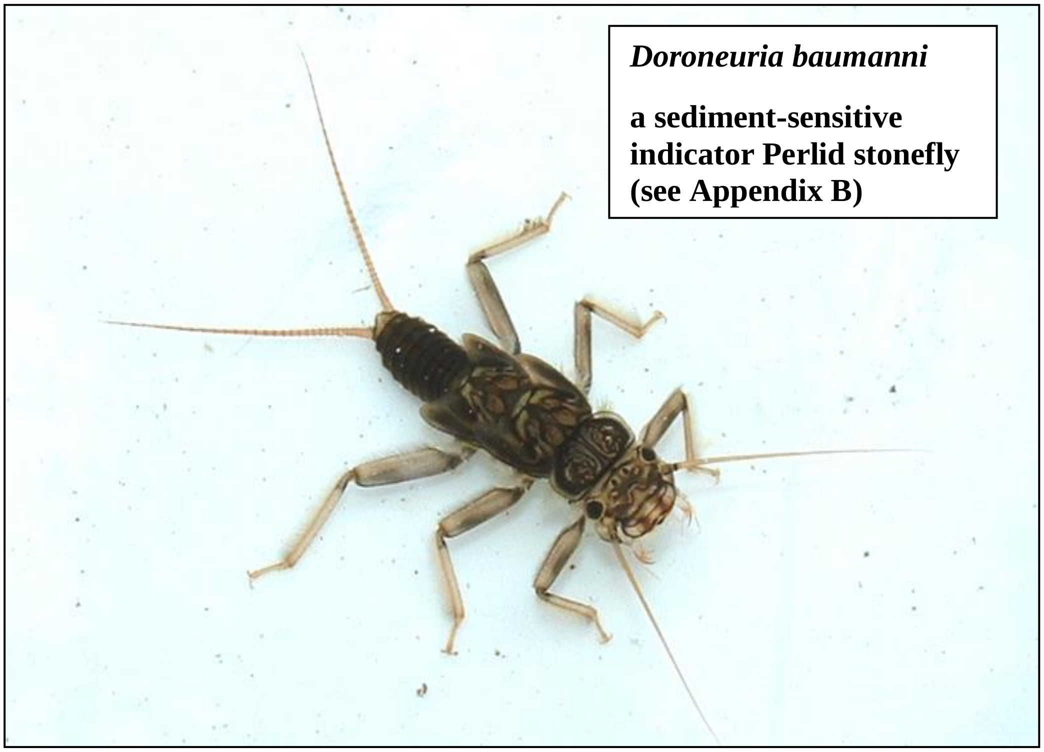


Figure 1. Response of benthic invertebrate multimetric Index of Biological Integrity over a gradient of deposition of fines, sand and gravel in streams of the eastern Sierra Nevada.



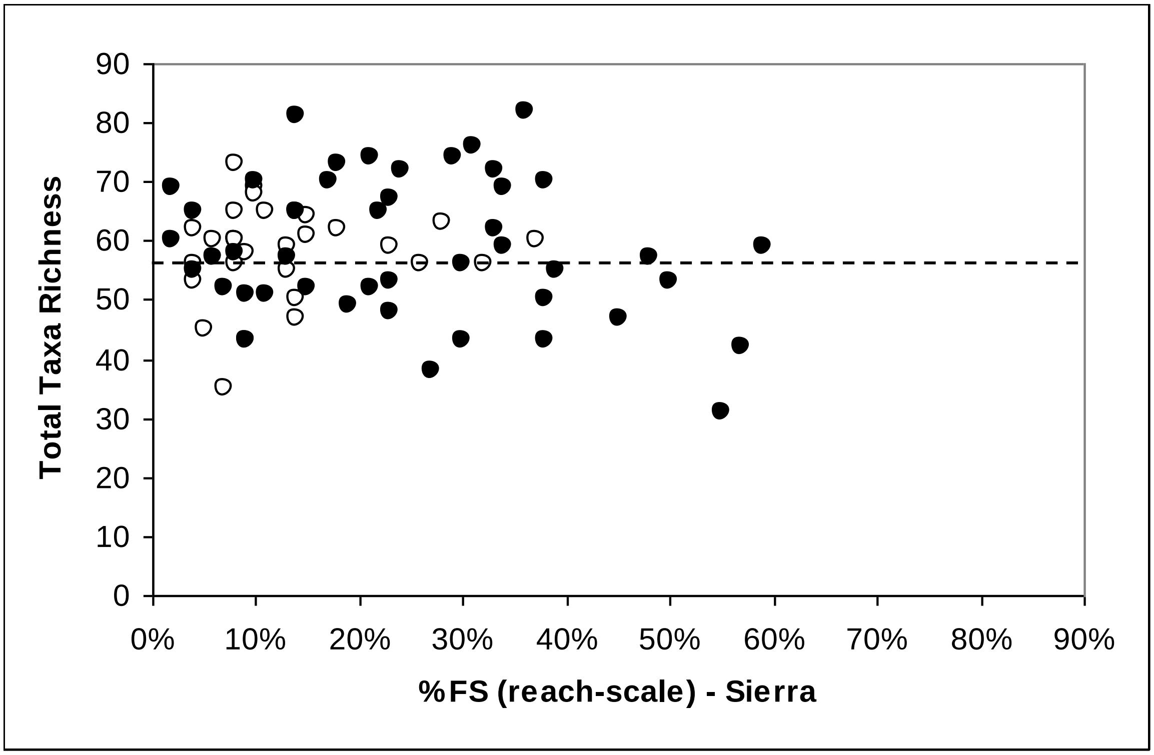


Figure 2. Total taxa richness from reach-wide benthos samples in the Sierra Nevada. Open symbols reference, filled symbols test, dashed line the 25th reference percentile.

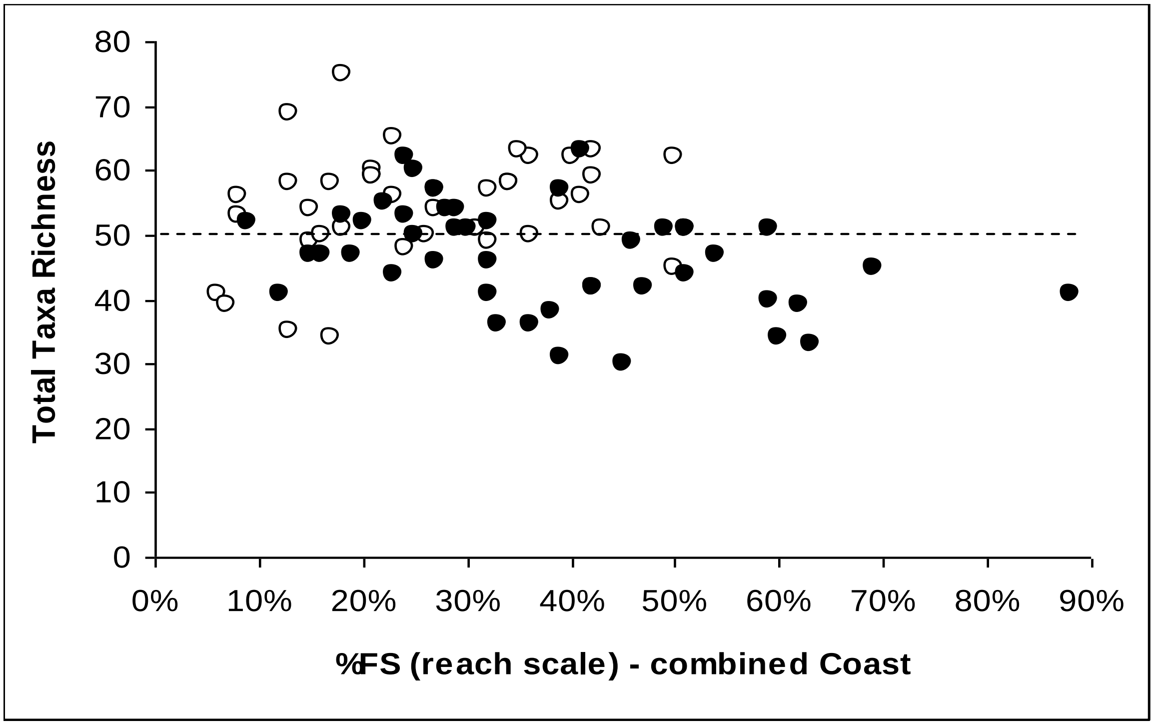


Figure 3. Total taxa richness from reach-wide benthos samples in the central coast. Open symbols reference, filled symbols test, dashed line the 25th reference percentile.

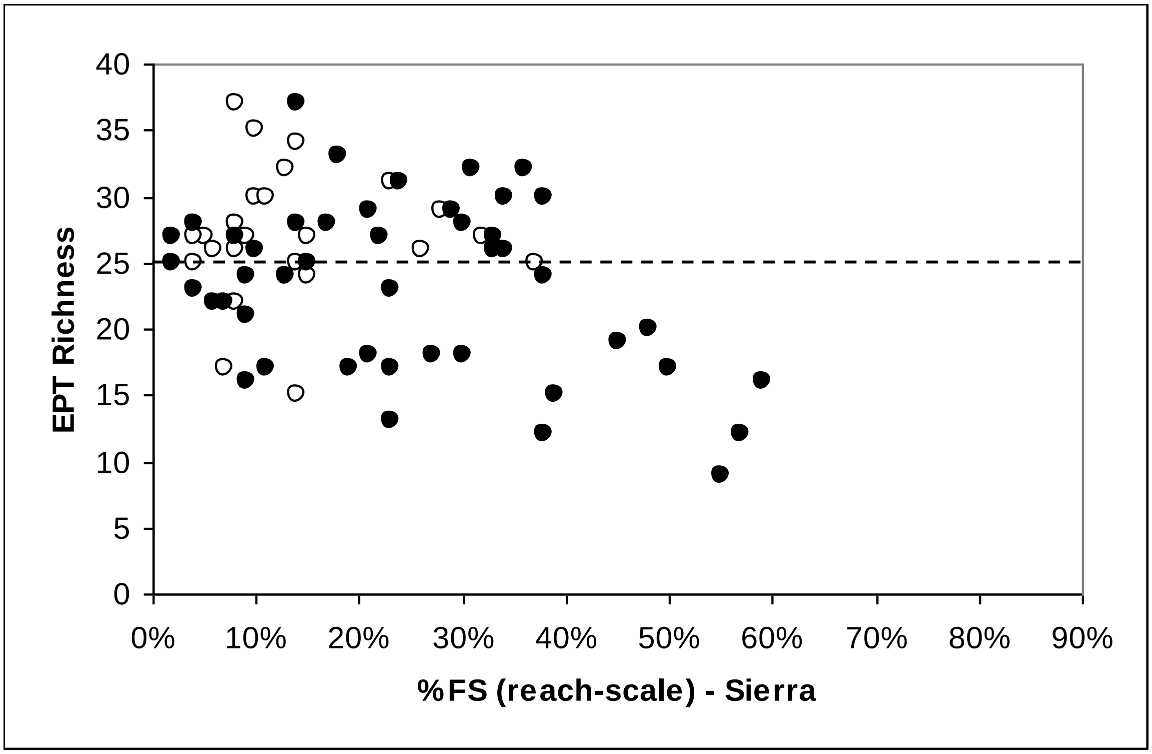


Figure 4. EPT taxa richness from reach-wide benthos samples in the Sierra Nevada. Open symbols reference, filled symbols test, dashed line the 25th reference percentile.

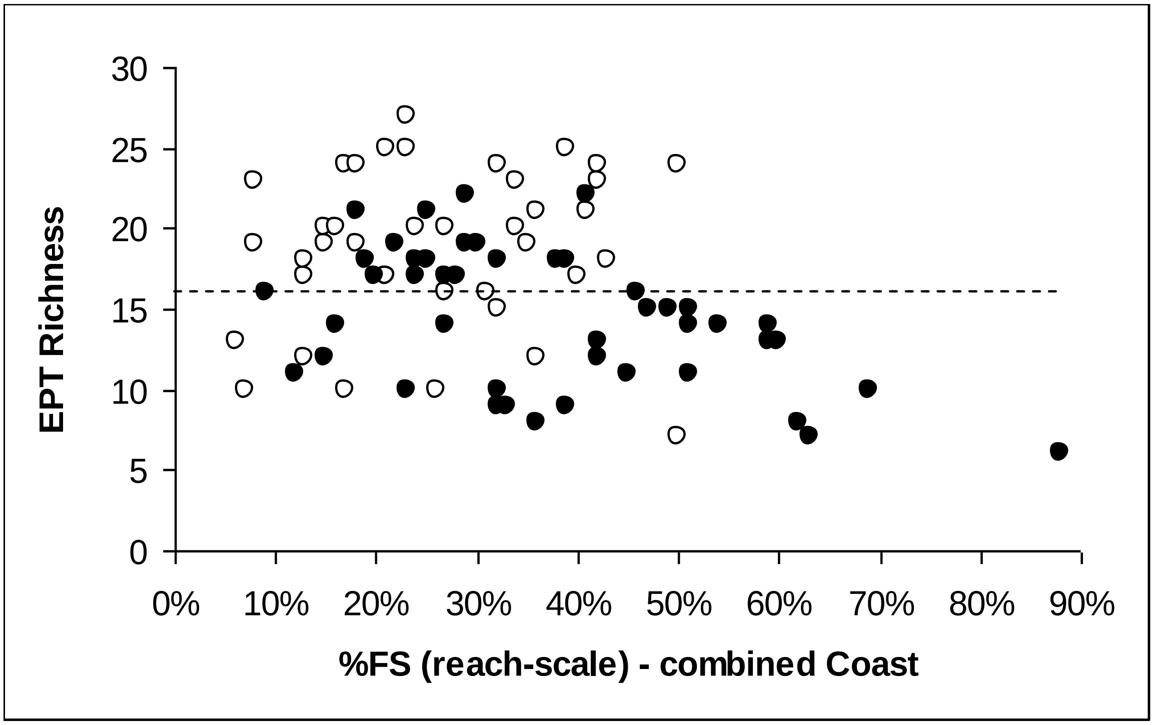


Figure 5. EPT taxa richness from reach-wide benthos samples in the central coast. Open symbols reference, filled symbols test, dashed line the 25th reference percentile.

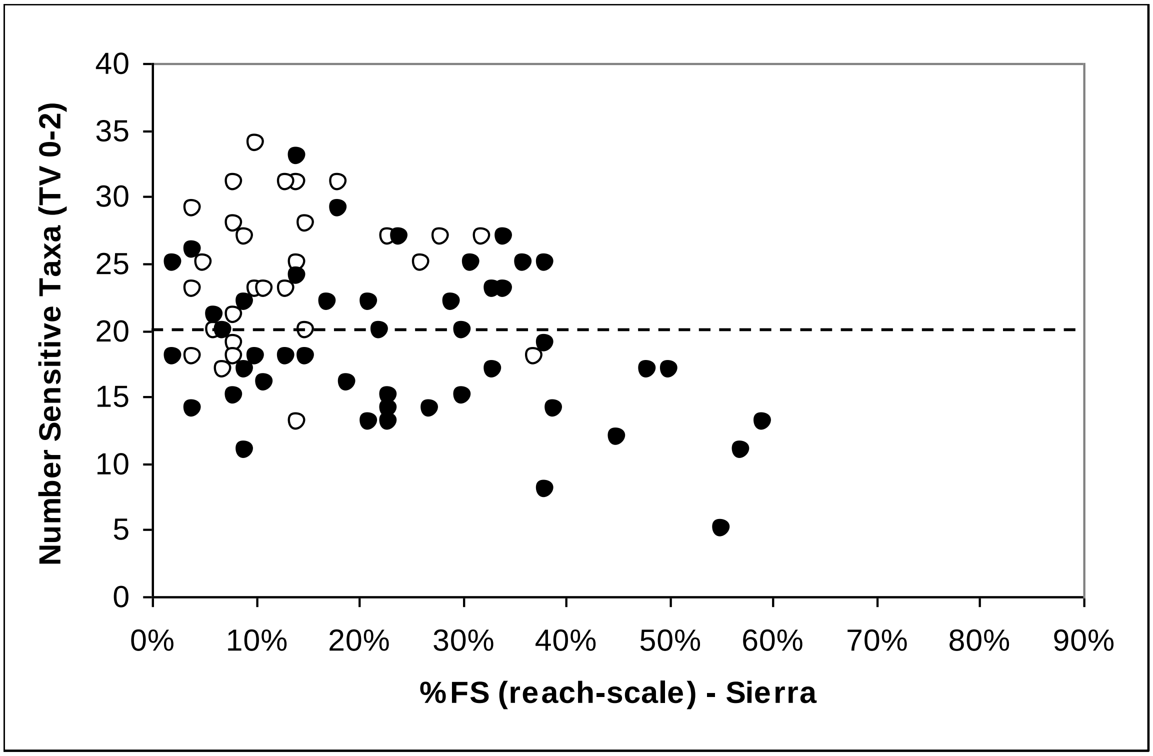


Figure 6. Sensitive taxa richness from reach-wide benthos samples in the Sierra Nevada. Open symbols reference, filled symbols test, dashed line the 25th reference percentile.

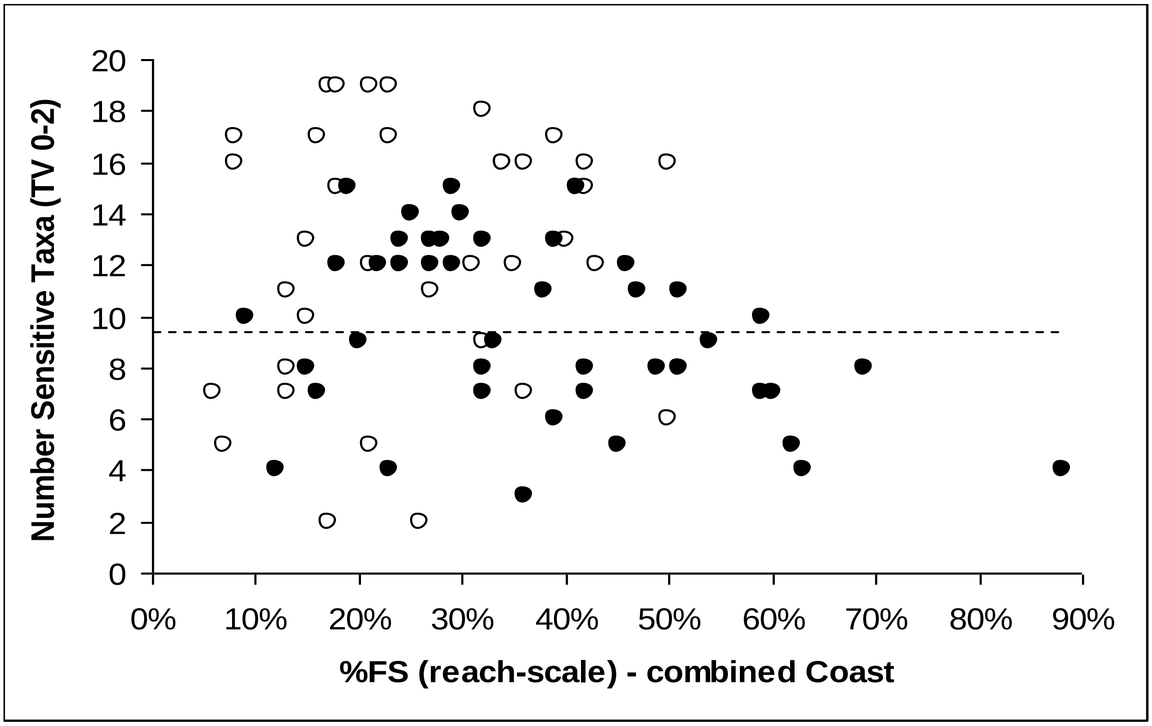


Figure 7. Sensitive taxa richness from reach-wide benthos samples in the central coast. Open symbols reference, filled symbols test, dashed line the 25th reference percentile.

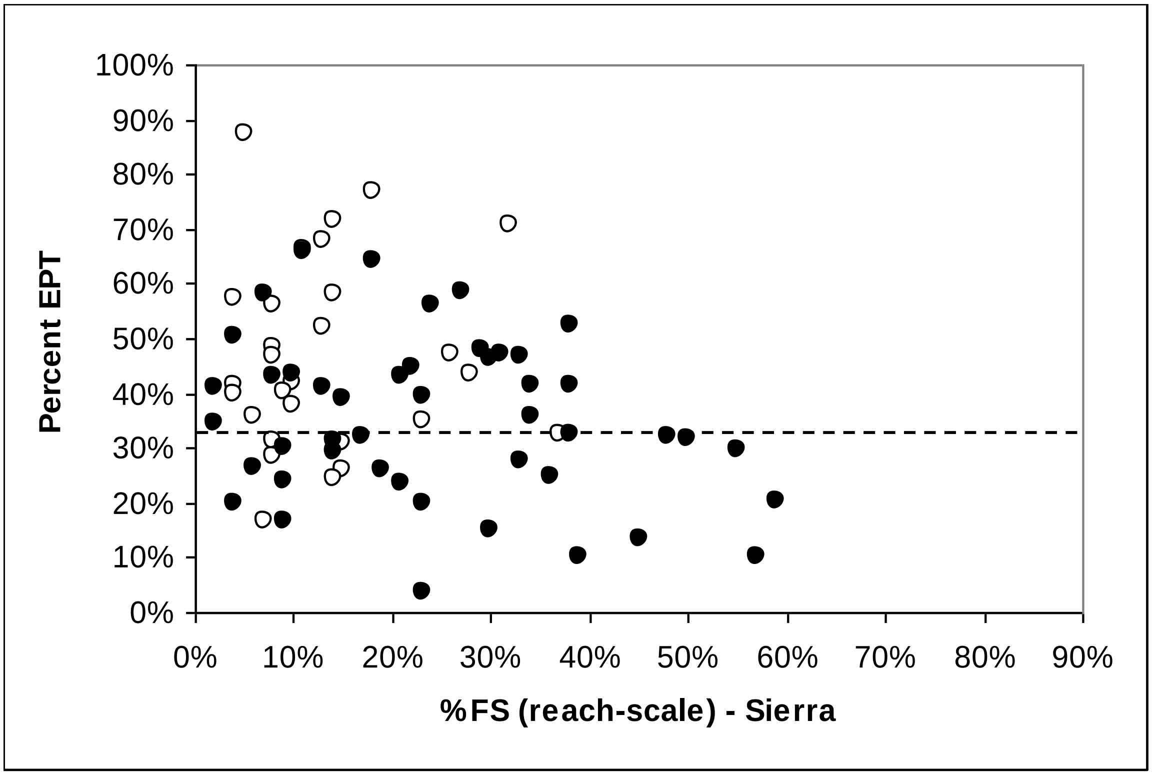


Figure 8. Percent EPT taxa from reach-wide benthos samples in the Sierra Nevada. Open symbols reference, filled symbols test, dashed line the 25th reference percentile.

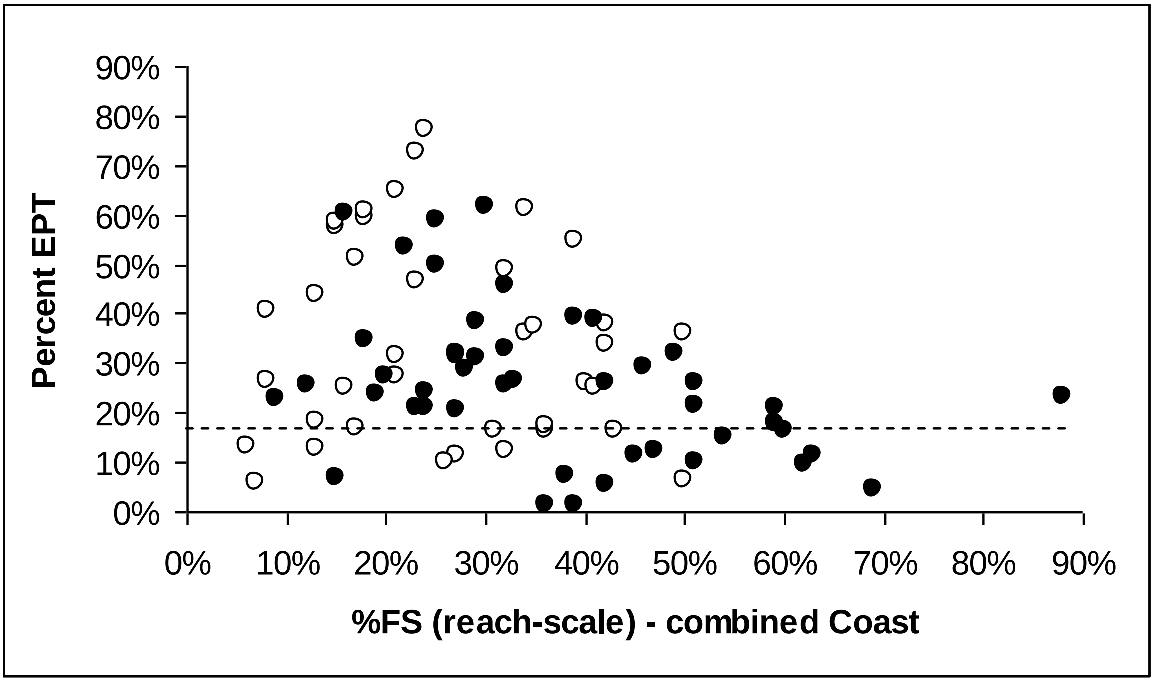


Figure 9. Percent EPT taxa from reach-wide benthos samples in the central coast. Open symbols reference, filled symbols test, dashed line the 25th reference percentile.

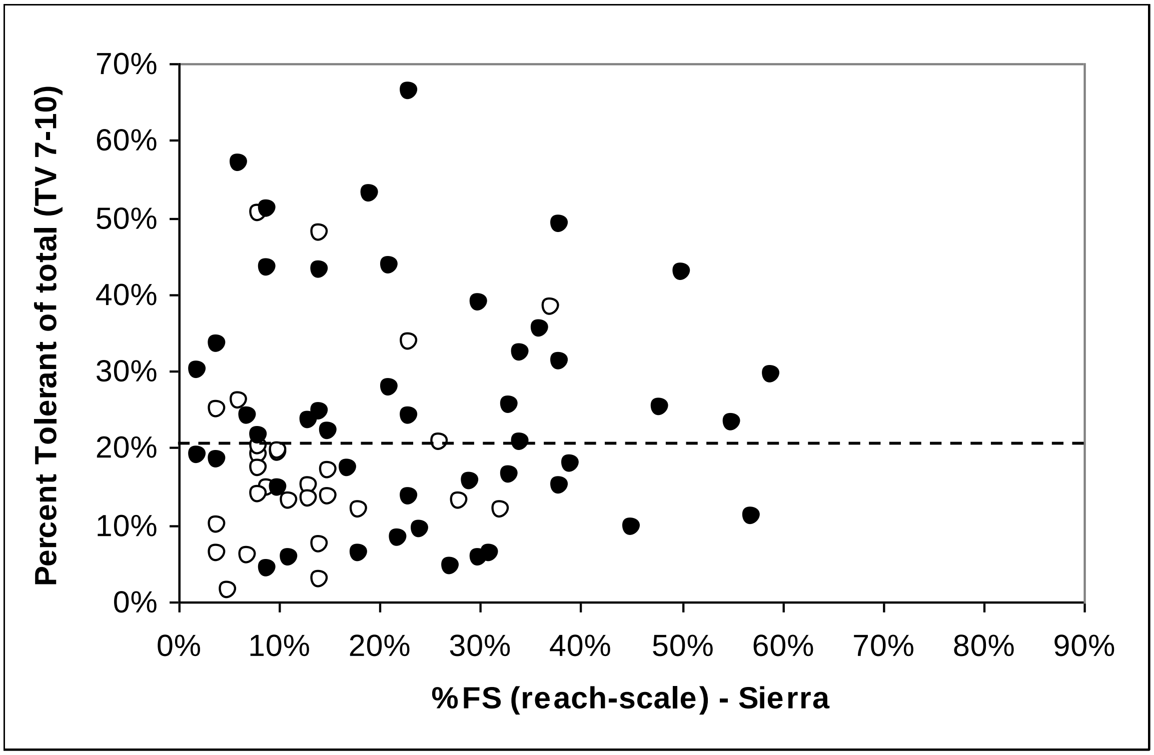


Figure 10. Percent tolerant total from reach-wide benthos samples in the Sierra Nevada. Open symbols reference, filled symbols test, dashed line the 75th reference percentile.

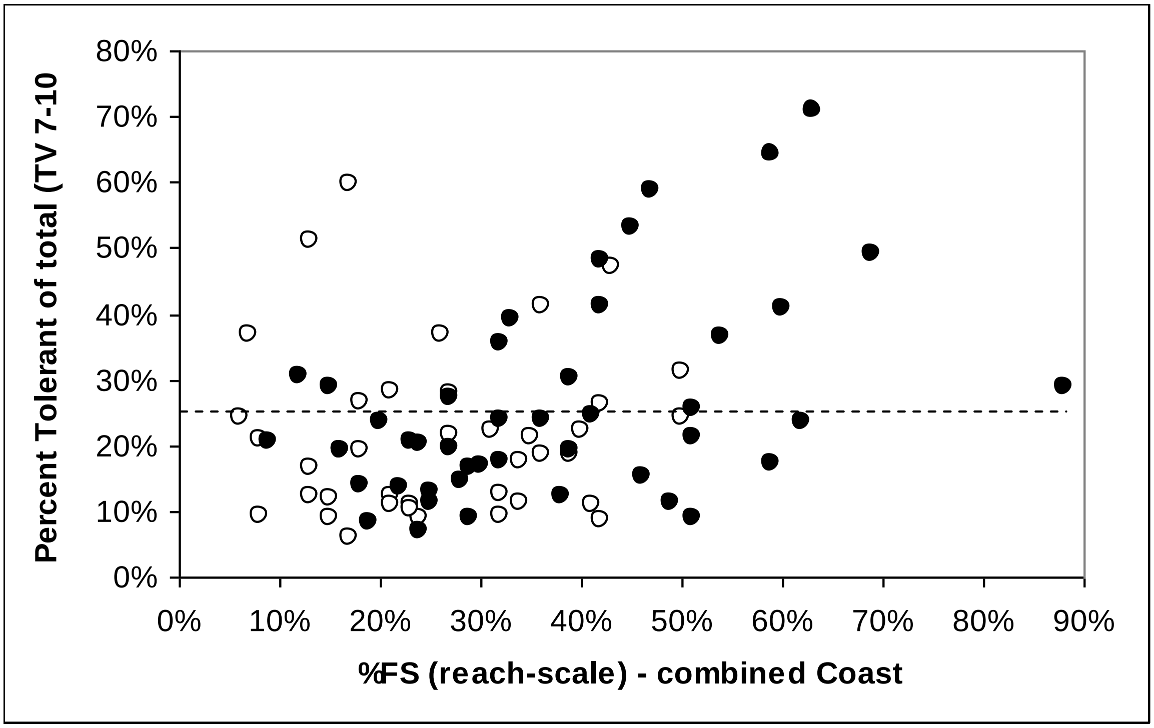


Figure 11. Percent tolerant total from reach-wide benthos samples in the central coast. Open symbols reference, filled symbols test, dashed line the 75th reference percentile.

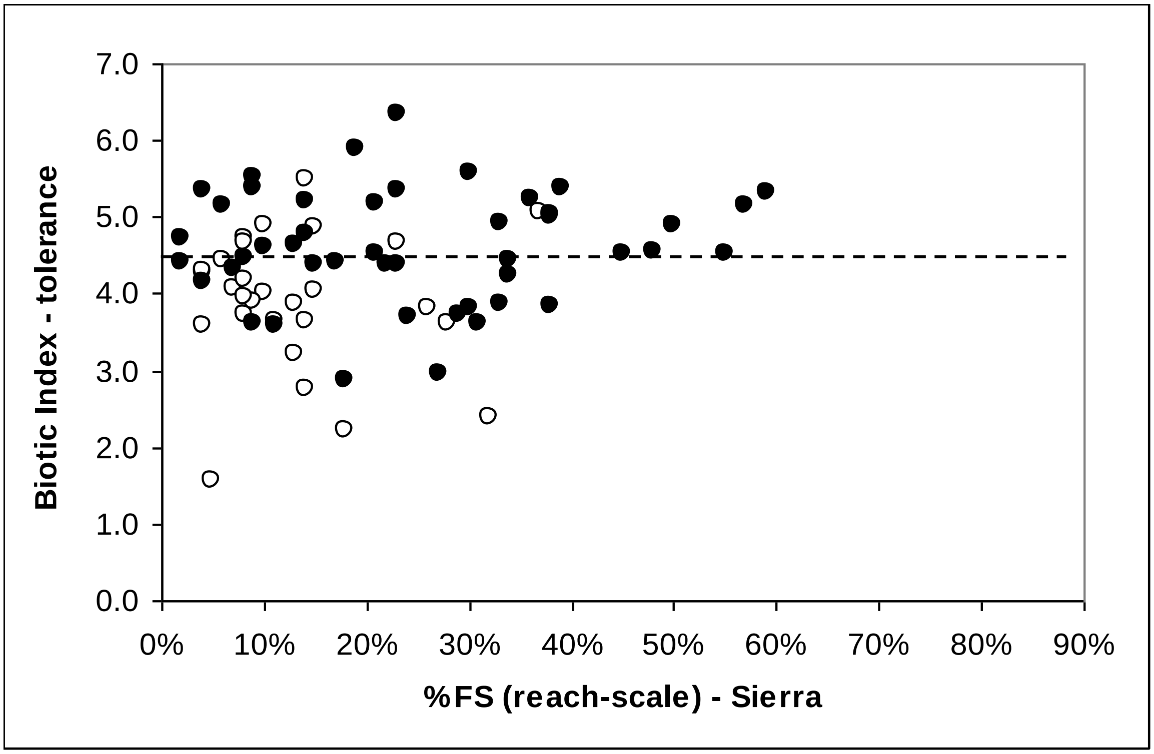


Figure 12. Biotic Index from reach-wide benthos samples in the Sierra Nevada. Open symbols reference, filled symbols test, dashed line the 75th reference percentile.

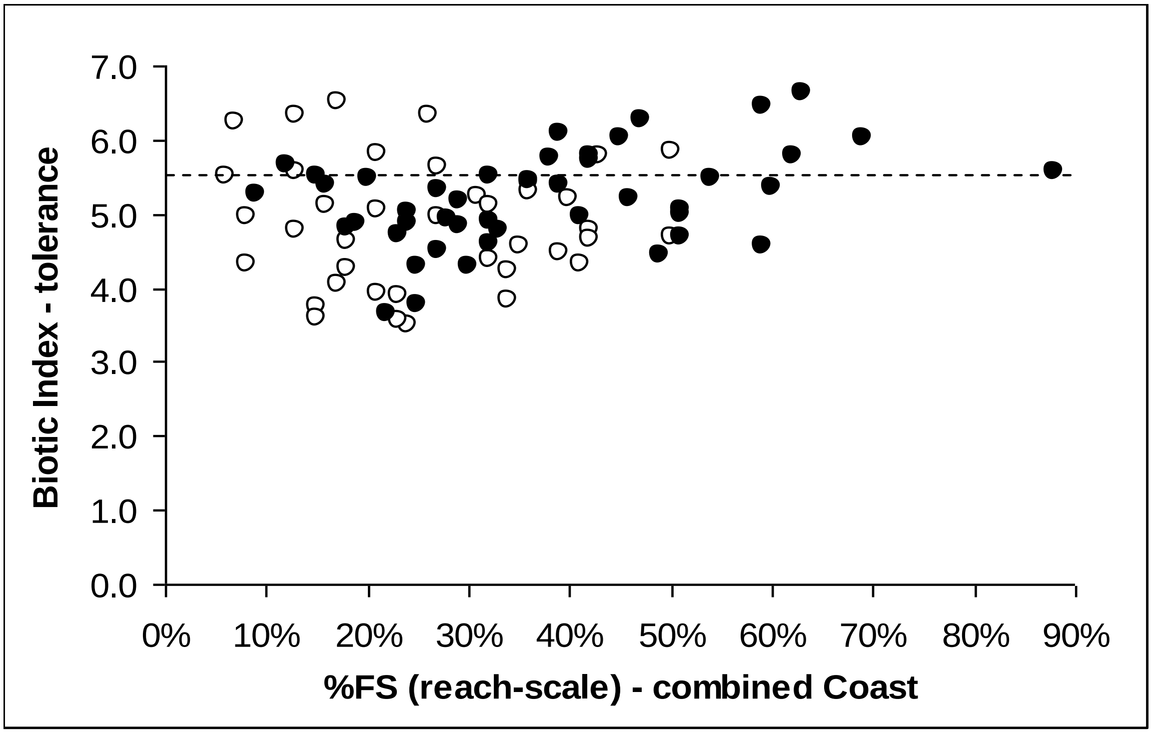


Figure 13. Biotic Index from reach-wide benthos samples in the central coast. Open symbols reference, filled symbols test, dashed line the 75th reference percentile.

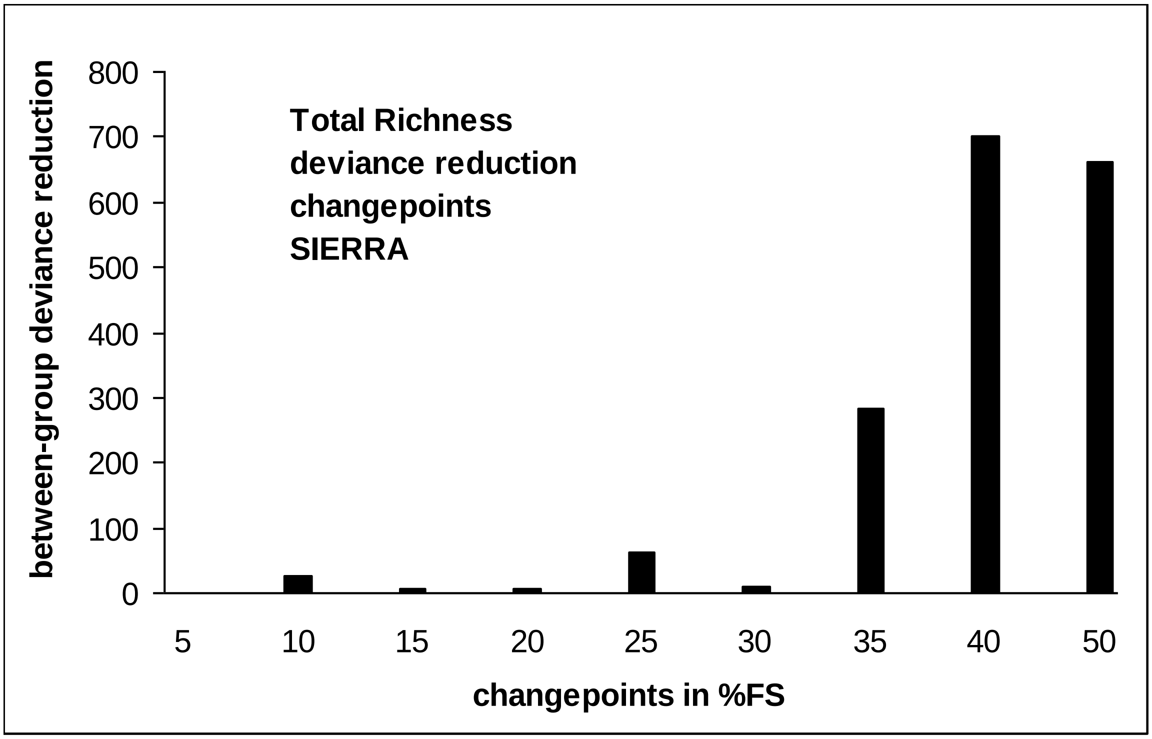


Figure 14. Sierra total richness and %FS sediment - analysis of threshold responses using deviance reduction method. See Figure 2.

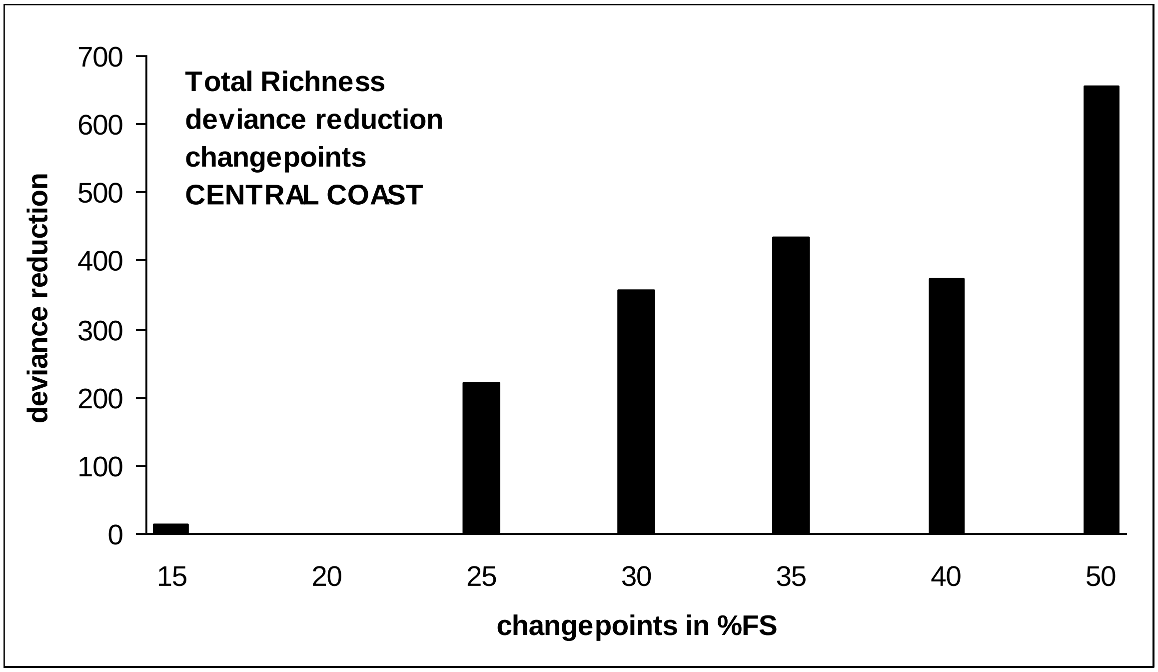


Figure 15. Central coast total richness and %FS sediment - analysis of threshold responses using deviance reduction method. See Figure 3.

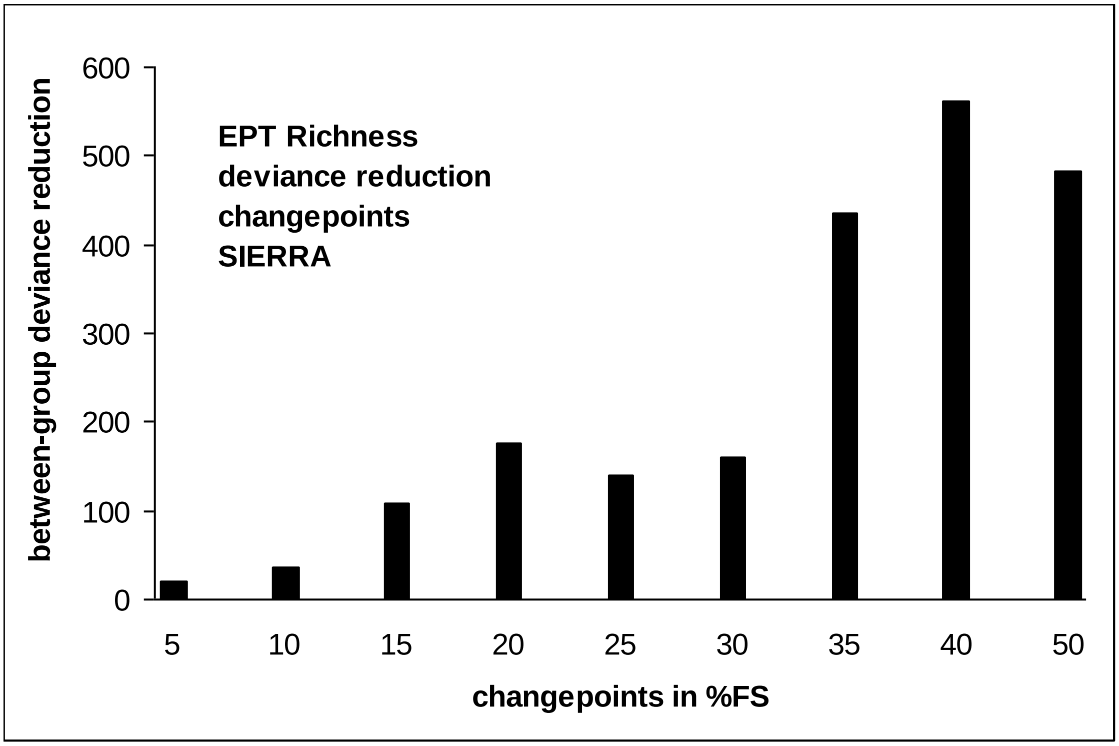


Figure 16. Sierra EPT richness and %FS sediment - analysis of threshold responses using deviance reduction method. See Figure 4.

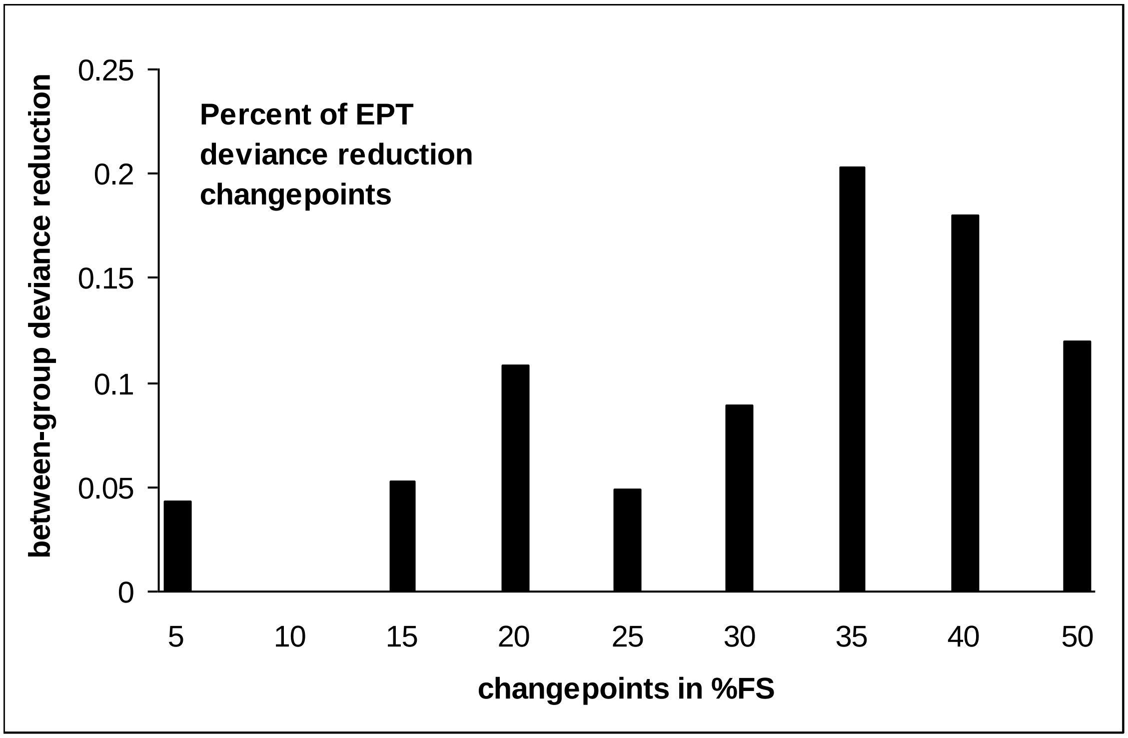


Figure 17. Sierra EPT percent of total and %FS sediment - analysis of threshold responses using deviance reduction method. See Figure 8.

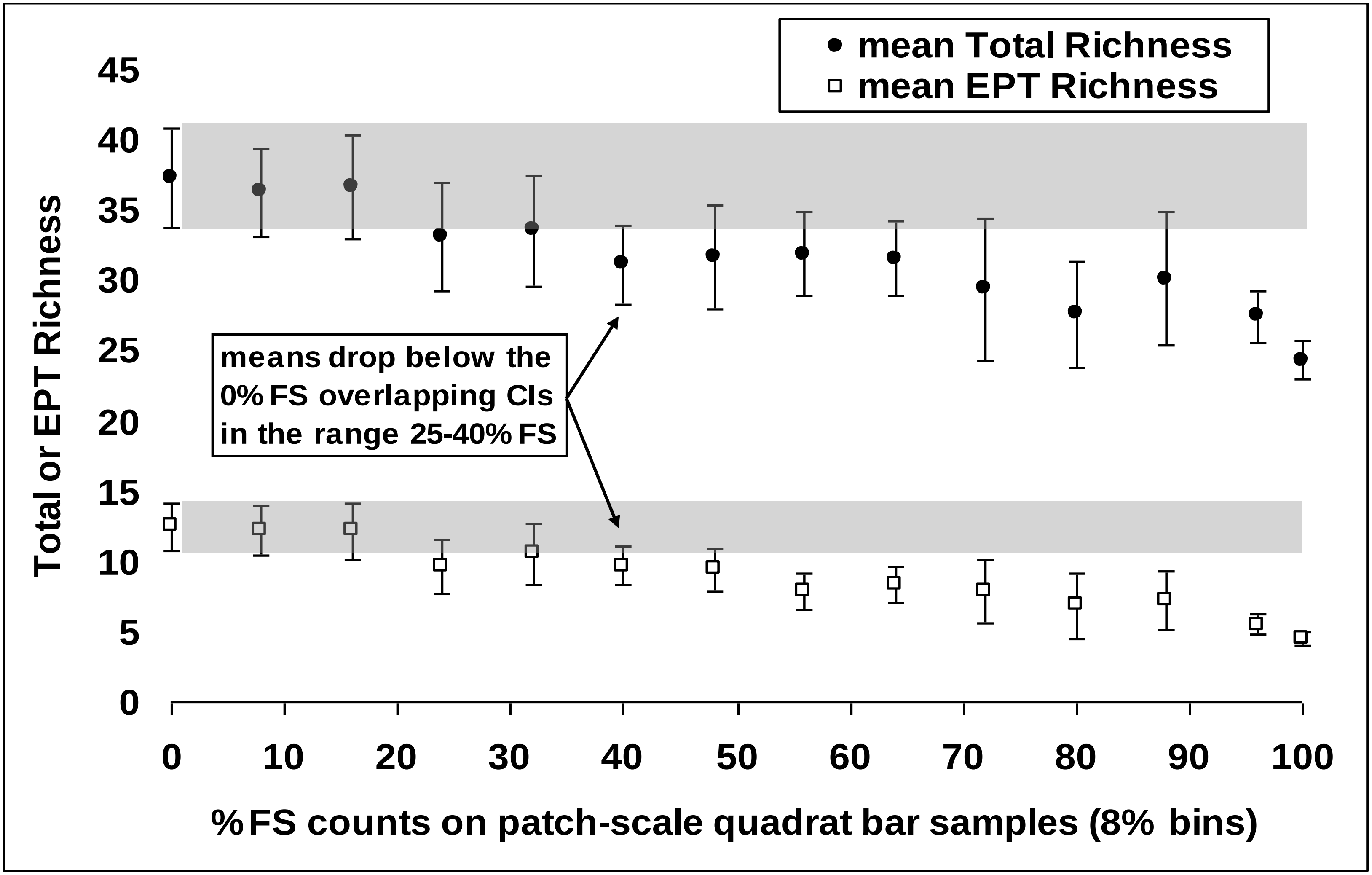


Figure 18. Patch-scale samples (20x20 cm grid quadrats) taken on depositional bar formations show that means of total and EPT richness decline significantly below the 95% confidence intervals of patches with no FS cover (0) above 25-40% FS.

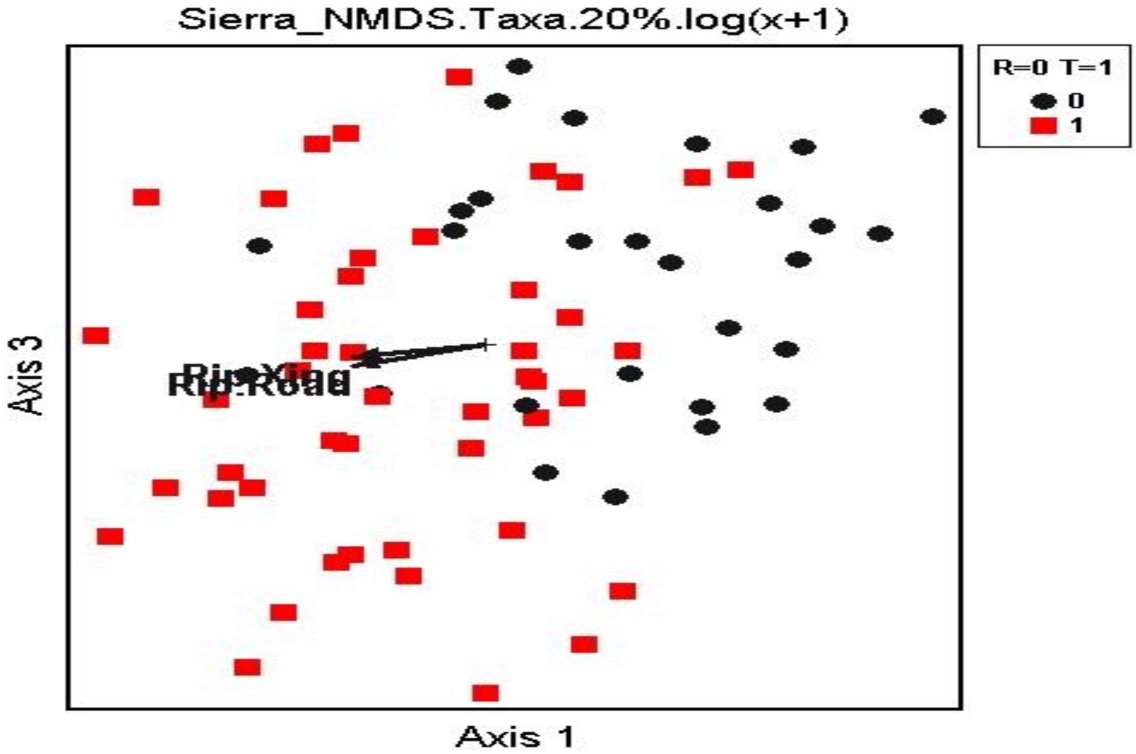


Figure 19. NMDS ordination of RWB samples from the Sierra, R=Reference(0), and T=Test(1). Environmental vectors most related to R/T separation linked to riparian roads.

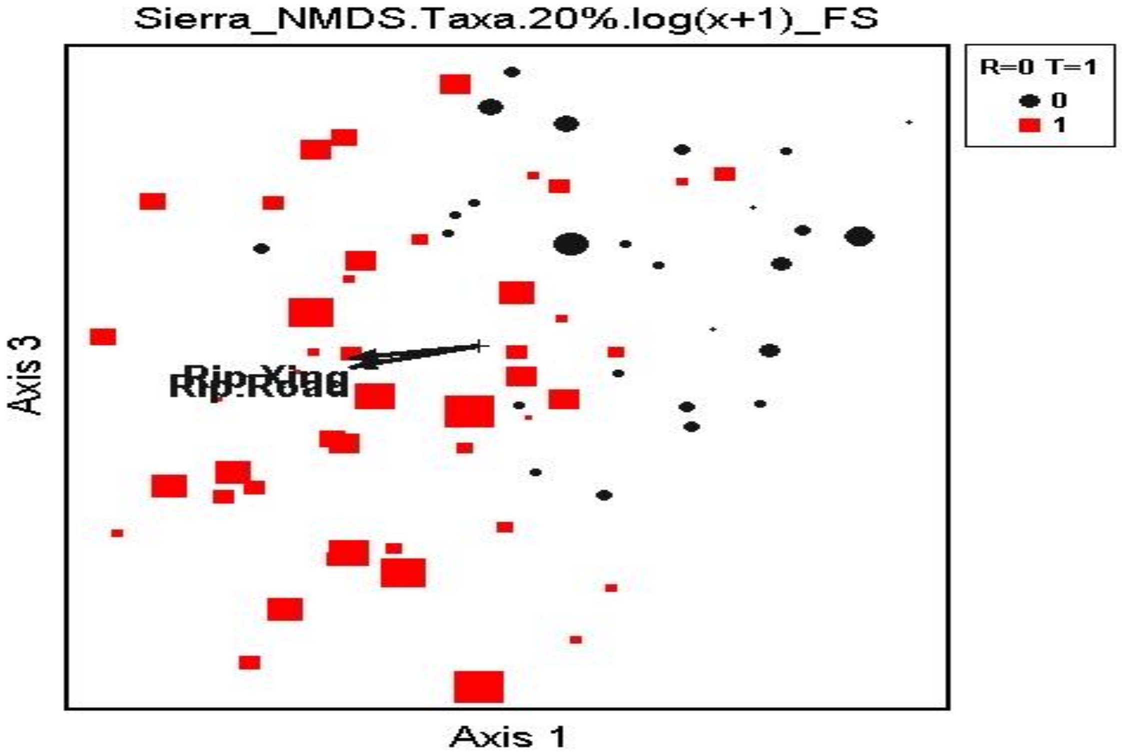


Figure 20. Same ordination as above, symbol size proportional to %FS, related to roads.

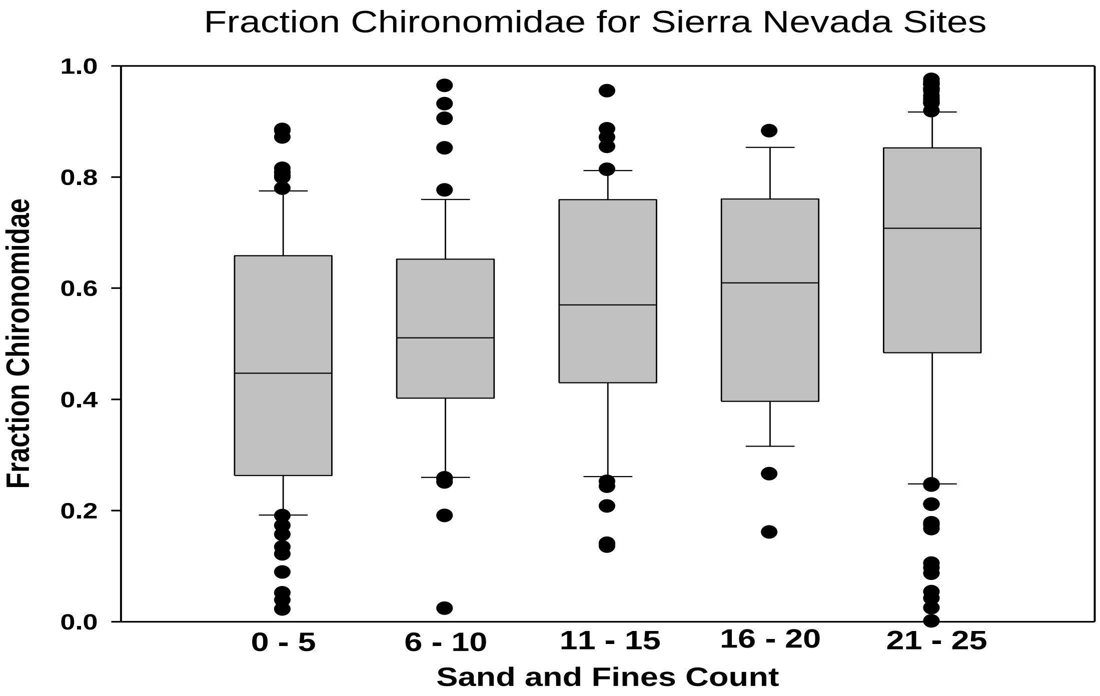


Figure 21. Fraction of Chironomidae (small midge flies, often sediment-tolerant) in relation to fines and sand deposition within patch-scale samples (20 x 20 cm grid frame) on bar formations in the Sierra Nevada. Bar (25th-75th %tile) and whisker (10th-90th %tile) plots with median and outliers. N = 92, 53, 56, 27, 142 in sequence.

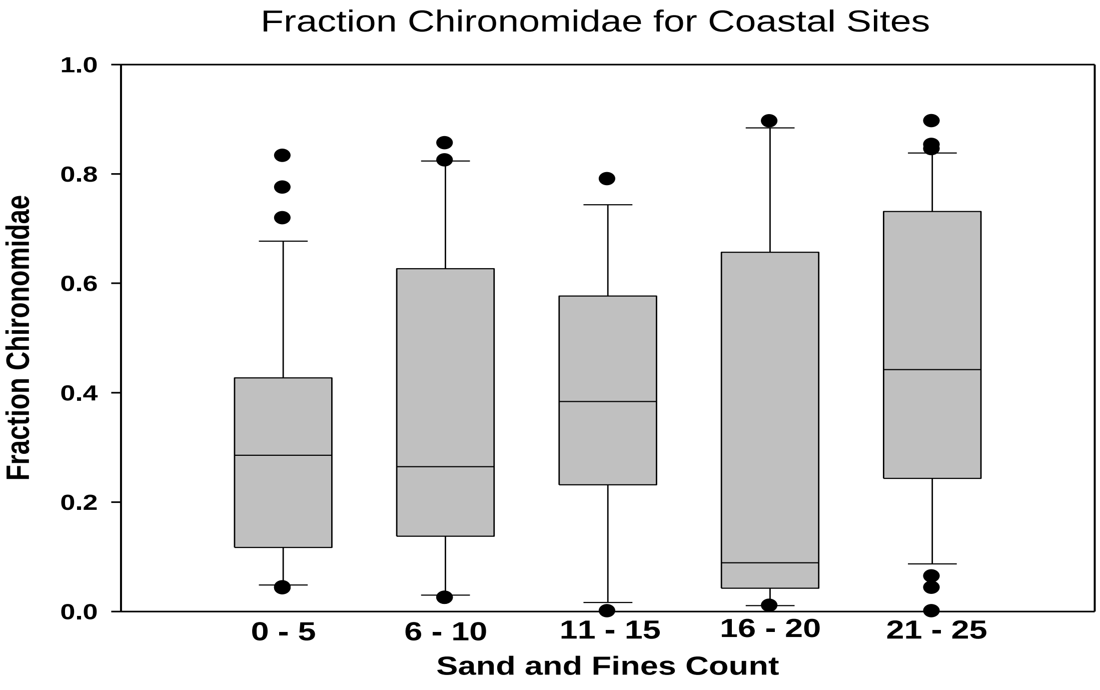


Figure 22. Fraction of Chironomidae (small midge flies, often sediment-tolerant) in relation to fines and sand deposition within patch-scale samples (20x20 cm grid frame) on bar formations in the central coast range. Bar (25th-75th %tile) and whisker 10th-90th %tile) plots with median and outliers. N = 32, 20, 15, 14, 39 in sequence.

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APPENDIX A. Biological metric criteria for Sierra streams. Moderate to high disturbance exceed 75th /90th reference percentiles for 3 or more of 6 metrics selected (red/red-gray). Reference distribution based on the 28 streams shown, Test exceedances on next page. Sediment Criteria refers to report 1 findings of this series, showing where 5 or more of 9 sediment criteria were exceeded.

Stream	Site	R or T	Total Richness	EPT Richness	Sensitive Richness	%EPT	Biotic Index	Percent Tolerant	Exceed ≥3 Criteria	Sediment Criteria ≥5 of 9
West Walker R	Above Leavitt Oxbow	Reference	**45**	27	25	87.2%	1.56	1.3%		
Trout Cr	Above Pioneer Trail	Reference	56	26	25	47.0%	3.83	**20.8%**		
Stanislaus R (Clark Fk)	Above Arnot	Reference	65	34	31	58.3%	2.76	2.9%		
Blackwood Cr	Below Barker Pass Road	Reference	**35**	**17**	**17**	**16.5%**	4.06	6.1%	X	
General Cr	Above Loop Road	Reference	**47**	25	25	71.7%	3.63	7.4%		
Arnot Cr	At Trailhead	Reference	69	35	34	41.9%	4.01	19.1%		
Tuolumne R (Middle Fk)	Below Mather Camp	Reference	61	**24**	20	**26.2%**	**4.85**	17.0%		
Pitman Cr	Below Highway 168	Reference	68	30	23	37.9%	**4.90**	19.6%		
Home Camp Cr	Inside Wilderness	Reference	63	29	27	43.6%	3.62	13.0%		X
Kern River (South Fork)	Above Campground	Reference	60	25	**18**	**32.4%**	**5.06**	**38.3%**		X
Boulder Creek	Above Florence Lake Trail	Reference	**50**	**15**	**13**	**24.4%**	**5.49**	**48.0%**	X	
Salmon Creek	Horse Meadow CG	Reference	60	26	20	35.6%	4.44	**26.0%**		
Silver Creek	Above Silver Mountain Site	Reference	62	33	31	76.7%	2.21	11.8%		
Silver King Creek	Lower Meadow	Reference	**53**	25	23	41.4%	4.27	**25.0%**		
Carson River (East Fork)	Above Silver King Creek	Reference	59	31	27	35.1%	**4.66**	**33.7%**		
Hot Springs Creek	Above Footbridge	Reference	56	28	28	**31.4%**	**4.74**	**50.4%**		
Willow Creek	Above West Carson	Reference	56	27	27	70.8%	2.39	11.8%		X
Little Walker River	Above Cow Camp Creek	Reference	62	28	29	57.1%	3.59	6.2%		
Green Creek	Above Green Creek Road	Reference	60	**22**	21	**28.4%**	**4.67**	19.1%		
Minaret Creek	Below Falls	Reference	59	**24**	23	52.1%	3.86	15.1%		
San Joaquin (Middle Fork)	Below Soda Springs CG	Reference	58	27	27	40.2%	3.90	14.9%		
Lyons Creek	Below Wright Lake Road	Reference	73	26	**19**	48.5%	3.96	13.8%		
Onion Valley Creek	Above MF Feather River	Reference	56	27	**18**	39.8%	4.31	9.8%		
Nelson Cr	Above Feather River	Reference	65	37	31	46.9%	4.19	20.2%		
Feather River (North Fork)	Below Gun Club	Reference	64	27	28	**30.9%**	4.04	13.6%		
Warner Creek	Above CG	Reference	**55**	32	31	68.0%	3.21	13.4%		
Hatchet Creek	Above Moose Camp	Reference	60	28	**18**	56.0%	3.73	17.3%		
Martin Cr	at Mineral	Reference	65	30	23	66.3%	3.65	13.1%		
		75th criterion	**56**	**25**	**20**	**34.4%**	**4.50**	**20.4%**		
		90th criterion	**49.1**	**23.4**	**18**	**27.7%**	**4.87**	**35.1%**		
		exceeds	**<**	**<**	**<**	**<**	**>**	**>**		

TEST STREAMS			Total R	EPT R	Sensitive	%EPT	BI	%Tol	Biol Crit	Sed Crit
Deadman Cr	Above Road Crossing	Test	49	17	16	26.1%	5.89	53.1%	X	
Lewis Fork	Below Cedar Valley	Test	56	28	20	46.4%	3.83	5.7%		
Ward Cr	Top Avulsed Meadow	Test	51	24	22	23.9%	3.61	4.1%		
West Carson R	Upper Hope	Test	38	18	14	58.6%	2.96	4.5%	X	
Jawbone Cr	Above Falls	Test	76	32	25	47.1%	3.61	6.3%		
Nelder Cr	Below California Cr	Test	82	32	25	24.8%	5.24	35.4%	X	X
Dry Meadow Creek	Camp 4	Test	62	27	23	46.8%	3.87	16.4%		
Nobe Young Creek	Camp Whitsett	Test	70	30	25	52.6%	3.84	15.0%		
South Creek	Below Johnsondale	Test	59	16	13	20.3%	5.33	29.5%	X	X
Peppermint Creek	Above Lower Campground	Test	74	29	22	43.1%	4.52	27.9%		
Freeman Creek	Pyles Camp	Test	42	12	11	10.1%	5.16	11.2%	X	X
Willow Creek (North Fork)	Above Gray Mountain CG	Test	43	21	17	16.7%	5.38	43.5%	X	
Tenmile Creek	Below Tenmile CG	Test	55	15	14	10.3%	5.38	17.7%	X	X
Sagehen Creek	Below Highway 89	Test	57	22	21	26.5%	5.14	57.0%	X	
Prosser Creek	Above Highway 89	Test	65	28	26	20.0%	5.36	33.5%		
Little Truckee River	Upper Perazzo Meadow	Test	65	28	24	29.3%	5.22	43.0%		
Swauger Creek	Above Gauging Station	Test	47	19	12	13.6%	4.51	9.7%	X	X
Consumnes River (Middle Fork)	Pipi CG	Test	65	27	20	44.7%	4.37	8.2%		
Consumnes River (North Fork)	Above Caps Crossing CG	Test	70	26	18	43.5%	4.60	14.6%		
Jones Fork Silver Creek	Above Icehose Road	Test	43	18	15	15.2%	5.59	38.8%	X	X
American River (Middle Fork)	Above Ahart Campground	Test	51	17	16	66.0%	3.59	5.8%		
Meadow Valley Creek	Above Meadow Camp	Test	67	23	13	19.9%	5.35	13.6%	X	
Spanish Cr	Below Meadow Valley Cr	Test	55	23	14	50.5%	4.17	18.4%		
Sulfur Creek	Above White Hawk Ranch	Test	50	24	19	41.4%	5.03	49.2%		
Jameson Creek	Above Plumas Eureka CG	Test	59	30	27	41.6%	4.45	32.3%		
Butt Creek	Above Soldier Cr	Test	81	37	33	31.3%	4.79	24.6%		
Willard Creek	Above 29N02	Test	43	16	11	30.1%	5.53	51.1%	X	
Wolf Cr	At County CG	Test	58	27	15	43.0%	4.46	21.6%		
Susan River	By Biz Johnson Trail	Test	52	18	13	23.5%	5.18	43.5%	X	
Goodrich Creek	Above Hwy 36 Bridge	Test	53	17	14	39.3%	4.39	24.0%		
Susan River	Above Hobo Camp	Test	43	12	8	32.6%	5.01	31.2%	X	X
McCloud River	Abvoe Algoma CG	Test	60	27	25	41.1%	4.74	29.9%		
Lassen Cr	Below Lassen Cr C.G.	Test	72	26	17	27.8%	4.93	25.4%		
Pit River (South Fork)	Below Jess Valley Bridge	Test	31	9	5	29.6%	4.53	23.2%	X	X
Burney Creek	Above Jackrabbit Bridge	Test	74	29	22	47.8%	3.72	15.7%		
Hat Creek	Below Twin Bridges CG	Test	57	24	18	41.2%	4.64	23.5%		
Big Meadow Cr	At Big Meadow Camp	Test	48	13	15	3.7%	6.36	66.3%	X	
Little Boulder Cr	Little Boulder Sequoia Grove	Test	69	26	23	35.8%	4.23	20.7%		
Mugler Cr	Below Beasore Rd	Test	53	17	17	31.7%	4.89	42.7%	X	X
Oregon Cr	above Millers Crossing	Test	69	25	18	34.5%	4.41	19.1%		
Poplar Cr	above gravel yard	Test	52	25	18	39.0%	4.37	22.1%		
Fall Cr	above FS Road #24	Test	73	33	29	64.3%	2.88	6.2%		
Cascade Cr	below FS Road #94	Test	72	31	27	56.0%	3.69	9.3%		
Deer Cr	DFG fishing access	Test	70	28	22	32.2%	4.42	17.2%		
Butte Cr (Shasta)	above wooden bridge	Test	57	20	17	32.1%	4.54	25.1%		
Mill Cr	below summer homes	Test	52	22	20	57.9%	4.33	24.1%		

Appendix B. Sediment Tolerance Values

Taxa (Genus_species/group)	Sample Type Reach-Wide Benthos & Grid Quadrats	Region	Total # Samples N=98 streams & 490 bar quadrats (minimum 15)	Sediment Tolerance Value
Apatania	RWB+Bar-Patch	Sierra	58	0
Atherix_pachypus	RWB	Sierra	17	0
Cricotopus_Nostococladius	RWB+Bar-Patch	Sierra+Coast	120	0
Dicosmoecus	RWB	Sierra	22	0
Doroneuria_baumanni	RWB	Sierra	26	0
Eukiefferiella_devonica	RWB	Sierra+Coast	18	0
Nixe	RWB+Bar-Patch	Sierra+Coast	72	0
Rhyacophila_angelita	RWB	Sierra	20	0
Rhyacophila_sibirica	RWB	Sierra+Coast	20	0
Ampumixis_dispar	RWB+Bar-Patch	Sierra+Coast	36	1
Calineuria_californica	RWB+Bar-Patch	Sierra+Coast	108	1
Ceratopsyche	RWB+Bar-Patch	Sierra+Coast	75	1
Cinygmula	RWB+Bar-Patch	Sierra+Coast	186	1
Cultus	RWB	Sierra	15	1
Drunella_spinifera	RWB+Bar-Patch	Sierra	77	1
Epeorus	RWB+Bar-Patch	Sierra+Coast	120	1
Eukiefferiella_brehmi	RWB+Bar-Patch	Sierra+Coast	73	1
Glossosoma	RWB+Bar-Patch	Sierra+Coast	66	1
Heterlimnius_corpulentus	Bar-Patch	Sierra+Coast	28	1
Lepidostoma	RWB+Bar-Patch	Sierra+Coast	305	1
Malenka	RWB+Bar-Patch	Sierra+Coast	91	1
Micrasema	RWB+Bar-Patch	Sierra+Coast	169	1
Neophylax	RWB+Bar-Patch	Sierra+Coast	102	1
Orohermes_crepusculus	RWB	Sierra	16	1
Polycentropus	RWB+Bar-Patch	Sierra+Coast	37	1
Polypedilum_aviceps	RWB+Bar-Patch	Sierra+Coast	103	1
Protzia	RWB+Bar-Patch	Sierra+Coast	59	1
Rheotanytarsus	RWB+Bar-Patch	Sierra+Coast	162	1
Rhyacophila_betteni	RWB+Bar-Patch	Sierra+Coast	67	1
Tinodes	Bar-Patch	Sierra+Coast	16	1
Turbellaria	RWB+Bar-Patch	Sierra+Coast	116	1
Agapetus	RWB+Bar-Patch	Sierra+Coast	110	2
Ameletus	RWB+Bar-Patch	Sierra+Coast	224	2
Amiocentrus_aspilus	RWB+Bar-Patch	Sierra+Coast	38	2
Antocha	RWB+Bar-Patch	Sierra+Coast	98	2

Attenella_delantala	RWB+Bar-Patch	Sierra	82	2
Baetis	RWB+Bar-Patch	Sierra+Coast	261	2
Cryptolabis	RWB+Bar-Patch	Sierra+Coast	46	2
Diphetor_hageni	RWB+Bar-Patch	Sierra+Coast	175	2
Drunella_doddsii	RWB+Bar-Patch	Sierra	53	2
Drunella_flavilinea	RWB+Bar-Patch	Sierra+Coast	83	2
Drunella_grandis	RWB+Bar-Patch	Sierra	65	2
Eubrianax_edwardsii	RWB+Bar-Patch	Sierra+Coast	104	2
Eukiefferiella_gracei	RWB+Bar-Patch	Sierra+Coast	60	2
Haploperla	Bar-Patch	Sierra+Coast	40	2
Ljania	Bar-Patch	Sierra+Coast	25	2
Microtendipes_rydalensis	RWB+Bar-Patch	Sierra+Coast	122	2
Nilotanypus	Bar-Patch	Sierra+Coast	51	2
Ordobrevia_nubifera	RWB	Sierra+Coast	15	2
Pagastia	RWB+Bar-Patch	Sierra+Coast	89	2
Pentaneura	RWB+Bar-Patch	Sierra+Coast	107	2
Physa	RWB+Bar-Patch	Sierra+Coast	62	2
Rhithrogena	RWB+Bar-Patch	Sierra+Coast	49	2
Rhyacophila_brunnea	RWB+Bar-Patch	Sierra	42	2
Skwala	RWB+Bar-Patch	Sierra	68	2
Sperchon	RWB+Bar-Patch	Sierra+Coast	126	2
Suwallia	RWB+Bar-Patch	Sierra+Coast	97	2
Sweltsa	RWB+Bar-Patch	Sierra+Coast	210	2
Synorthocladius	RWB+Bar-Patch	Sierra+Coast	178	2
Torrenticola	RWB+Bar-Patch	Sierra+Coast	328	2
Tvetenia_bavarica	RWB+Bar-Patch	Sierra+Coast	105	2
Zaitzevia	RWB+Bar-Patch	Sierra+Coast	112	2
Brachycentrus_americanus	RWB	Sierra	18	3
Cricotopus_Orthocladius	RWB+Bar-Patch	Sierra+Coast	420	3
Fossaria	Bar-Patch	Sierra+Coast	16	3
Glutops	Bar-Patch	Sierra	19	3
Hydrozetes	Bar-Patch	Sierra+Coast	63	3
Lopescladius	Bar-Patch	Sierra	25	3
Octogomphus_specularis	Bar-Patch	Sierra+Coast	17	3
Paraleptophlebia	RWB+Bar-Patch	Sierra+Coast	365	3
Potthastia_gaedii	RWB+Bar-Patch	Sierra+Coast	39	3
Procloeon_venosum	Bar-Patch	Sierra	27	3
Rheocricotopus	RWB+Bar-Patch	Sierra+Coast	165	3
Serratella	RWB+Bar-Patch	Sierra+Coast	291	3
Simulium	RWB+Bar-Patch	Sierra+Coast	123	3
Thienemanniella_xena	RWB+Bar-Patch	Sierra+Coast	136	3

Wormaldia	RWB	Sierra+Coast	23	3
Yoraperla	RWB	Sierra	19	3
Zapada	RWB+Bar-Patch	Sierra+Coast	215	3
Atractides	RWB+Bar-Patch	Sierra+Coast	219	4
Attenella_soquele	RWB+Bar-Patch	Sierra	65	4
Bezzia_Palpomyia	RWB+Bar-Patch	Sierra+Coast	413	4
Caloparyphus	Bar-Patch	Coast	15	4
Clinocera	Bar-Patch	Sierra+Coast	24	4
Corynoneura	RWB+Bar-Patch	Sierra+Coast	323	4
Dicranota	RWB+Bar-Patch	Sierra+Coast	54	4
Ephemerella_dorothea_excrucians	Bar-Patch	Sierra+Coast	17	4
Ephemerella_maculata	RWB+Bar-Patch	Coast	58	4
Eukiefferiella_claripennis	RWB+Bar-Patch	Sierra+Coast	53	4
Frontipodopsis	Bar-Patch	Sierra+Coast	27	4
Gumaga	RWB+Bar-Patch	Sierra+Coast	103	4
Hydroptila	RWB+Bar-Patch	Sierra+Coast	136	4
Isoperla	RWB+Bar-Patch	Sierra+Coast	65	4
Mucronothrus	RWB+Bar-Patch	Sierra+Coast	266	4
Neoplasta	RWB+Bar-Patch	Sierra+Coast	78	4
Oecetis	Bar-Patch	Sierra+Coast	22	4
Optioservus_quadrimaculatus	RWB+Bar-Patch	Sierra+Coast	339	4
Oreodytes	RWB+Bar-Patch	Sierra+Coast	105	4
Pedomoecus_sierra	RWB+Bar-Patch	Sierra	36	4
Pericoma	RWB+Bar-Patch	Sierra+Coast	111	4
Sigara_mckinstryi	Bar-Patch	Sierra+Coast	21	4
Stempellinella	RWB+Bar-Patch	Sierra+Coast	406	4
Testudacarus	RWB+Bar-Patch	Sierra+Coast	70	4
Thienemanniella_fusca	Bar-Patch	Sierra+Coast	17	4
Thiennemannimyia	RWB+Bar-Patch	Sierra+Coast	294	4
Timpanoga_hecuba	Bar-Patch	Sierra+Coast	34	4
Aturus	RWB+Bar-Patch	Sierra+Coast	120	5
Brachypoda	Bar-Patch	Sierra+Coast	82	5
Capniidae	RWB+Bar-Patch	Sierra+Coast	174	5
Cladotanytarsus	RWB+Bar-Patch	Sierra+Coast	238	5
Dasyhelea	Bar-Patch	Sierra+Coast	20	5
Dicrotendipes	Bar-Patch	Sierra+Coast	17	5
Hemerodromia	RWB+Bar-Patch	Sierra+Coast	55	5
Hesperoconopa	Bar-Patch	Sierra	20	5
Heteroplectron_californicum	RWB+Bar-Patch	Sierra	39	5
Hexatoma	RWB+Bar-Patch	Sierra+Coast	134	5
Hydra	Bar-Patch	Sierra+Coast	91	5

Larsia	RWB+Bar-Patch	Sierra+Coast	252	5
Lauterborniella	Bar-Patch	Sierra+Coast	17	5
Lebertia	RWB+Bar-Patch	Sierra+Coast	292	5
Micropsectra	RWB+Bar-Patch	Sierra+Coast	355	5
Ostracoda	RWB+Bar-Patch	Sierra+Coast	417	5
Parametriocnemus	RWB+Bar-Patch	Sierra+Coast	201	5
Paratanytarsus	RWB+Bar-Patch	Sierra+Coast	74	5
Phaenopsectra	RWB+Bar-Patch	Sierra+Coast	206	5
Polypedilum_convictum	Bar-Patch	Sierra+Coast	29	5
Sialis	RWB+Bar-Patch	Sierra+Coast	143	5
Stempellina	Bar-Patch	Sierra+Coast	67	5
Tanytarsus	RWB+Bar-Patch	Sierra+Coast	522	5
Tricorythodes	RWB+Bar-Patch	Sierra+Coast	206	5
Virgatanytarsus	Bar-Patch	Sierra+Coast	24	5
Wandesia	Bar-Patch	Sierra+Coast	29	5
Ablabesmyia	Bar-Patch	Sierra+Coast	22	6
Brillia	RWB+Bar-Patch	Sierra+Coast	115	6
Heleniella	Bar-Patch	Sierra+Coast	84	6
Hydropsyche	RWB+Bar-Patch	Sierra+Coast	35	6
Limnesia	Bar-Patch	Sierra+Coast	33	6
Microtendipes_pedellus	RWB+Bar-Patch	Sierra+Coast	174	6
Mystacides_alafimbriata	Bar-Patch	Sierra+Coast	26	6
Nanocladius_balticus	Bar-Patch	Sierra+Coast	21	6
Oligochaeta	RWB+Bar-Patch	Sierra+Coast	544	6
Polypedilum_tritum	RWB+Bar-Patch	Sierra+Coast	82	6
Psectrocladius_sordidellus	Bar-Patch	Sierra+Coast	49	6
Psychoglypha	RWB+Bar-Patch	Sierra+Coast	99	6
Zavrelimyia	RWB+Bar-Patch	Sierra+Coast	138	6
Centroptilum	RWB+Bar-Patch	Sierra+Coast	302	7
Chironomus	Bar-Patch	Sierra+Coast	108	7
Cleptelmis_addenda	RWB	Sierra+Coast	18	7
Hygrobates	RWB+Bar-Patch	Sierra+Coast	99	7
Krenosmittia	Bar-Patch	Sierra	16	7
Laccobius	Bar-Patch	Sierra+Coast	39	7
Limnophila	Bar-Patch	Sierra+Coast	35	7
Limnophora	Bar-Patch	Sierra+Coast	17	7
Nudomideopsis	Bar-Patch	Sierra+Coast	20	7
Polypedilum_laetum	Bar-Patch	Sierra+Coast	66	7
Polypedilum_scalaenum	RWB+Bar-Patch	Sierra+Coast	132	7
Pseudochironomus	Bar-Patch	Sierra+Coast	41	7
Siphlonurus	Bar-Patch	Sierra+Coast	52	7

Apedilum	Bar-Patch	Sierra+Coast	81	8
Callibaetis	Bar-Patch	Sierra+Coast	22	8
Ceratopogon	Bar-Patch	Sierra+Coast	93	8
Cordulegaster_dorsalis	Bar-Patch	Sierra+Coast	36	8
Cryptochironomus	Bar-Patch	Sierra+Coast	60	8
Culicoides	Bar-Patch	Sierra+Coast	38	8
Heterotrissocladius_marcidus	RWB+Bar-Patch	Sierra+Coast	186	8
Parakiefferiella	RWB+Bar-Patch	Sierra+Coast	345	8
Paratendipes	Bar-Patch	Sierra	42	8
Pisidium	RWB+Bar-Patch	Sierra+Coast	134	8
Polypedilum_halterale	Bar-Patch	Sierra+Coast	17	8
Sphaeromias	Bar-Patch	Sierra+Coast	50	8
Apsectrotanypus	Bar-Patch	Sierra+Coast	38	9
Brundiniella	Bar-Patch	Sierra+Coast	59	9
Frontipoda	Bar-Patch	Sierra+Coast	15	9
Hydrobaenus	Bar-Patch	Sierra+Coast	34	9
Macropelopia	Bar-Patch	Sierra+Coast	17	9
Odontomesa	Bar-Patch	Sierra+Coast	87	9
Paracladopelma	RWB+Bar-Patch	Sierra+Coast	132	9
Monodiamesa	Bar-Patch	Sierra	26	10
Ptychoptera	Bar-Patch	Sierra	17	10