Development of Biological Indicators and Targets to Guide Sediment TMDLs for Streams of the Central Coast Region of California and the San Lorenzo River

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Main Findings:

- **At a threshold in the range of 30-40% fine and sand (FS) sediment cover, there is substantial loss of biological diversity of invertebrates**
- **Along with changes in selected biological indicators, this level of FS sediment cover can be used as numeric criteria for sediment impairment**
- **Where biological indicator metrics fall below the 25th percentiles of their reference stream levels, biological criteria can be set for impaired condition**
- **Rainbow trout abundance is reduced above 6% fine substrate cover, so this may be used a separate criterion for steelhead streams**

1. Introduction and Overview

The San Lorenzo River and associated tributaries are listed as impaired due to sediment, and the RWQCB must utilize Total Maximum Daily Loads (TMDLs) to address the impairments. In order to develop TMDLs and associated implementation actions for sediment, the Central Coast RWQCB need better information on the linkage between sediment loads, deposition, and impairment of aquatic life beneficial uses at both a local watershed and regional scale. This report develops numeric criteria for aquatic life impairment and should be used in conjunction with an earlier report that documents conditions of excess sediment deposition degrading physical habitat (Herbst et al. 2011).

The objectives of this project are to build upon concurrent efforts that provide a comprehensive picture of aquatic health of the San Lorenzo River and its tributaries with respect to sediment loading. This project will provide additional information on the relationship to sediment and aquatic life indicators region-wide, and determine numeric target measurements that demonstrate healthy aquatic habitat. The project will consist of:

(a) combining survey data from 2007-2009 collected in the San Lorenzo River watershed to monitor sediment deposition and develop numeric targets
(b) characterizing benthic invertebrate communities in conjunction with instream physical habitat in the San Lorenzo River watershed, and combine these with available results from throughout the central coast region
(c) conducting additional and repeat field surveys to further understand instream physical habitat and associated salmonid populations in the San Lorenzo River watershed, and
(d) utilizing information on sediment and benthic invertebrate metrics at a regional scale to develop and coordinate numeric targets that measure tangible improvements to water quality and salmonid habitat in the San Lorenzo River Sediment TMDLs

Sequence of Stream Sediment Studies in the San Lorenzo (2007-2009)

In May of 2007, as part of a broader geographic survey of stream sedimentation in 24 streams of the Central Coast Range, five streams within the San Lorenzo drainage were sampled to gather preliminary data. In 2008, 40 streams were sampled within the San Lorenzo River watershed and in adjacent catchments that were used to represent reference conditions with lower levels of roadedness and land use development. Three of the five sites sampled in 2007 were repeated in 2008, and 20 of the 40 sites sampled in 2008 were repeated in 2009. Physical habitat surveys in 2008 and 2009 were conducted over a reach length of 50 m, and though this differed from the 150-250 m reach lengths used in 2007, most of the same sediment-related measurements were conducted with the same sampling intensity (e.g. 100-point transect counts, cobble embeddedness).

Integrated Data Analysis

Benthic macroinvertebrate data from all surveys (24 surveys over the central coast in 2007, 40 surveys in the San Lorenzo and adjacent catchments in 2008, and 20 surveys within the San Lorenzo only in 2009; total sample size = 84) were combined to provide a more comprehensive data set. These data were used to examine relationships of community metrics (diversity and tolerance indicators) to measures of sedimentation, and community ordination was used to evaluate similarity among sites in overall biological response to environmental gradients of sediment and other habitat variables.

The combined data set was also used to document different physical habitat measures of sedimentation contrasting reference and test streams for the population of 84 combined surveys. As described in the more detailed report on sediment loads, deposition, and land use, the upper quartile of the reference range of stream sediment deposition was use to define impairment thresholds (Herbst et al. 2011).

In addition to habitat and macroinvertebrate data, surveys of anadromous rainbow trout (steelhead, *Oncorhynchus mykiss*) and crayfish (*Pacifastacus leniusculus*) were conducted in June of 2009 at 20 sites in the San Lorenzo River drainage (repeats of 2008 study sites). At these sites we also collected non-native crayfish, and in this way, we incorporate multiple biological indicators and key species that may be affected by the varied levels of sedimentation found.

2. Physical Habitat Survey Methods (2008-2009) and Reference-Test Designations

Surveys of the physical habitat of each study site emphasized measures of sediment deposition taken concurrent with benthic invertebrate samples in order to link both habitat and biological response variables to the land use and sediment loading of each catchment. Methods for documenting physical habitat characteristics differed between the 2007 sediment TMDL surveys, and San Lorenzo surveys in 2008 and 2009. These methods are outlined below (refer also to Herbst et al. 2011 sediment report).

- Study reaches were 50 meters in length (San Lorenzo 2008 and 2009); 150 meters in length for streams with an average width of less than 10 m, or 250 meters in length for streams wider than 10 meters (sediment TMDL 2007).
- We measured substrate particle size distribution along cross-sectional transects spaced over the entire study reach. For San Lorenzo 2008 and 2009: 10 transects at 10 points, for the sediment TMDL project of 2007: 20 transects at 5 points. Substrate size was measured as the intermediate axis of all particles larger than 2 mm, or recorded as sand for particles estimated as 0.25 to 2 mm, or as fines if < 0.25 mm (surveyors were trained to recognize these classes by texture).
- When cobble substrates (64 – 256 mm in diameter) were encountered at sample points, embeddedness was measured as the percentage (±5%) of the stone volume embedded/buried in sand and or fine substrate. Group training of observers was conducted prior to surveys to achieve consistent scoring of embeddedness. If 25 embeddedness measurements were not recorded on completion of transects, remaining counts were obtained from random locations throughout the reach.
- At ten transects, we measured cross-sectional width and depth to determine bankfull channel dimensions. For 2007 sites, we recorded twenty evenly-spaced depth (height) measurements as the distance from the stream bed to a taught meter tape stretched between bankfull marks on both banks. For San Lorenzo 2008 and 2009 sites, we measured bankfull height from the water surface to the bankfull level. Depth of water measurements were taken at ten evenly-spaced points along each transect. In the case of dry points, the measurement was marked as dry. For the wetted locations, the final bankfull depth was simply the water depth plus the

bankfull height above water. For the dry locations, we had to make assumptions about the channel profile. For dry locations that were on the edges of the transect, we assumed that the channel elevation profile followed a linear path between the last wetted point and the bankfull elevation. Dry locations that were between wetted points were assumed to be relatively close to the water surface, and we assigned the water surface elevation to these points.

- In addition to these sediment deposition measures, we also measured depth profiles across all transects; channel slope; bankfull channel width; and temperature, conductivity and pH (Oakton con10 meter). Photographs were taken from the middle of the channel, looking downstream and upstream, at fifty meter intervals. GPS coordinates were recorded to provide a georeference point for each study reach.

For San Lorenzo 2008 and 2009 only:

- In order to generate high-resolution data on fine particle distribution at the patch-scale within each study reach, we used a grid-frame to measure separate counts of fine and sand particles at twenty-five intersecting grid line points of the grid-frame (Figures 1 and 2) at twenty different locations within the study reach, for a total of 500 point-counts in each study reach. These twenty locations included eleven locations (corresponding to the macroinvertebrate sample locations) at alternating combinations of left-center-right longitudinal positions starting at the beginning of the reach, at zero meters, and at every five meters until the end of the reach, at 50 meters. Nine additional grid counts of fines and sand were positioned offset and upstream of these other eleven locations (Figure 1).
- We drew stream bed facies maps depicting the distribution and composition of contiguous large patches of substrates within the fifty meter reach. These maps were drawn on grid paper scaled to the width and length of each study reach. Fines and sand facies were used to express sedimentation. Gravel facies may be used as an indicator of potential area available for salmonid spawning (redds). Facies can be defined as discrete deposits of bed-surface sediments or rock of uniform grain size where most of the material is comprised of a single class (fines, sand, gravel, pebble, cobble, boulder).

Physical Habitat Analysis

The first category of measures are standard geomorphic measurements taken during pebble counts, including percent sands and fines, percent sands, fines, and gravel, D50 median grain size, and embeddedness. The second category, for the San Lorenzo 2008 and 2009 sites, is taken from the grid sampling and facies mapping procedures, and includes the percent of sands and fines coverage measured at random grid sample sites and the percent of sand and fines visually estimated by facies mapping. A third category, relative bed stability involves comparing the difference between the expected particle size distributions (based on theory of stream power effects on particles) and those particles observed (usually expressed as the median particle size or D_{50}).

Our methodology for calculating Relative Bed Stability (RBS) was taken from the Environment Protection Agency methodology (Kaufmann et al 1999) that has been used for the western EMAP rivers and streams assessment (Stoddard et al. 2005). These measures calculate the departure of substrate conditions from what is the expected condition, based on reach slope and geometry. The equation for Relative Bed Stability is:

> RBS = $[D_{50}] / [13.7 * R_{bf} * S]$, where D_{50} is the median grain size (mm), R_{bf} is the mean reach hydraulic radius, and S is reach slope.

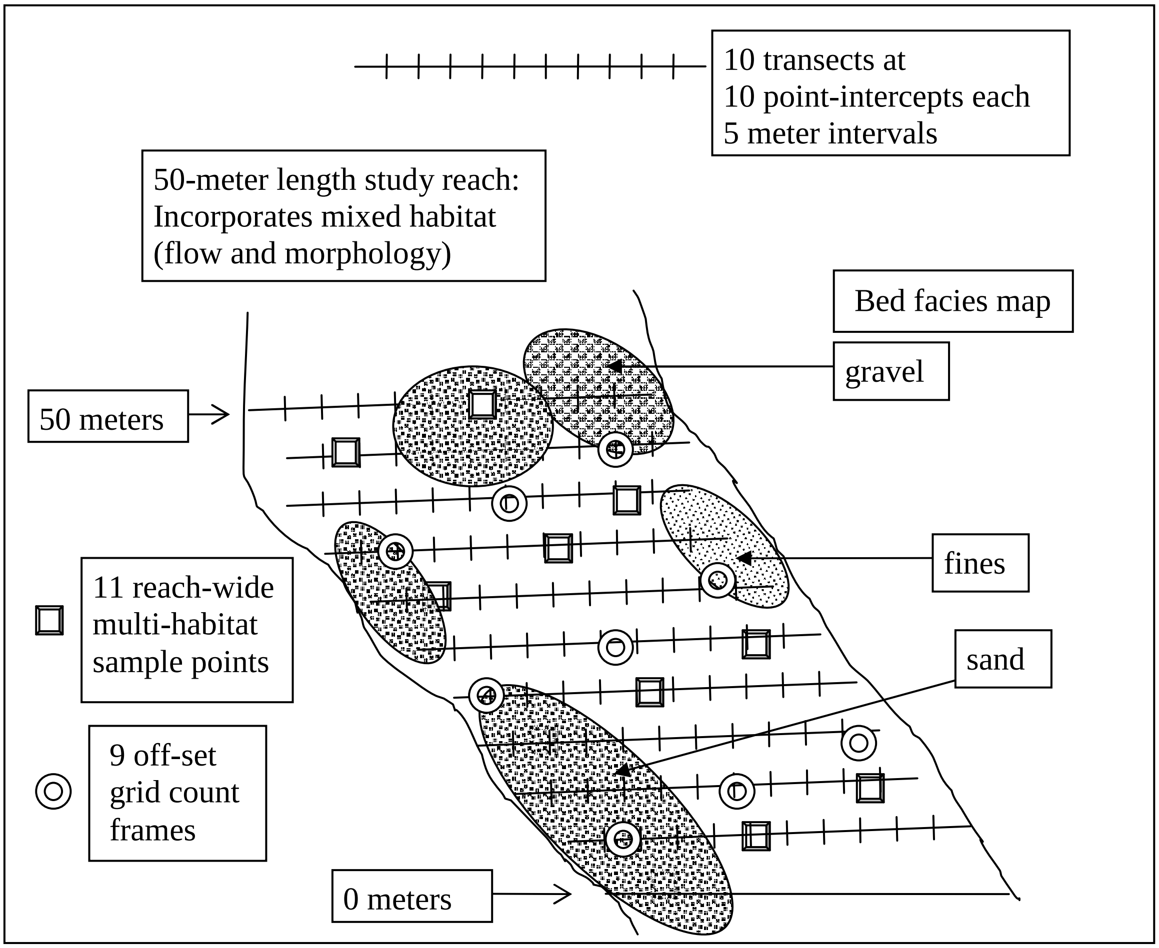


Figure 1. Transects for determination of particle size distribution and embeddedness, bed facies maps, and locations of grid counts of fines/sand (and invertebrate sample points). This is the systematic lay-out for stream surveys conducted in 2008 and 2009 for the San Lorenzo and adjacent watersheds of the region (see maps section at end of report for locations).

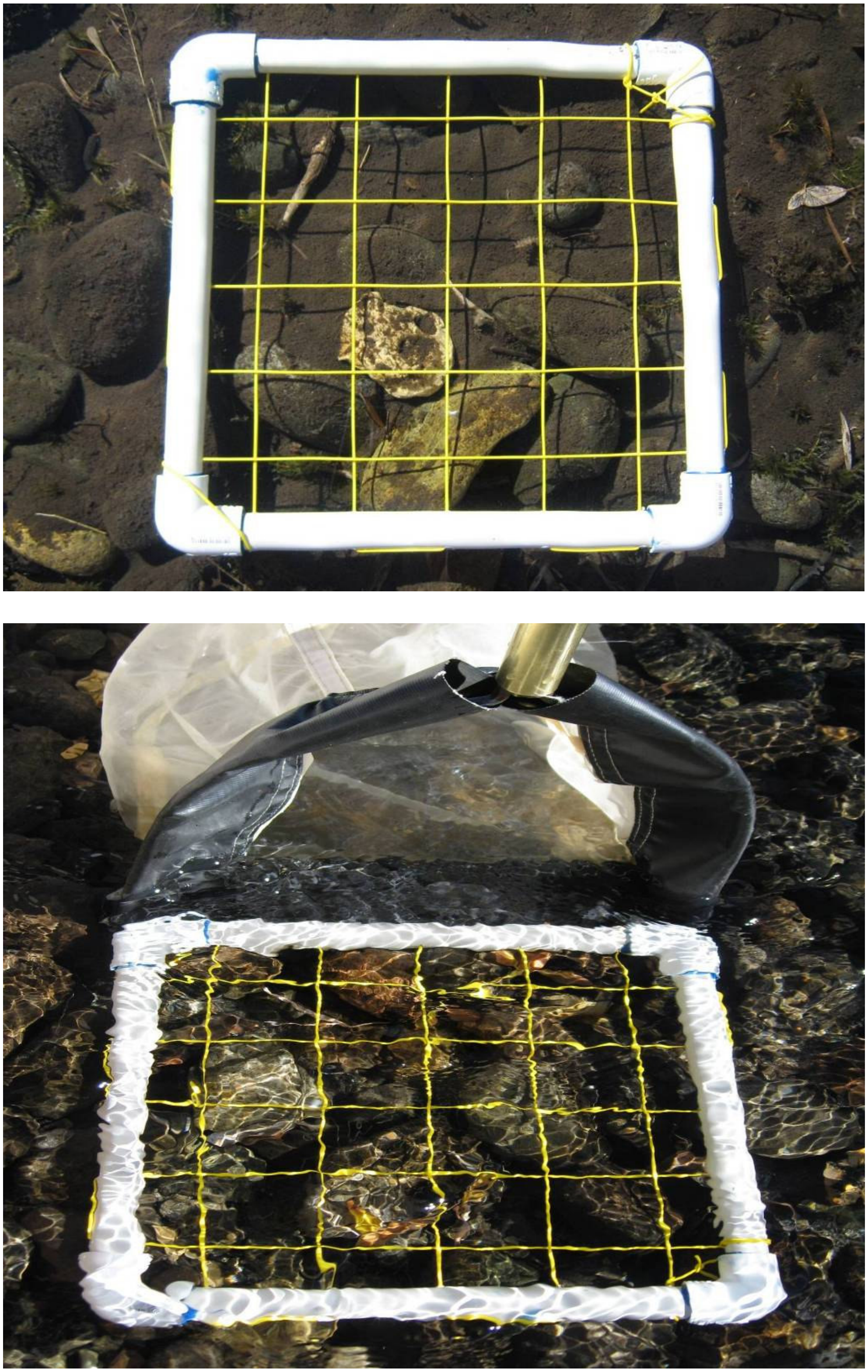


Figure 2. Quadrat grid-frame for particle counting of substrate composition (upper) and with D-frame net positioned for sampling benthic macroinvertebrates (lower).

Reference-Test Designations

We partitioned sites into reference and test groups based on their exposure to human-related sources of sediment input. These were identified from breaks or discontinuities in site distribution for co-plots of road density and human land use within the catchment. We derived road locations from Topologically Integrated Geographic Encoding and Referencing (TIGER) dataset produced by the U.S. Census Bureau. We calculated road density as the length of road within a one hundred meter riparian buffer divided by the area of the one hundred meter riparian buffer (km/km^2). Road crossings were calculated as the number of road-stream intersections in a watershed divided by the total length of stream segments in a watershed (road crossings/km). We derived human land use from the 2001 National Land Cover Dataset (NLCD). NLCD 2001 provides a classification of land surfaces from 2001 Landsat 7 satellite data (Appendix A). We defined human influence cover as all NLCD classes that are the result of human-related activities. These include 21 (developed, open space), 22 (developed, low intensity), 23 (developed medium intensity), 24 (developed high intensity), 71 (grassland/herbaceous), 81 (pasture/hay), and 82 (cultivated crops). We calculated the percentage of surface cover of these classes within each catchment.

For the Central Coast Range sites surveyed in 2007, we designated reference sites as having ≤3.0 km/km^2 riparian road density and ≤10% combined human land uses within the watershed (Figure3). Some reference exclusions were made based on local disturbances not evident in GIS. Through our selection process, we identified 14 reference sites and 10 test sites in the Central Coast Range. For San Lorenzo sites surveyed in 2008 and 2009, we also designated references as having ≤3.0 km/km^2 of riparian road density and ≤10% combined human land uses within the watershed (Figure 4), partitioning 19 reference and 21 test sites. Reference sampling was repeated at 6 sites in 2009, bringing the total reference site surveys to 39.

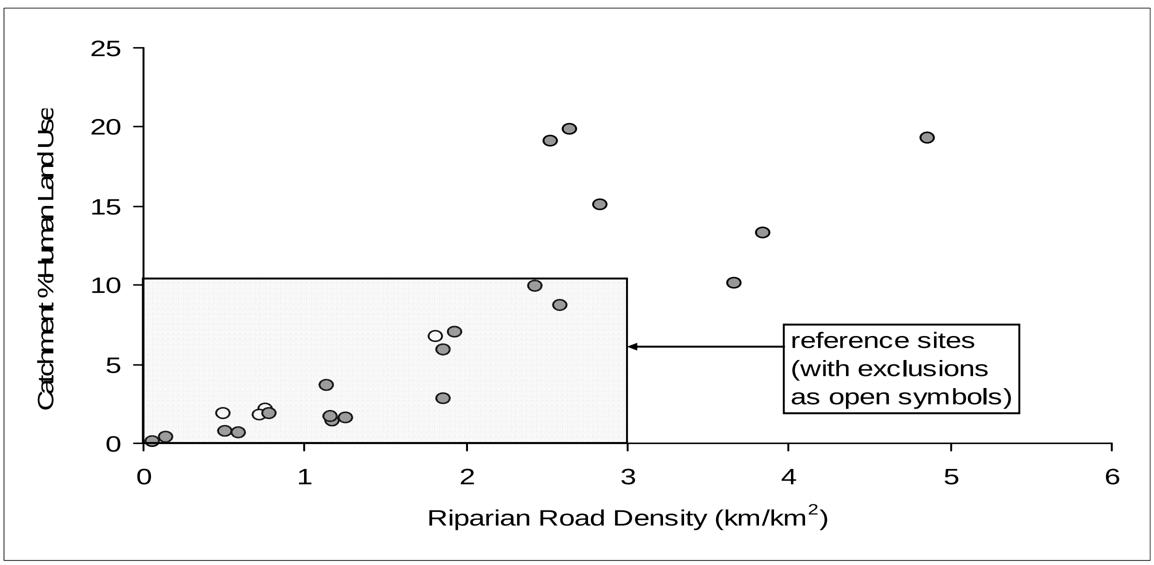


Figure 3. Partition of reference site data set for the Central Coast Range sites surveyed in 2007 based on low levels of riparian road disturbance (≤3 km/km^2) and combined human land use ≤10%. [specific exclusions (open symbols) based on local disturbances present]

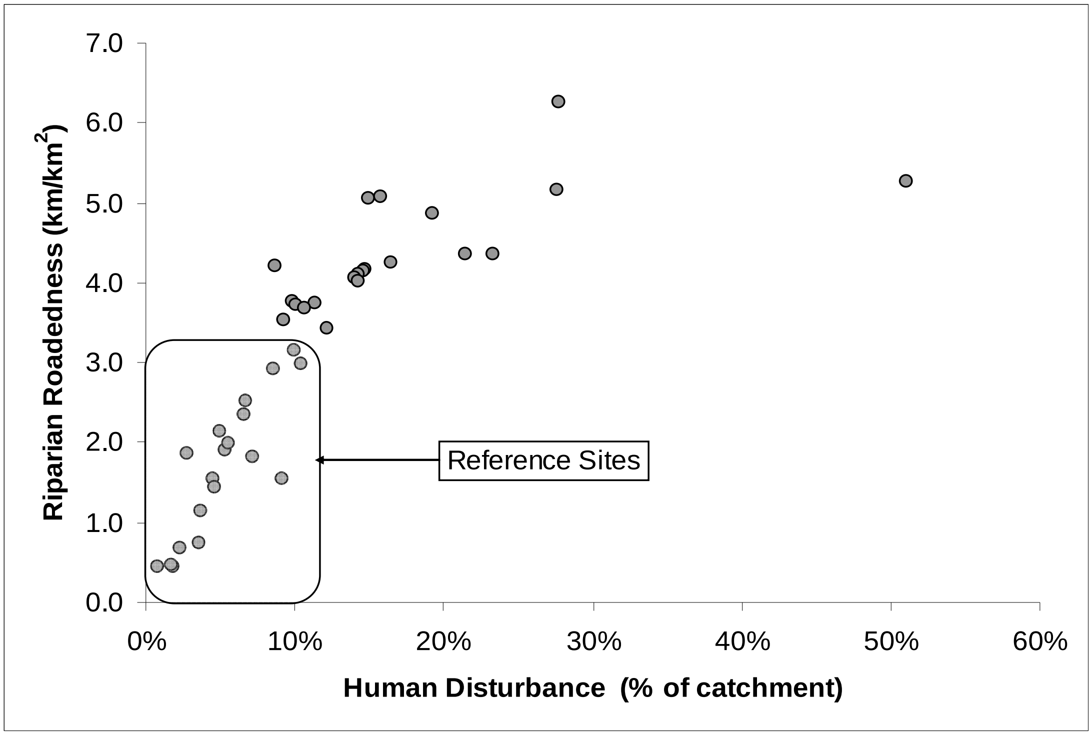


Figure 4. Partitioning of reference and test sites for the San Lorenzo sites surveyed in 2008 and 2009 based on discontinuity in plot of human disturbance measures. References represents least-disturbed state for this population of study sites (≤10% human influence, and ≤3 km /km^2 roads in riparian area).

Differences Between Reference and Test Sites

- We found differences in instream physical habitat measures between reference and test sites. All contrasts and statistical differences were consistent with our expectations for the response of channel geomorphology and sediment storage to increased landscape disturbance. The test sites, with greater levels of road and land use disturbance, contained more deposition of sediment.

- On average, reference sites had lower percentages of fines and sand and higher percentages of pebble, cobble and boulder than test sites, whether considered as all surveys combined (Figure 5), or the San Lorenzo and adjacent drainages only (Figure 6). Reference sites had significantly less fine and sand cover measured at the reach scale in point transects (Figure 7) as well as at the patch scale in grid quadrats (Figure 8).

- Measures of habitat, water quality and substrate features were mostly consistent between years of measurement for those sites where 2008 surveys were repeated in 2009 (Table 1)

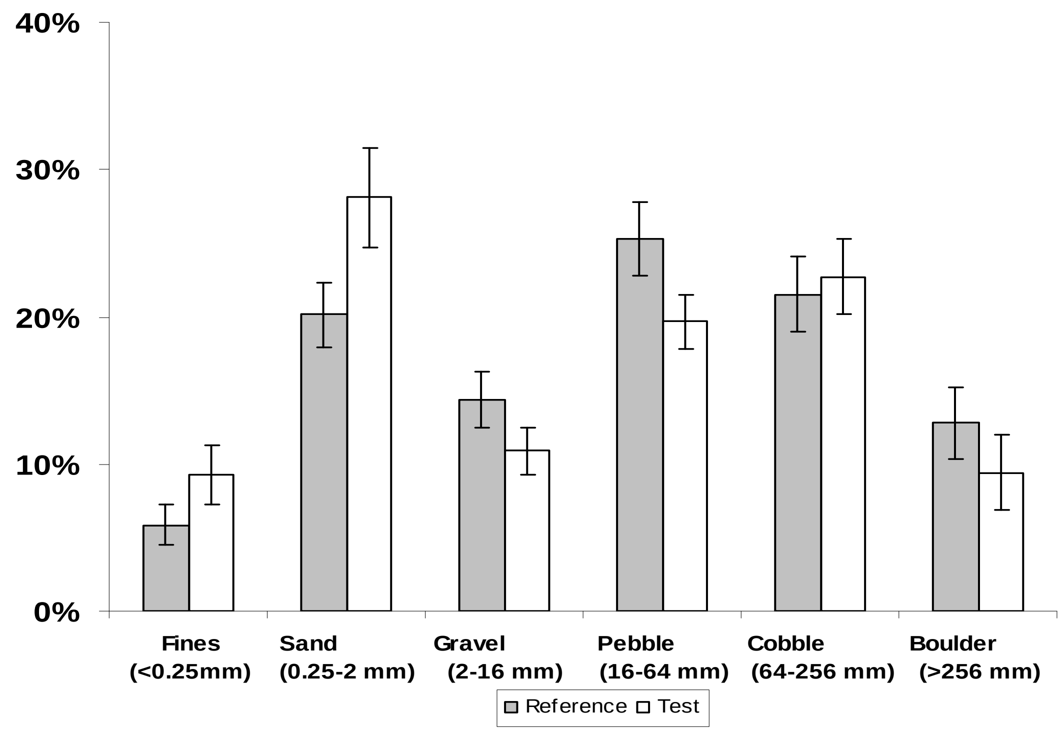


Figure 5. Average particle size distributions from transect point counts of all 84 surveys. Error bars show 95% confidence intervals, equivalent to t-tests of significance of differences ($p<0.05$ if bars do not overlap paired means).

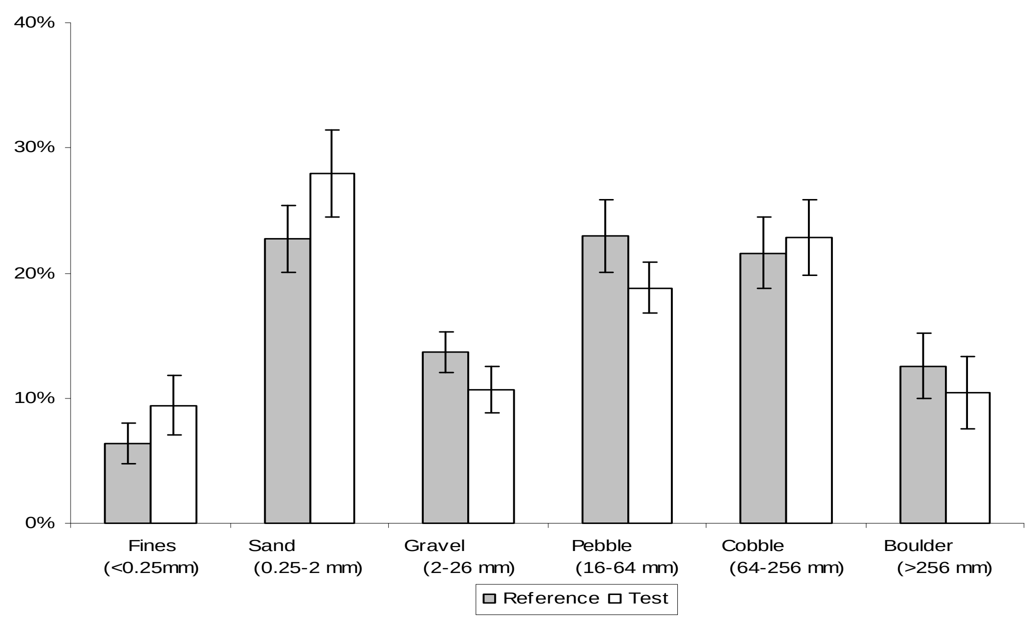


Figure 6. Average particle size distributions from transect point counts of the 60 San Lorenzo 2008 and 2009 surveys. Standard errors, approximating t-test of significance of differences ($p<0.05$ if bars do not overlap paired means), are included.

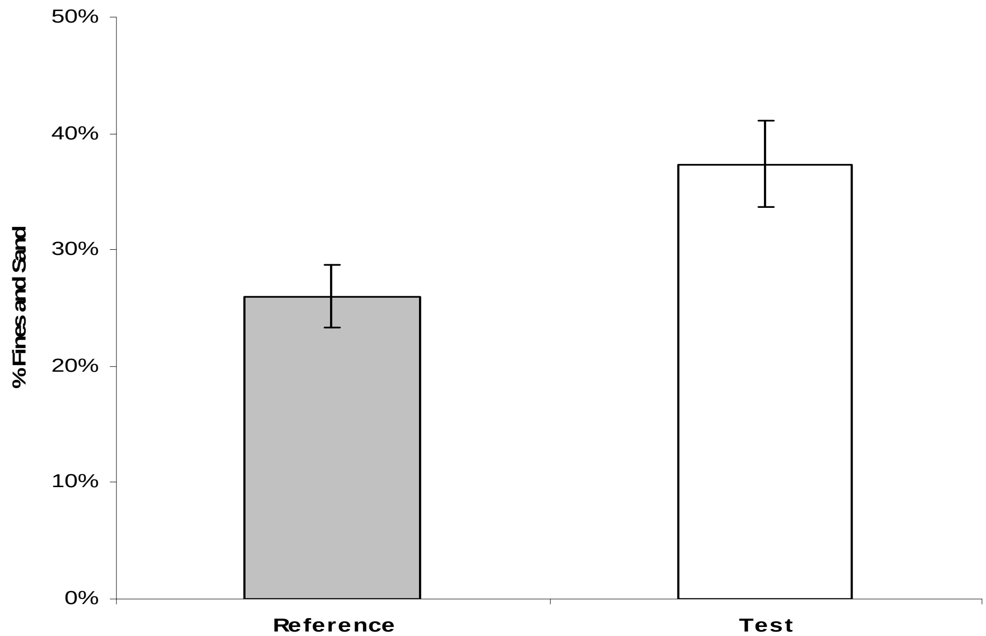


Figure 7. Percent Fines and Sand from transect point counts of all 84 surveys. Standard errors, approximating t-test of significance of differences ($p<0.05$ if bars do not overlap paired means), are included.

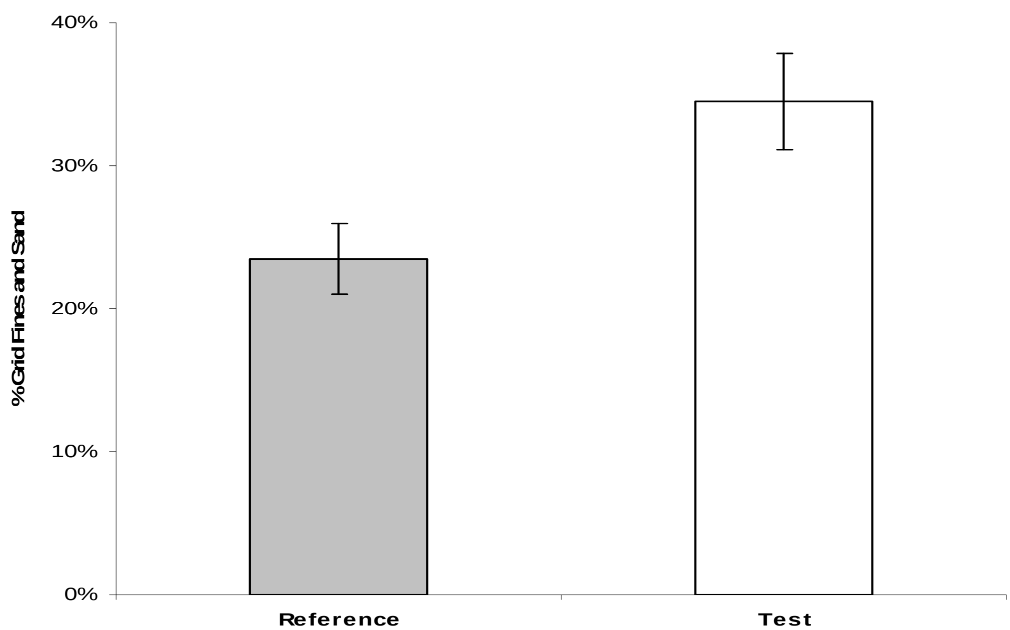


Figure 8. Percent Fines and Sand from grid counts of all 84 surveys. Error bars show 95% confidence intervals, equivalent to t-tests of significance of differences ($p<0.05$ if bars do not overlap paired means).

Stream Name	Site Name	2008 data / 2009 data						
		Conductivity	%Slope	Bankfull Area	%FS	Geometric Mean	Grid %FS	Embeddedness
Aptos Creek	Below Aptos Rancho trail	798 / 794	1.8 / 1.58	3.47 / 1.4	36 / 50	10.64 / 6.38	34.8 / 50.2	34 / 28.4
Bean Creek	At end of Locateli Rd.	475 / 496	0.38 / 0.4	2.65 / 1.98	60 / 59	5.46 / 4.90	59.8 / 50.8	32.4 / 42.4
Bean Creek	Upstream of Morgan Runs Rd.	636 / 637	0.7 / 0.72	1.31 / 1.12	30 / 32	11.89 / 15.8	23.4 / 21	27.8 / 21.8
Bear Creek	Above treatment plant	666 / 630	0.69 / 0.74	2.83 / 2.92	32 / 18	20.28 / 39.08	17.8 / 19	34.6 / 43.6
Bear Creek	Eurella	618 / 607	0.52 / 0.38	2.58 / 2.43	25 / 22	18.63 / 20.24	16 / 12.8	32 / 36.6
Boulder Creek	Below Highway 9	254 / 198.9	1.06 / 1.06	2.79 / 2.63	9 / 16	69.90 / 45.70	20.6 / 19.6	21.2 / 35.4
Branciforte Creek	DeLaveaga Park	704 / 681	0.77 / 0.74	2.48 / 1.86	51 / 49	4.05 / 4.97	44.2 / 40.4	42.8 / 36.4
Carbonera Creek	Above Carbonera Rd.	389 / 442	0.32 / 0.7	2.55 / 2.08	33 / 32	11.62 / 18.47	41.8 / 55.2	37.4 / 21.4
Fall Creek	Cowell Unit H.C. State Park	252 / 263	1.734 / 1.34	1.6 / 1.41	43 / 41	7.37 / 7.94	20.4 / 24.2	13.2 / 15.8
Kings Creek	Above Kings Creek Road Bridge	650 / 663	1.39 / 0.6	1.88 / 1.93	24 / 39	17.40 / 13.91	5.2 / 26.4	14.2 / 28.8
San Lorenzo River	Below H.C. entrance bridge	426 / 385	0.03 / 0.42	7.93 / 7.67	69 / 42	2.94 / 6.90	69.8 / 60.2	36.6 / 18
San Lorenzo River	Above Brimblecom Rd.	696 / 653	0.78 / 0.94	3.18 / 2.17	17 / 8	23.17 / 44.38	12.4 / 5.4	8.8 / 12.6
San Lorenzo River	Above city intake	424 / 443	0.16 / 0.03	7.02 / 10.13	59 / 63	2.98 / 1.87	50.4 / 57	40.2 / 32.4
San Lorenzo River	Above East Lomand Rd. Bridge	526 / 485	1.52 / 1.53	4.42 / 5.14	29 / 18	22.06 / 47.51	14.2 / 9.2	14.6 / 16.2
San Lorenzo River	Above Hwy 9 - Ben Lomond	456 / 462	1.36 / 1.29	4.82 / 4.69	39 / 20	10.03 / 28.27	28.4 / 27	22.6 / 20.2
San Lorenzo River	Below San Lorenzo Way bridge	407 / 424	0.3 / 0.8	4.69 / 5.08	41 / 29	9.32 / 13.50	28.2 / 17.8	33.6 / 8.6
San Lorenzo River	Lower Castle Rock State Park	570 / 558	1.16 / 1.25	1.65 / 2.02	50 / 42	6.18 / 10.09	25.8 / 33	44.2 / 23.2
San Lorenzo River	Lower H.C. State Park	411 / 452	0.22 / 0.1	9.27 / 10.90	47 / 45	4.00 / 4.64	28 / 40.8	21 / 33.6
San Lorenzo River	Paradise Park	419 / 445	0.65 / 0.6	7.62 / 6.57	42 / 32	9.51 / 15.26	30.6 / 34.6	25.2 / 8
Zayante Creek	Above Railroad bridge	471 / 505	1.118 / 1.19	4.31 / 3.87	27 / 28	22.59 / 29.01	24 / 15.6	32.8 / 17.2
Boulder Creek	Highway 236 - Mile marker 4.0	410	0.55	1.17	34	13.95	26.4	22.6
Branciforte Creek	Below Shady Brook bridge	661	1.32	1.74	46	12.73	40.2	32.8
E. Waddell Creek	Above confluence	385	0.904	2.45	15	47.97	20	23
E. Waddell Creek	Above treatment plant	341	1.54	2.91	34	16.85	26.8	42.6
Jamison Creek	Next to fire station	145.4	1.68	1.25	27	28.07	41	15.8
Little Creek	Above Swanton Rd. bridge	345	5.17	1.20	36	12.63	28.8	33.8
Lompico Creek	Above Lompico Cr. Rd. bridge	585	1.288	1.83	27	31.83	43.8	27.2
Love Creek	Below Glen Arbor St. bridge	442	0.91	0.85	24	19.46	23.2	38.6
Newell Creek	Above Rancho Rio Rd.	415	0.97	1.63	51	4.14	43.8	38.2
Pescadero Creek	Above bridge crossing @ Cloverdale Rd.	737	0.47	3.20	40	5.55	45.2	43.2
Pescadero Creek	At Oakland YMCA Camp	719	0.772	3.58	15	56.18	13.8	24.4
Pescadero Creek	Below Sequoia nature trail	699	0.64	2.46	16	29.14	16.4	8.2
Peters Creek	Above campground	777	1.06	1.94	21	35.21	13.6	31.8
Scott Creek	Below Little Creek (OSH property)	237	0.53	6.21	23	18.31	17.2	32.8
Scott Creek	Upper tributary	271	0.32	1.90	31	10.99	33.8	9.4
Shingle Mill Creek	Above Hwy 9	280	3.14	0.99	54	6.37	31.4	28.4
W. Waddell Creek	Above confluence	386	0.7	2.42	23	13.89	15	34.4
Waddell Creek	Above Alder Camp	368	0.72	2.12	13	16.33	13.8	33.6
Zayante Creek	Above Quail Hollow Rd. bridge	600	0.09	4.04	38	7.76	49	34.2
Zayante Creek	Below Zayante Market bridge	715	0.97	4.06	19	60.37	35.2	26

Table 1: Select physical habitat characteristics for 2008 and 2009 San Lorenzo surveys. Sites surveyed in 2008 and again in 2009 contain two values for each field (i.e., 2008 / 2009). FS is fine and sand cover from transects, Grid FS is cover from 20 25-point quadrats (see text). Geometric mean particle size is the Nth root of the product of all observations (all 100 transect counts multiplied, and the 1/100 root taken).

3. Native Salmonids and Non-Native Crayfish in 2009 Surveys

Methods

The fish community was quantified in June of 2009 at 20 sites of the San Lorenzo River drainage. Standard three-pass backpack electro-shocking was used with block nets at the head and tail of each study reach. Reaches surveyed were usually the full 50 m length, but a few were 20-30 m long where obstructions prevented full length sampling. Fish and crayfish collected were identified to species, measured, and weighed.

Results

Rainbow trout (*Oncorhynchus mykiss*) steelhead density decreased as fine sediments increased (Figure 9). If less than 0.1 fish/m^2 is taken as the lowest level of abundance for steelhead, this minimal density occurred in 9 of 11 cases above 6% fines, whereas sites having less fine sediment showed fish numbers exceeded this level in 6 of 8 cases. No relationship was exhibited between substrate quality and average length or body condition of rainbow trout (Figures 10, and 11).

Crayfish (*Pacifastacus leniusculus*) density increased with fine sediment (Figure 12) and average weight of crayfish also increased with greater fine and sand sediment fraction cover (Figure 13).

Conclusions

These results suggest that rainbow trout densities are limited by fine sediments above approximately 6% surface area cover, and that numbers and size of non-native crayfish are favored by increased levels of fine and sand sediment deposition. These crayfish are also known to have an important influence in consumption and processing of organic matter (leaf litter, detritus), and may limit the local abundance of native macroinvertebrates.

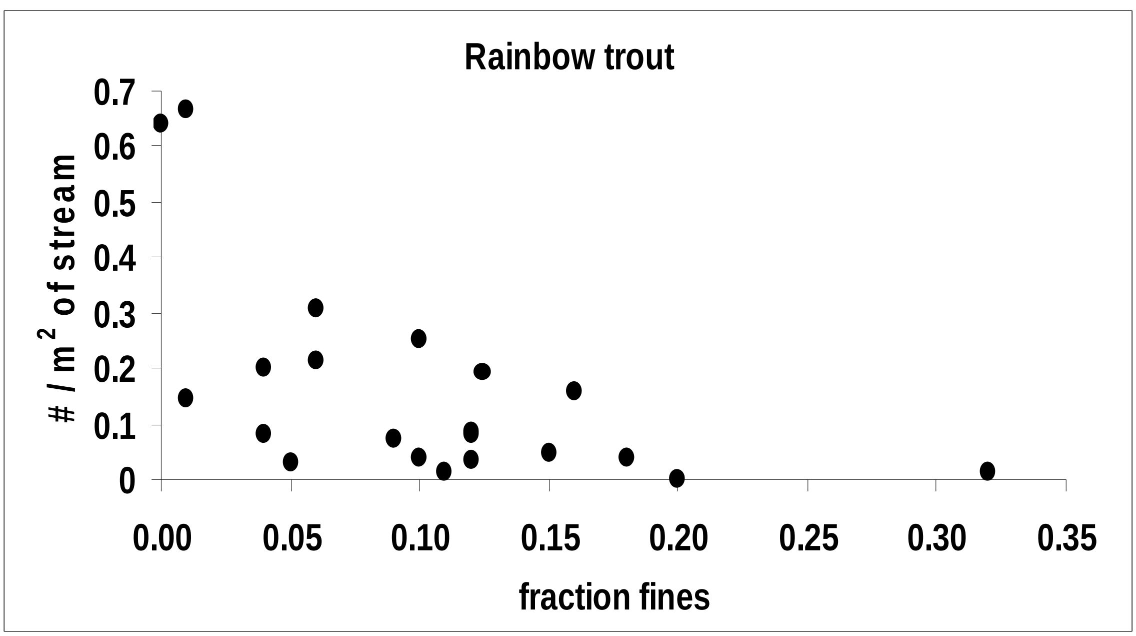


Figure 9. Relationship between density of Rainbow trout (# per square meter of stream shocked) and fraction of fine substrates for 20 sites within the San Lorenzo River.

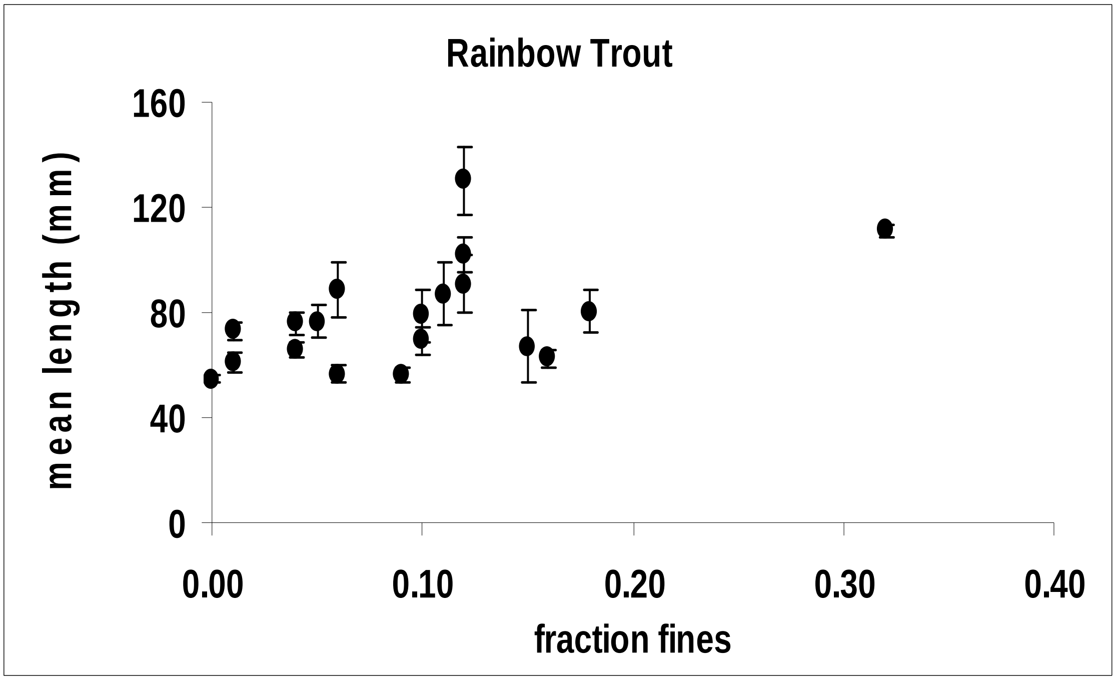


Figure 10. Relationship between mean length of Rainbow trout (+1SE) and fraction of fine substrates for 19 sites within the San Lorenzo River drainage (one site had no fish).

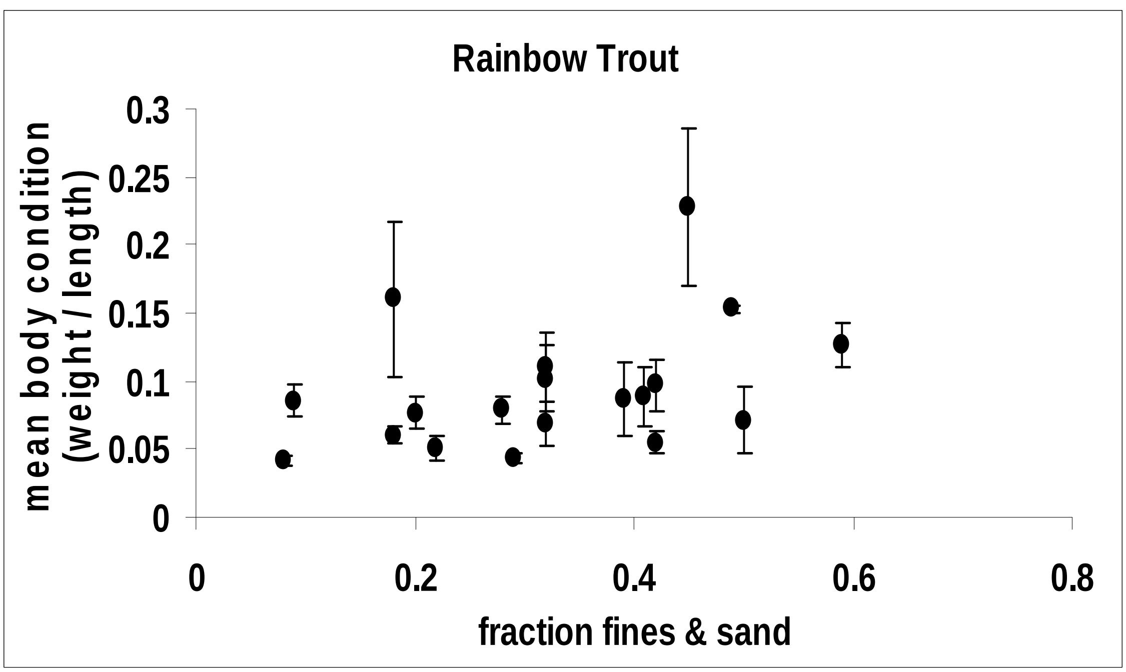


Figure 11. Relationship between average body condition of Rainbow trout (weight / length, +1 SE) and combined fraction of fine and sand substrates for 19 sites within the San Lorenzo River drainage (no fish at one site).

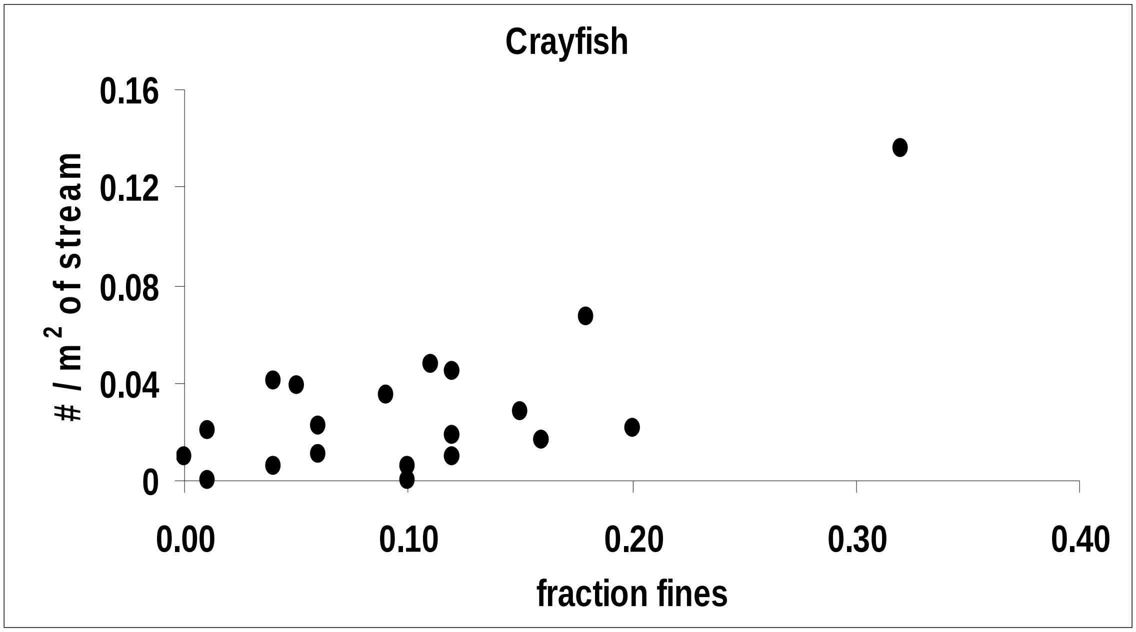


Figure 12. Relationship between density of Crayfish (# per square meter of stream shocked) and fraction of fine substrates for 20 sites within the San Lorenzo River drainage.

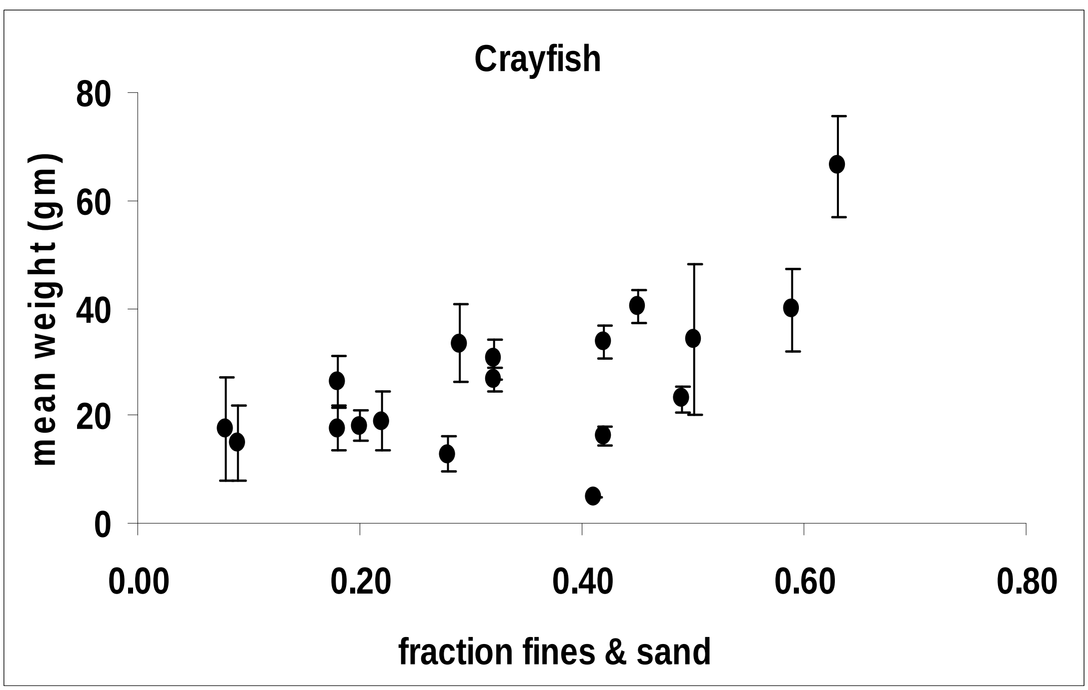


Figure 13. Relationship between mean weight of Crayfish (+1 SE) and combined fraction of fine and sand substrates for 18 sites within the San Lorenzo River drainage (2 sites had no crayfish).

4. **Macroinvertebrate Community Metrics and Sediment Deposition**

Using the reach-wide benthos (RWB) sampling methodology (SWAMP standard method), and the different methods for measuring sediment deposition at reach-scale and patch-scale, the responses of different community metrics to sediment were examined as simple univariate relationships of sediment cover to invertebrate diversity and tolerance.

Based on the reference distribution alone, numeric guidance criteria for sediment deposition greater than the 75th and 90th percentiles of the reference distribution (Herbst et al. 2011) can be used to define impaired by bedded sediment as follows:

Sediment Indicator	Moderately Disturbed [partially supporting] (75/25)	Disturbed [not supporting] (90/10)
1. Percent Fines (F) on transects	>8.5%	>15.2%
2. Percent Sand (S) on transects	>27.5%	>35.3%
3. Percent FS on transects	>35.5%	>42.0%
4. Percent FSG<8mm on transects	>40.0%	>50.2%
5. D50 median particles size	<15 mm	<7.7 mm
6. Percent patch-scale grid FS	>28.8%	>38.5%
7. Log RBS (relative bed stability)	<−0.39	<−0.90

There is a clear loss of diversity with increased sediment deposition. This relationship is most pronounced when related to the patch-scale fines and sand measured at the locations of invertebrate sampling (Figure 14) than when measured at the reach scale (Figure 15).

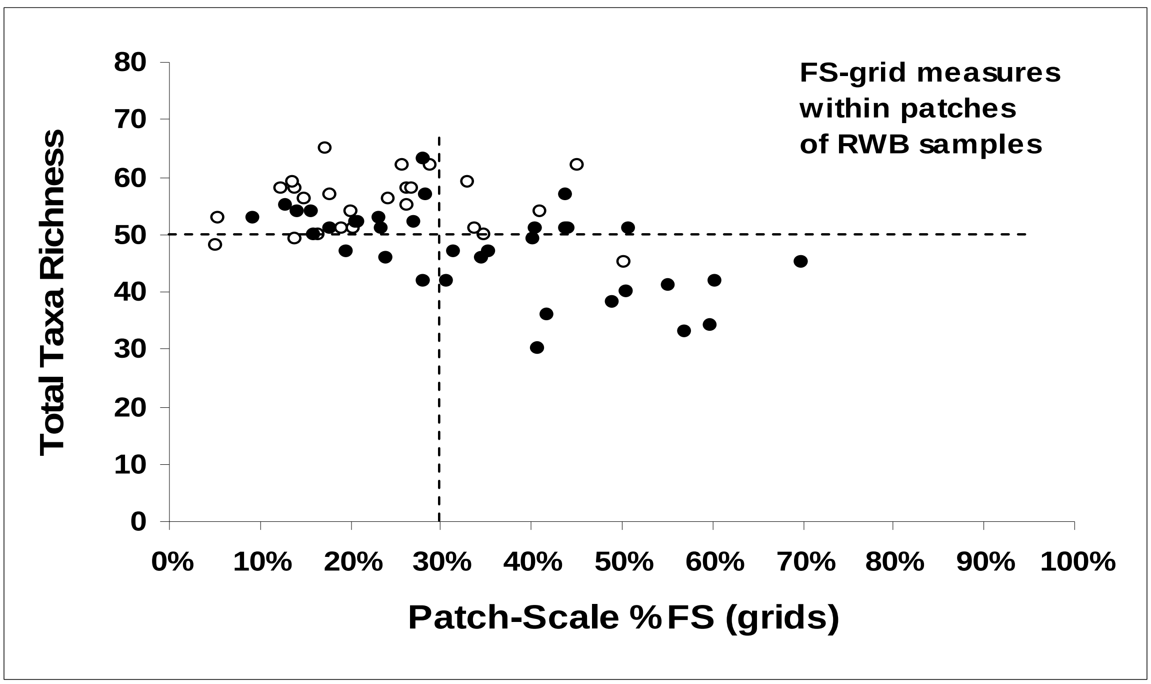


Figure 14. Total taxa richness in relation to percent fines and sand measured at the patch-scale using a 20x20 cm grid quadrat frame for all San Lorenzo area stream surveys (2008 and 2009). Dashed lines show apparent threshold effects of sediment limits on diversity above 30% FS. Open circles are reference, filled circles test.

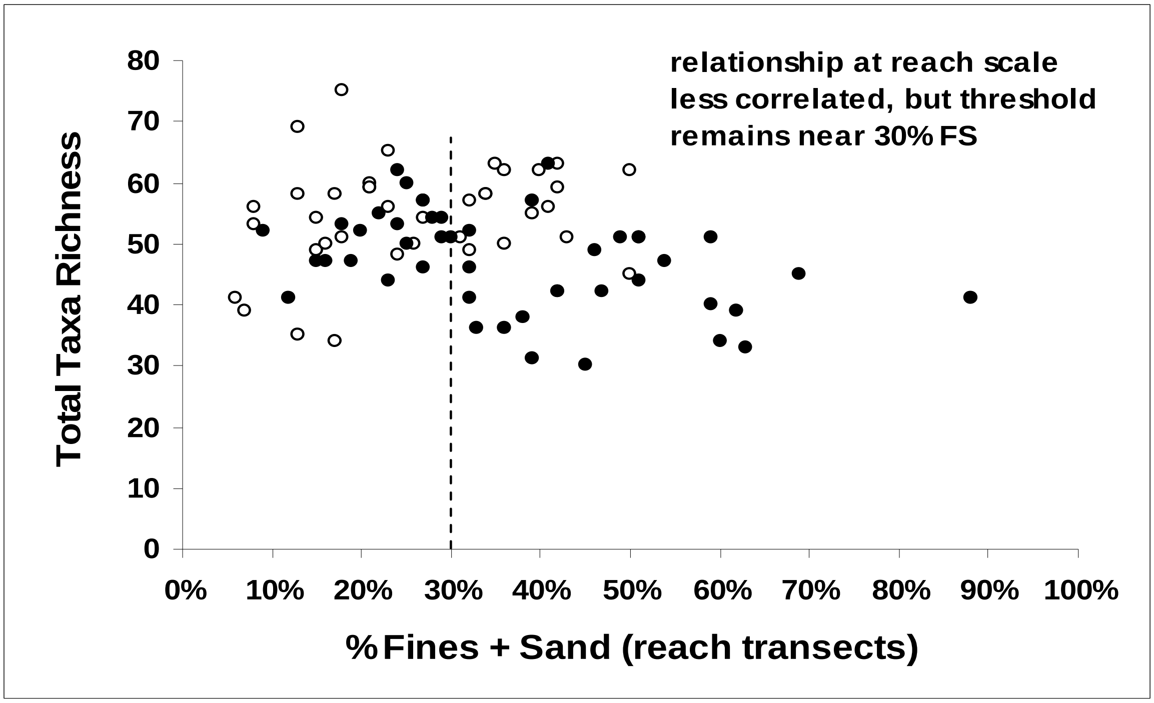


Figure 15. Total taxa richness in relation to percent fines and sand measured at the reach-scale along transects for central coast region (2007), and San Lorenzo area stream surveys (2008 and 2009). Dashed lines shows apparent threshold effects of sediment limits on diversity above 30% FS. Correlation is lower because FS was recorded from across the entire reach rather than at invertebrate sampling points. Open circles are reference, filled circles test.

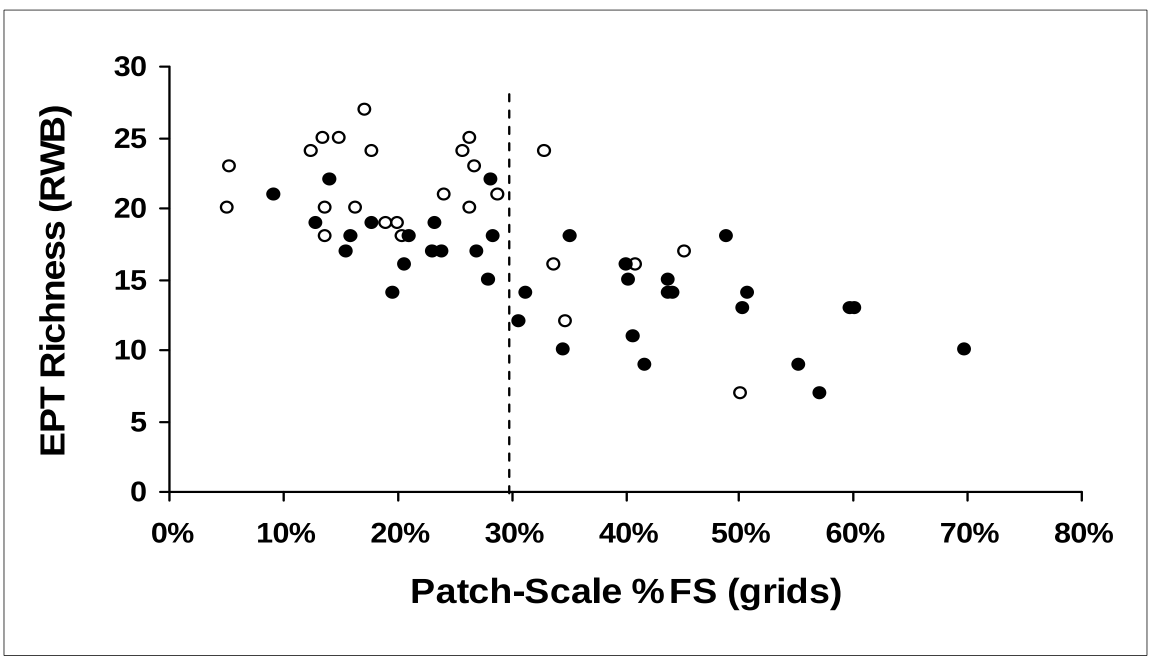


Figure 16. EPT taxa richness in relation to percent fines and sand measured at patch-scale from quadrat grids (20) for San Lorenzo stream surveys (2008 and 2009). Open circles are reference, filled circles test.

These changes in diversity at threshold levels provides evidence for the limiting effect of sediment deposition on biological integrity. In particular the influence of percent fines and sand (%FS) measured at different spatial scales (reach, patch, facies) was apparent above a range of 30-40% (Figures 14-22). Thresholds for impairment are shown at breaks in data distribution above 30% for patch-scale %FS (Figure 14) and reach-scale %FS (Figure 15) for total richness falling below 50 taxa, which also corresponds to the 25th percentile of the reference distribution (see Appendix). This 25th percentile of measures of biological integrity is the level that was used in EPA's Western Stream Assessment (Stoddard et al. 2005) to define an impaired state of moderate disturbance to separate from streams above this level that support the reference least-disturbed condition. The taxa belonging to the mayfly, stonefly, and caddisfly groups (EPT) are often regarded as the most sensitive stream invertebrates, requiring clean, flowing, cold, stable stream bed conditions to thrive. Above 30% patch FS and 40% reach FS, much of the EPT richness falls below 15 taxa (Figure 16, 25th percentile reference =16.5 EPT). Increasing the small particle measure of deposition to include gravel 2-8 mm (%FSG<8mm), the level increases to 50% where most sites fall below 15 taxa. The percent of individuals in the community comprised by EPT taxa also responds above 30% patch-scale (Figure 17) and reach-scale FS (Figure 18), but at the reach-scale there also appears to be an optimum between 20-30% FS, with the fraction EPT declining both above and below this range. The biotic index measure of composite community pollution tolerance increases (more pollution-tolerant individuals present) as both reach- and facies-scale measures of %FS increase (Figures 19 and 20), and again change most above 30%. The percent of individuals defined as tolerant (tolerance values 7 to 10) increase markedly above 30% patch-scale FS (Figure 21), with only 15% of sites exceeding 25% tolerant below this sediment level, but above this 44% of sites have more than 25% tolerant individuals present (75th percentile of reference at 26.3% tolerant). The number of sensitive taxa (tolerance values 0-2) also shifts most at 30% patch-scale FS, with 94% of sites having 10 or more sensitive taxa below this FS level (25th reference percentile 9.5 sensitive taxa), and just 40% of sites above this level (Figure 22).

As with the sediment deposition indicators of impairment, the poorest quartile of the reference distribution can be used as a criterion for biological indicators of impaired condition. Using the lowest quartile (25%) of biological performance of the reference stream range to indicate impairment is supported by correspondence with the observed threshold levels of most biotic responses to sediment deposition (see Appendix for criterion levels of selected indicators). Combining sediment indicators with biological indicators provides a system for prioritizing sites for sediment control and restoration where more than half of indicators of both types are exceeded (red-flags in Appendix). Where sediment but not biological indicators are exceeded suggests that biological communities have either adapted to potential sediment limitations or are in transition and should be re-evaluated periodically. Where biological but not sediment indicators are exceeded suggests that limitations may be produced by stressors other than sediments or only partly by sediments. Stressor identification procedures may be useful in such cases (USEPA 2000; CADDIS: http://www.epa.gov/caddis/). It is also important to recognize where natural sources of sedimentation cause red-flag warnings, such as at Scott Creek (Swanton) where tidal conditions may alter both the physical and biological conditions, and the Big Sur River where wildfire and dredging may have altered sediment flux.

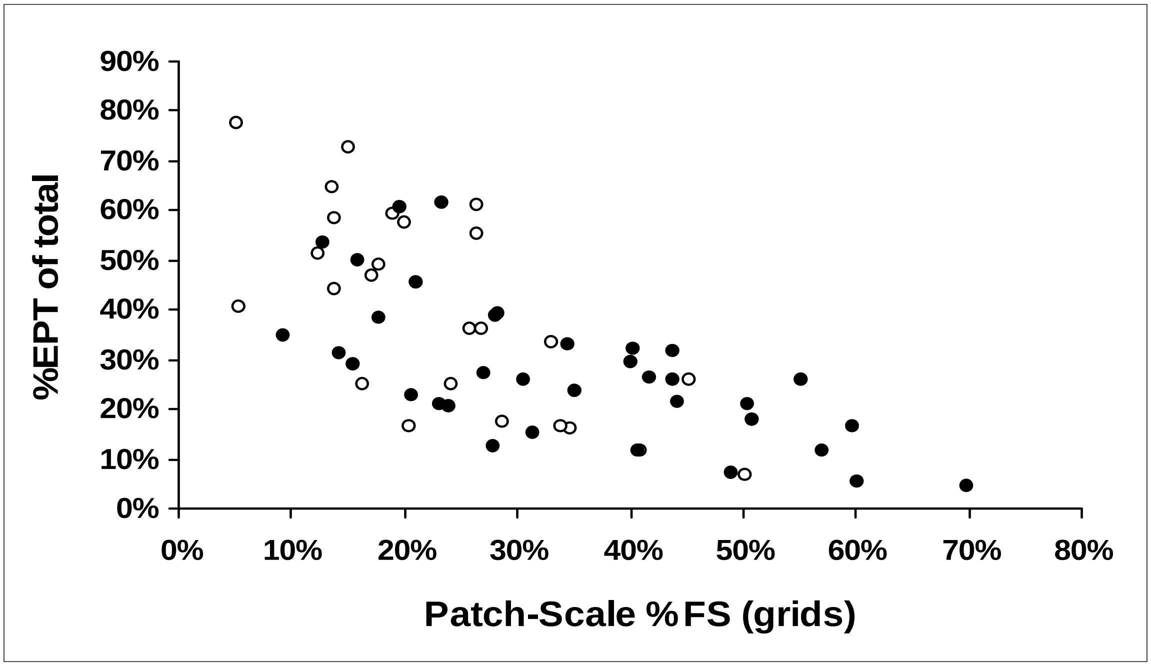


Figure 17. Percent EPT of total invertebrate counts in relation to percent fines and sand measured at patch-scale from quadrat grids (20) for San Lorenzo stream surveys (2008 and 2009). Above 30%FS all samples fall below 40% EPT. Open circles are reference, filled circles test.

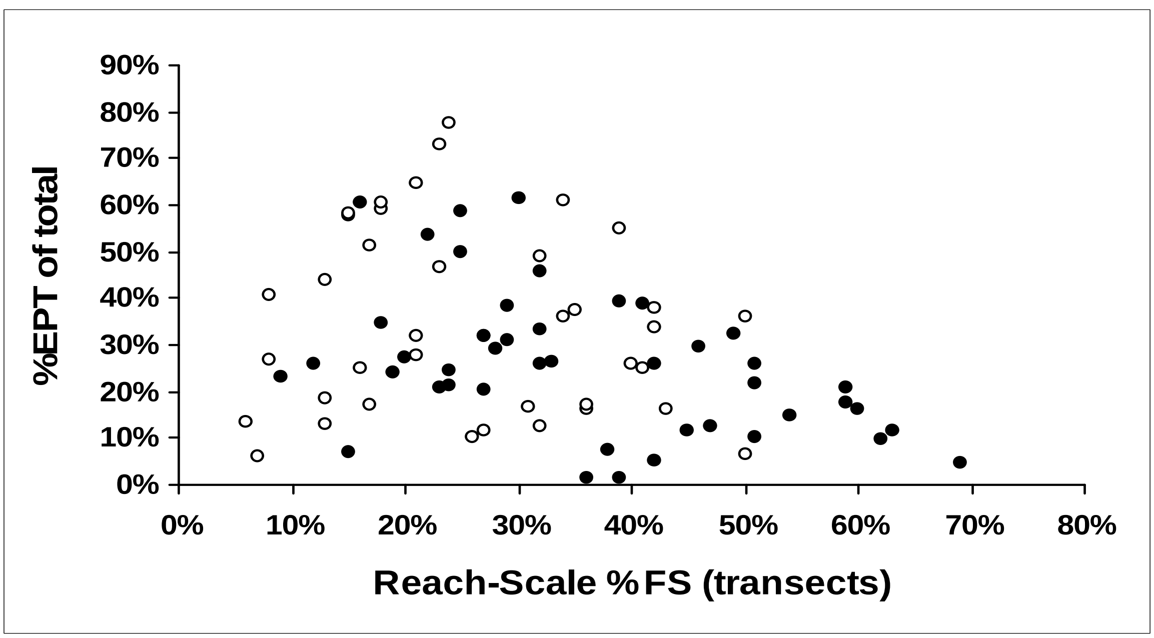


Figure 18. Percent EPT of total invertebrate counts in relation to percent fines and sand measured at rech-scale transects for San Lorenzo stream surveys (2008 and 2009). Optimum at 20-30% FS, with limits on EPT apparent as %FS increases above 30% or decreases below 20%. Open circles are reference, filled circles test.

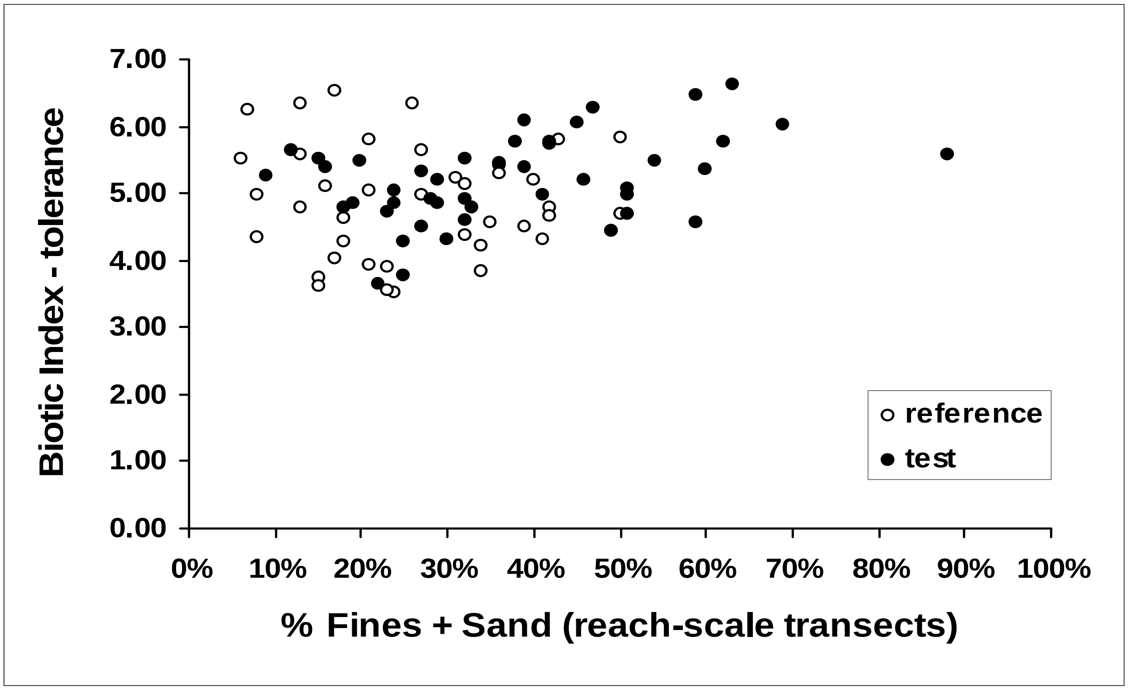


Figure 19. Index of community tolerance to pollution or habitat degradation in relation to percent fines and sand measured at reach-scale transects for San Lorenzo stream surveys (2008 and 2009). Above 30-40% FS, biotic index values are mostly elevated. Open circles are reference, filled circles test.

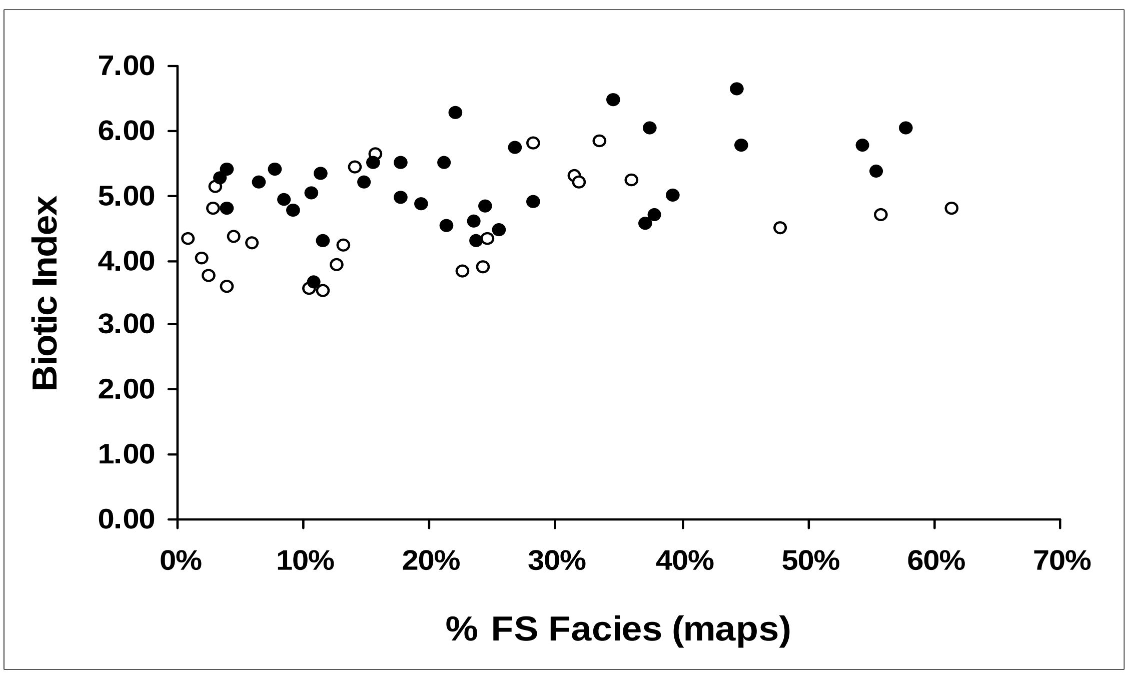


Figure 20. Index of community tolerance to pollution or habitat degradation in relation to percent fines and sand measured at facies-scale from maps prepared for San Lorenzo stream surveys (2008 and 2009). Open circles are reference, filled circles test.

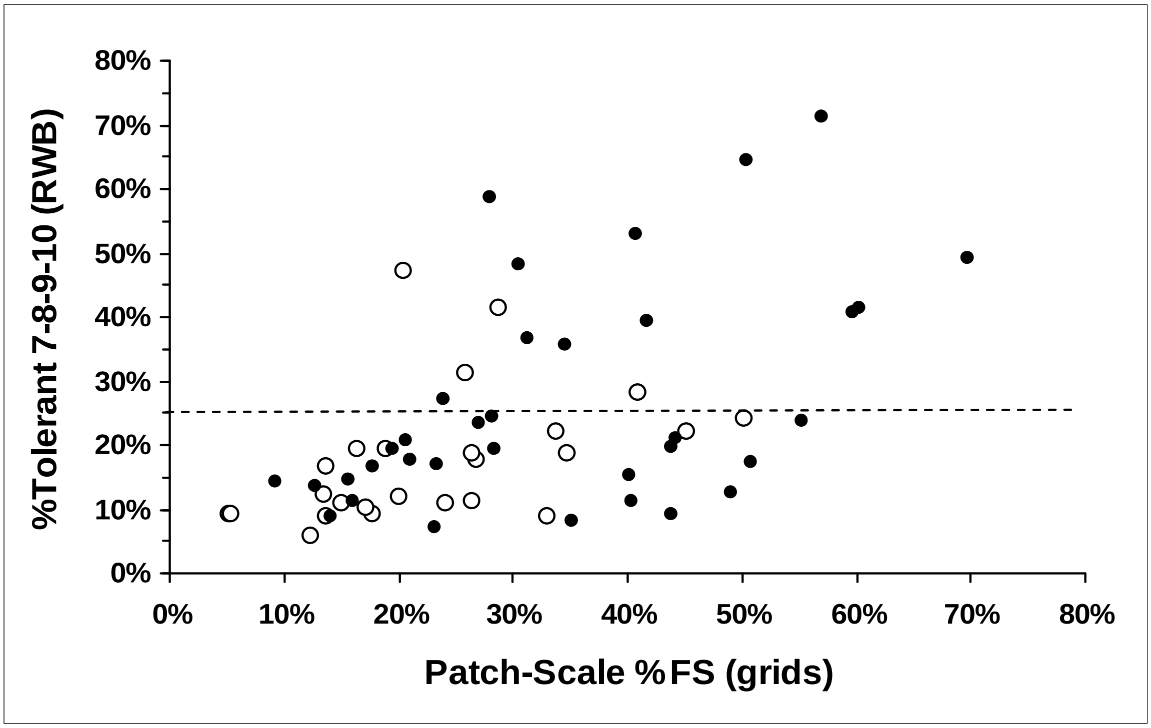


Figure 21. Percent of individuals in community that are considered tolerant of environmental pollution (tolerance values of 7-10) increases with the facies areas that are covered by fines and sand. Open circles are reference, filled circles test.

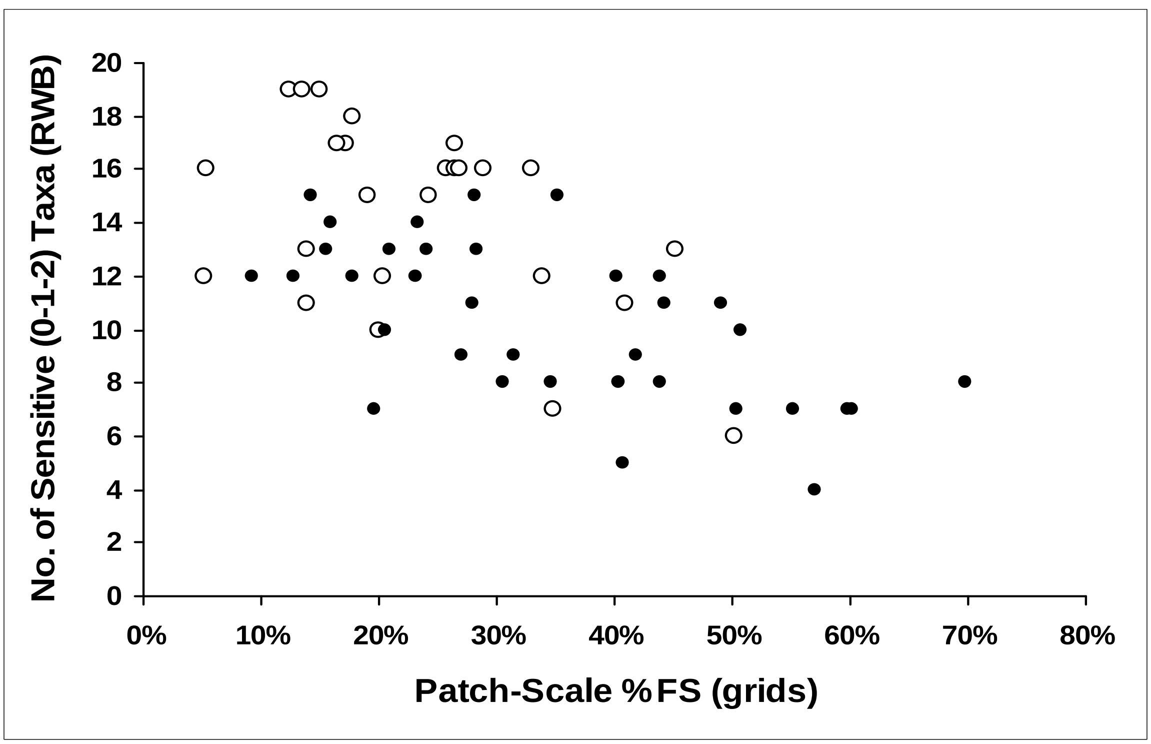


Figure 22**.** Number of sensitive taxa (having tolerance values of 0 to 2) declines with increased level of patch-scale cover of fines and sand. Open circles are reference, filled circles test.

Statistical methods for NMDS ordinations
NMDS provide a tool for visualizing the similarity between biological communities by how close they plot in ordination space. Taxa present at fewer than 20% of sites (15 of 84, or 12 of 60 for San Lorenzo sites only) were removed from analysis, and invertebrate densities were relativized in PC ORD using the general relativization procedure. An NMDS ordination was run in autopilot mode at medium resolution.

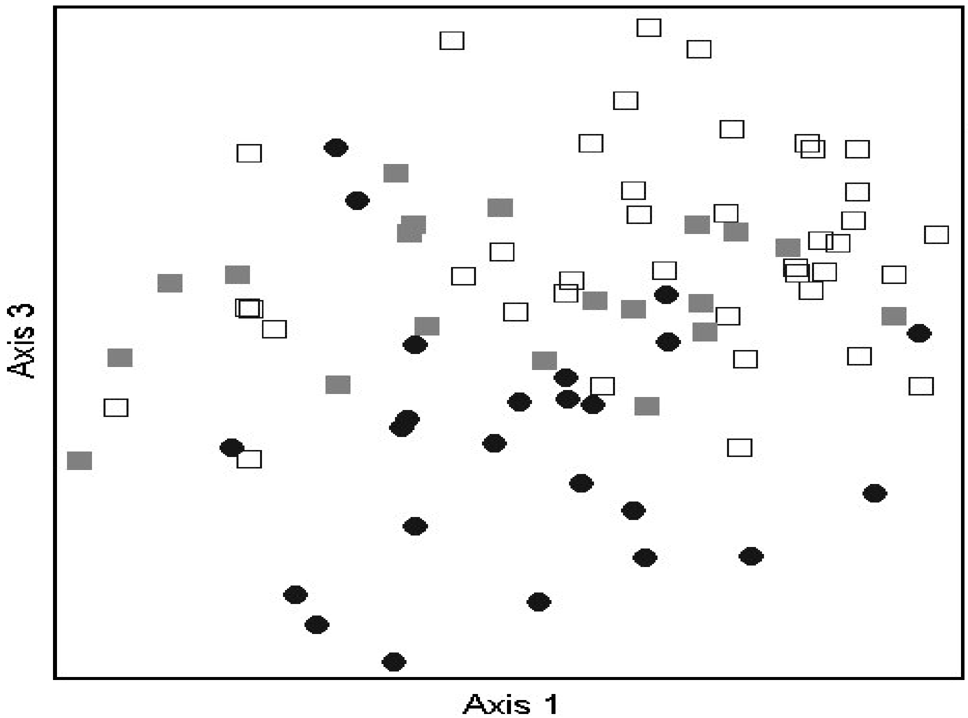


Figure 23. Community ordination showing geographic differences for 84 surveys from 2007 (solid circles) over the central coast region, 2008 (open squares) San Lorenzo and adjacent watersheds, and 2009 (grey squares) from the San Lorenzo only.

Community ordination similarity measures shows the geographic distinctions in taxonomic composition between the local San Lorenzo area and the larger central coast region (Figure 23). In addition to these biogeographic sources of variation in community structure, an examination of the contrasts between the combined central coast streams (Figure 24) and the San Lorenzo region streams (Figure 25) shows that reference and test sites are separated by environmental correlations with sediment fines and sand deposition (%FS), and with elevation from upper to lower watershed (from higher gradient or slope to greater average bankfull area, Avg.Bkf.). The streams with the most extensive cover of fines and sand (shown by symbol size in Figure 25) were also those that showed the most dissimilar community composition by separation in ordination space.

Sediment Tolerance

In addition to ordinations showing community dissimilarities over environmental gradients of sediment, individual taxa can be ranked according to their tolerance to sediment according to the abundance of each at different sediment levels. A listing of taxa by relative sediment tolerance is given at the end of this report.

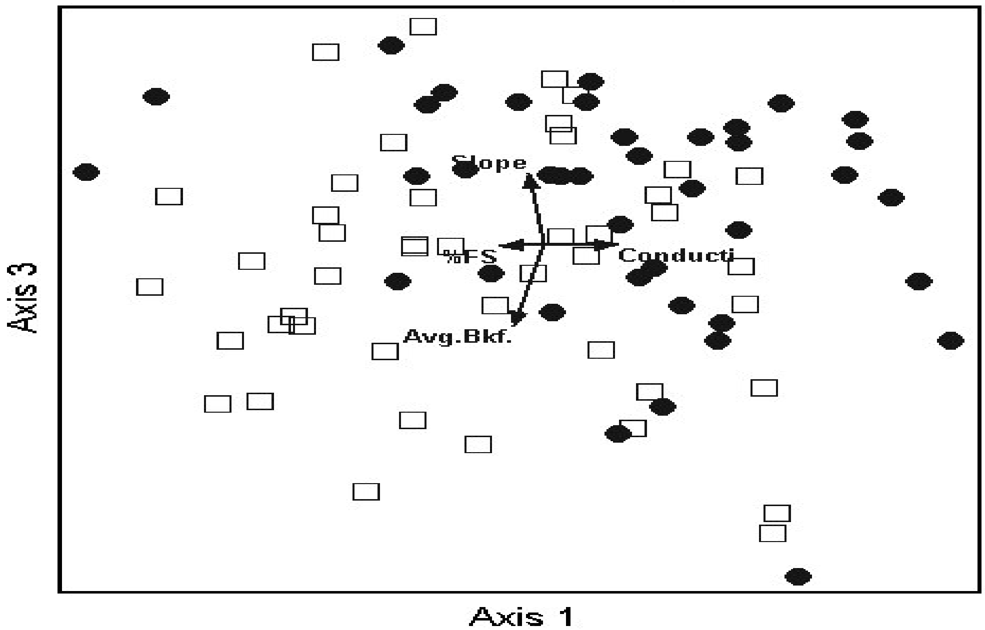


Figure 24. Community ordination for 84 surveys from 2007, 2008, and 2009 separated by Reference (solid circles) and Test (open squares). Several environmental metrics were correlated with ordination axes 1 and 3 (stress=17.5, 3-D solution).

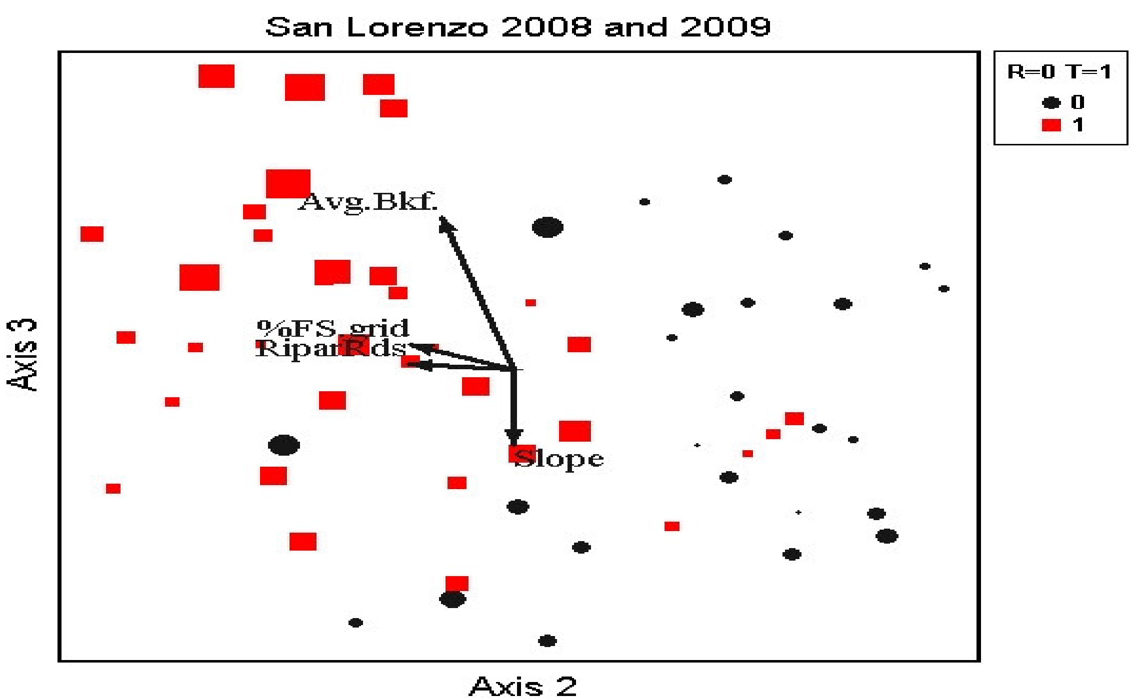


Figure 25. Community ordination for 60 surveys in 2008 and 2009 divided into Reference (25 black circles) and Test (35 red squares) groups. Vectors represent the magnitude of correlation with environmental factors. Elevation gradient along axis 3 from upper to lower catchment small to larger size and slope decreasing. Percent of fines & sand in patch scale grids of substrate) represented by size of symbol, increasing at test sites and with increase in riparian roadedness (stress 18.5 for a 3D solution).

Summary and Conclusions:

- Using data from the central coast ranges streams sampled in 2007, and the San Lorenzo area streams sampled in 2008 and 2009, the coverage of fines and sand measured at reach-, patch-, or facies-spatial scales of resolution (refer to Figure 1, showing these reflect increased spatial coverages of fines/sand deposits) all show limiting biological effects in terms of:

1. A progressive loss of total taxa diversity with increased sedimentation, where above about 30-40% FS, most sites fall below 50 taxa, while most streams are above this level of richness at less than 30% FS (Figures 14, 15).
2. Similarly, there is a loss of sensitive EPT taxa with increased %FS measured at grid frame patches in samples taken in San Lorenzo area streams in 2008 and 2009, showing a threshold above 30% FS results in the greatest collective loss of these insect groups from streams (Figure 16).
3. The fraction of individuals belonging to EPT taxa (%EPT) also declines markedly above 30% patch-scale FS (Figure 17) but there is some indication that an optimum level of reach-scale sediment may exist at 20-30% FS (Figure 18).
4. There is an increase in the community tolerance for pollution or degradation (Biotic Index) as the cover of fines and sand at the reach-scale or facies deposits increases (San Lorenzo area streams in 2008 and 2009; Figures 19, 20).
5. The shift to increased percent of tolerant organisms found in streams, or loss of sensitive taxa, occurs at a threshold level of 30% patch-scale FS (Figures 21, 22).
6. Community ordinations (NMDS plots) show that there were differences between years, primarily because of geographic differences in communities sampled in each year. Although each year shared sites within the San Lorenzo, sites sampled in 2007 came from as far south as the Sespe River and from both west and east sides of the coast range, and many sites in 2008 came from watersheds adjacent to the San Lorenzo – only in 2009 did all sites come from within the San Lorenzo (Figure 23)
7. Community ordinations also showed that for all years combined, there were separations between reference and test (Figure 24), but these were more pronounced when just the 2008-09 data of the San Lorenzo and adjacent watersheds are considered (Figure 25).
8. Surveys of native salmonids (rainbow trout or steelhead) conducted in 2009 showed that percent cover of fines above 6% appeared to limit the density of fish in the San Lorenzo River system (Figure 9). Non-native crayfish number and size increase with cover of fines and fines and sand (Figures 12, 13).

Using both sediment and biological exceedance criteria based on the reference range, and corresponding to thresholds of response of biological indicators to sediment, we conclude that these data provide a system for prioritizing streams for TMDL listing or de-listing, and for monitoring control of sediment sources. Streams that are on the 303(d) list for sediment could be removed if these numeric criteria are not exceeded, or a TMDL could be prepared if criteria are exceeded. Streams not on the 303(d) list might become listed if they exceed the numeric critera. Greater certainty in any judgments is incorporated when multiple biological and physical indicators are used.

References:

Herbst, D.B., S.W. Roberts, R.B. Medhurst, and N.G. Hayden. 2011. Sediment Deposition Relations to Watershed Land Use and Sediment Load Models Using a Reference Stream Approach to Develop Sediment TMDL Numeric Targets for the San Lorenzo River and Central Coast California Streams. Revised report to the Central Coast Regional Water Quality Control Board, January 2011.

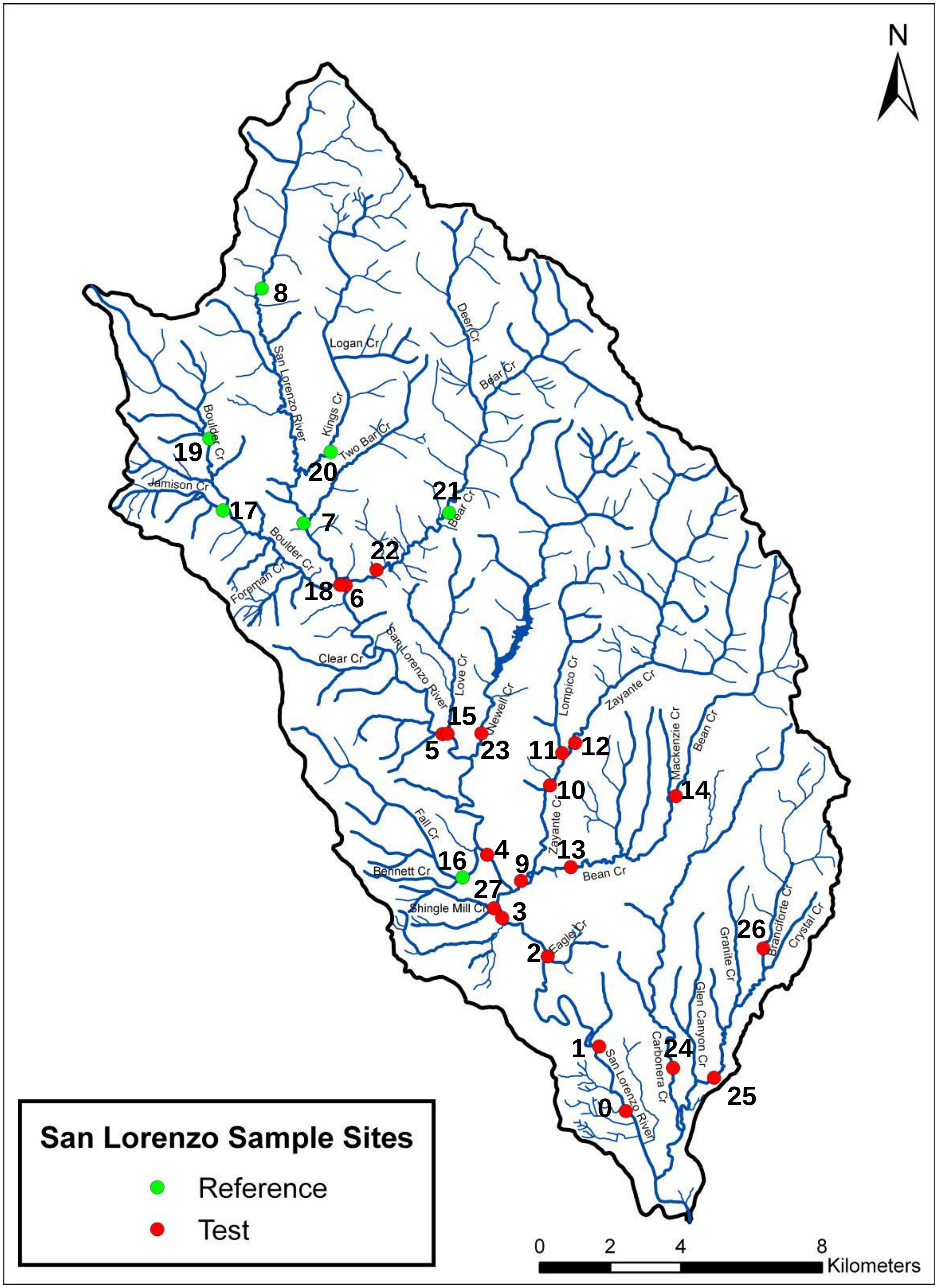
Kaufmann, P.R, P. Levine, E.G. Robison, C. Seeliger, and D.V. Peck. 1999. *Quantifying Physical Habitat in Wadeable Streams.* EPA/620/R-99/003. U.S. Environmental Protection Agency, Washington, D.C.

Stoddard, J.L., D.V. Peck, S.G. Paulsen, J. Van Sickle, C.P. Hawkins, A.T. Herlihy, R.M. Hughes, P.R. Kaufmann, D.P. Larsen, G. Lomnicky, A.R. Olsen, S.A. Peterson, P.L. Ringold, and T.R. Whittier. 2005. *An Ecological Assessment of Western Streams and Rivers*. EPA 620/R-05/005, U.S. Environmental Protection Agency, Washington, DC.

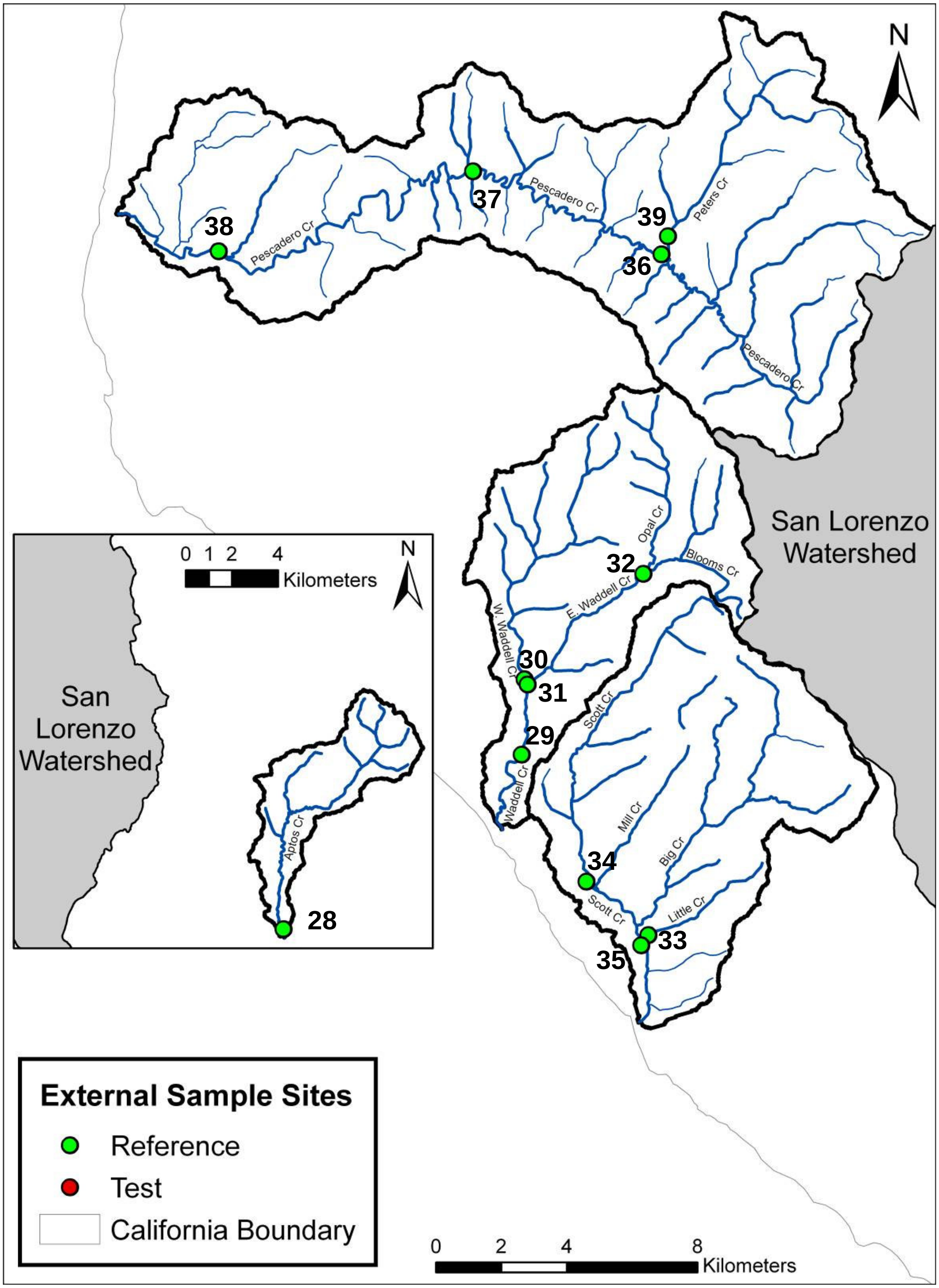
US Environmental Protection Agency. 2000. *Stressor Identification Guidance Document*. Office of Water, EPA-822-B-00-025. Washington, D.C.

Table 2. Correlations (Pearson) of substrate sediments, reach features, and land use with macroinvertebrate community indicators. Correlation coefficients >0.300 are shown in bold. Criterion thresholds for impaired condition are shown at the bottom of the table, for the six selected community metric indicators shown in green highlight and blue text font.

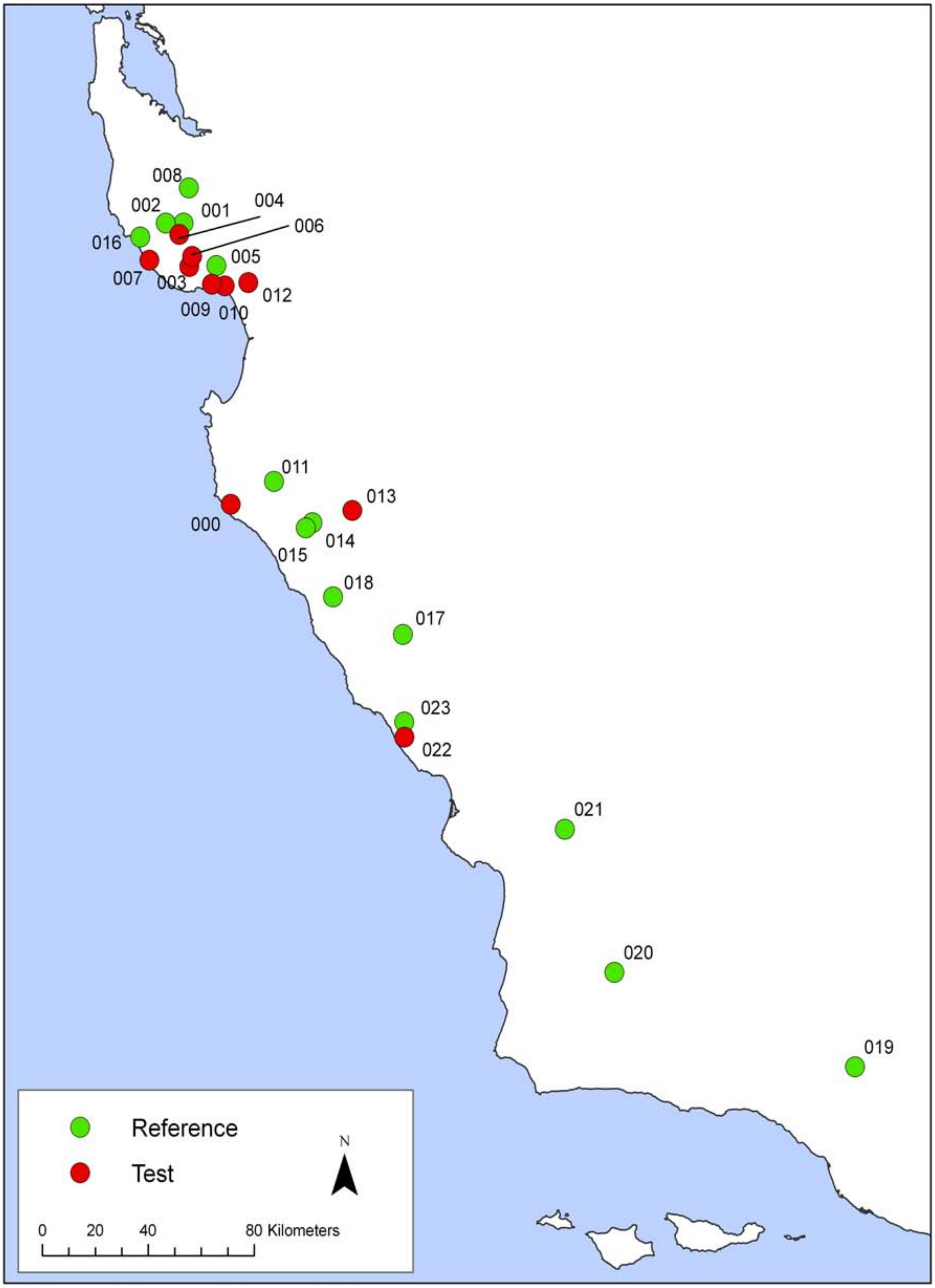
Environmental Variable	**Total Richness**	**EPT Richness**	**Percent EPT**	**Sensitive Taxa Richness**	**Biotic Index**	**Percent Tolerant of total**
%Fines (point-transects)	-0.188	-0.223	-0.220	-0.240	0.107	0.049
%Sand (point-transects)	-0.193	-0.257	-0.243	-0.131	0.239	**0.376**
%FS (point-transects)	-0.264	**-0.337**	**-0.324**	-0.237	0.262	**0.352**
%FSG<8mm (point-transects)	-0.252	**-0.303**	**-0.324**	-0.212	0.294	**0.414**
D50 (median particle size)	0.021	0.101	0.189	0.026	-0.111	-0.246
Geometric Mean (particle size)	-0.076	0.000	0.054	-0.061	0.004	-0.129
Embeddedness (% buried)	-0.029	-0.085	0.050	-0.061	-0.044	0.062
%Facies Fines (reach maps)	-0.237	-0.280	**-0.331**	**-0.312**	0.166	0.039
%Facies FS (reach maps)	-0.269	-0.267	**-0.474**	**-0.303**	**0.401**	**0.437**
%FS patch-scale grids (20)	**-0.523**	**-0.707**	**-0.690**	**-0.634**	**0.595**	**0.532**
%FS patch-scale grids (11 RWB)	**-0.541**	**-0.693**	**-0.684**	**-0.625**	**0.581**	**0.492**
Slope (reach average)	0.298	0.245	0.059	0.267	-0.098	-0.137
Average Bankfull Area	**-0.391**	**-0.394**	**-0.384**	**-0.413**	**0.446**	**0.432**
Relative Bed Stability.D50	-0.047	0.039	0.183	-0.057	-0.095	-0.104
LogRBS.D50	0.029	0.155	0.233	0.076	-0.133	-0.160
Conductivity	0.112	0.090	0.232	0.062	-0.165	-0.141
Temperature	-0.150	-0.191	-0.121	**-0.330**	**0.327**	**0.342**
Riparian Roadedness	-0.143	-0.104	0.008	0.011	-0.043	0.057
Riparian Combined Human Land Use	-0.231	-0.275	-0.171	-0.154	0.024	0.074
Riparian Imperviousness	**-0.306**	**-0.347**	-0.148	-0.218	0.029	0.118
Riparian Road Crossing Density	-0.158	-0.078	-0.038	-0.001	0.021	0.088
Numeric Criteria (impaired direction)	**<**	**<**	**<**	**<**	**>**	**>**
<25% lowest performing quartile	**50.0**	**16.5**	**16.7%**	**9.5**	**5.48**	**26.3%**
<10% lowest performing tenth	**44.2**	**11.6**	**12.3%**	**5.8**	**5.92**	**37.7%**



Map 1. Sites surveyed within the San Lorenzo River watershed in May-June of 2008 and 2009. Site numbers correspond to the code listings in Appendix..



Map 2. Sites surveyed outside of the San Lorenzo watershed in May-June of 2008 and 2009. Includes Aptos (inset), Scott, Waddell, and Pescadero Creeks (gray area is the boundary of the San Lorenzo). Site numbers correspond to the code listings in Appendix.



Map 3. Sites surveyed throughout the Central Coast during May 2007. Site numbers correspond to the code listings in Appendix.

Appendix. Biological metric and sediment exceedances (if > half of indicators exceeded, then red if both biological and physical, yellow if one or the other) – **<u>Reference sites</u>.**

Year	R or T	Stream Name	Site Name	Total richness	EPT richness	%EPT	Biotic Index	Percent Tolerant	Sensitive Number	BioIndicators Exceeded	Deposition Exceedances	<25th % bioindicators >3	>75th % Sediment if >half
2008	R	San Lorenzo River	Brimblecom	58	24	51.2%	4.03	5.9%	19	0	0		
2008	R	San Lorenzo River	Castle Rock	62	24	36.2%	4.70	**31.3%**	16	1	5		x
2008	R	Fall Creek	Cowell SP	51	18	**16.3%**	**5.78**	**47.1%**	12	3	5		x
2008	R	Jamison Creek	fire station	54	**16**	**11.5%**	**5.64**	**28.0%**	11	4	1	x	
2008	R	Boulder Creek	Hwy 236.4	58	20	61.0%	3.83	11.2%	16	0	0		
2008	R	Kings Creek	County Land	**48**	20	77.4%	3.50	9.1%	12	1	2		
2008	R	Bear Creek	treatment plant	57	24	48.9%	4.37	9.2%	18	0	2		
2008	R	Aptos Creek	Rancho trail	50	**12**	**16.2%**	5.43	18.7%	**7**	3	5		x
2008	R	Waddell Creek	Alder Camp	58	18	43.9%	4.79	16.6%	11	0	0		
2008	R	W. Waddell Creek	confluence	56	25	72.8%	3.55	10.9%	19	0	1		
2008	R	E. Waddell Creek	confluence	54	19	57.5%	3.74	11.9%	10	0	0		
2008	R	E. Waddell Creek	treatment plant	58	23	35.9%	4.22	17.6%	16	0	3		
2008	R	Little Creek	Swanton bridge	62	21	17.3%	5.29	**41.3%**	16	1	5		x
2008	R	Scott Creek	Upper trib	51	**16**	**16.5%**	5.24	22.2%	12	2	3		
2008	R	Scott Creek	Below Little	65	27	46.7%	3.89	10.2%	17	0	1		
2008	R	Pescadero Creek	Cloverdale bdg	62	17	25.8%	5.20	22.1%	13	0	5		x
2008	R	Pescadero Creek	Oakland YMCA	**49**	20	58.3%	3.60	8.9%	13	1	0		
2008	R	Pescadero Creek	Sequoia trail	50	20	25.0%	5.11	19.3%	17	0	0		
2008	R	Peters Creek	campground	59	25	64.7%	3.93	12.2%	19	0	0		
2009	R	Aptos Creek	Rancho trail	**45**	**7**	**6.5%**	**5.84**	24.1%	**6**	5	7	x	x
2009	R	Fall Creek	Cowell SP	56	21	24.9%	4.31	10.9%	15	0	6		x
2009	R	Bear Creek	treatment plant	51	19	59.2%	4.27	19.4%	15	0	1		
2009	R	San Lorenzo River	Brimblecom	53	23	40.4%	4.33	9.2%	16	0	0		
2009	R	San Lorenzo River	Castle Rock	59	24	33.6%	4.77	8.7%	16	0	6		x
2009	R	Kings Creek	County Land	55	25	55.0%	4.49	18.6%	17	0	2		
2007	R	Kings Creek	County Land	57	20	31.6%	4.96	21.6%	13	0	1		
2007	R	San Lorenzo R	Campbell	63	23	38.0%	4.65	26.1%	15	0	4		x
2007	R	Soquel Cr	Upper	63	19	37.5%	4.57	21.1%	12	0	0		
2007	R	Stevens Cr	Reservoir	60	17	27.5%	5.05	11.1%	12	0	1		
2007	R	Carmel R	Bluff Camp	**41**	**13**	**13.5%**	**5.52**	24.2%	**7**	5	0	x	
2007	R	Arroyo Seco	day use area	**39**	**10**	**5.9%**	**6.25**	**36.8%**	**5**	6	0	x	
2007	R	Tassajara Cr	Horse trail	**35**	**12**	18.4%	**5.58**	12.4%	**8**	4	0	x	
2007	R	Waddell Cr	Alder Camp	**49**	**15**	**12.5%**	5.13	12.7%	**9**	4	0	x	
2007	R	San Antonio R	Interlake Bridge	69	17	**13.0%**	**6.34**	**51.2%**	**7**	4	0	x	
2007	R	Nacimiento Cr	Campground	56	19	26.5%	4.98	20.8%	17	0	1		
2007	R	Sespe Cr	Lion	59	17	31.7%	**5.81**	**28.2%**	**5**	3	1		
2007	R	Sisquoc R	Above Dam	**34**	**10**	16.9%	**6.52**	**59.7%**	**2**	5	1	x	
2007	R	Salinas R	CDF Station	50	**10**	**10.0%**	**6.32**	**36.8%**	**2**	5	0	x	
2007	R	San Simeon Cr	Above Fence	75	24	60.7%	4.63	**26.6%**	19	1	1		
		bioindicator criteria	<25th percentile	**50.0**	**16.5**	**16.7%**	**5.48**	**26.3%**	**9.5**				
			<10th percentile	**44.2**	**11.6**	**12.3%**	**5.92**	**37.7%**	**5.8**				
			direction of impairment	**<**	**<**	**<**	**>**	**>**	**<**				

Appendix (continued). Biological metric and sediment exceedances (if > half of indicators exceeded, then red if both biological and physical, yellow if one or the other) – **Test sites**.

Year	R or T	Stream Name	Site Name	Total richness	EPT richness	%EPT	Biotic Index	Percent Tolerant	Sensitive Number	BioIndicators Exceeded	Deposition Exceedances	<25th % bioindicators >3	>75th % Sediment if >half
2008	T	San Lorenzo River	city intake	**40**	**13**	20.9%	**6.46**	**64.4%**	**7**	5	7	x	x
2008	T	San Lorenzo River	Paradise	**42**	**12**	26.0%	**5.74**	**48.3%**	**8**	5	5	x	x
2008	T	San Lorenzo River	RR bridge	**42**	**15**	**12.3%**	**6.26**	**58.8%**	11	5	5	x	x
2008	T	San Lorenzo River	entrance bdg	**45**	**10**	**4.6%**	**6.02**	**49.0%**	**8**	6	7	x	x
2008	T	San Lorenzo River	San Lo Way	63	22	38.9%	4.96	24.4%	15	0	3		
2008	T	San Lorenzo River	Hwy 9 X	57	18	39.2%	5.39	19.2%	13	0	5		x
2008	T	San Lorenzo River	E Lomond bdg	54	22	31.0%	5.18	9.0%	15	0	1		
2008	T	Zayante Creek	RR bridge	**46**	17	20.4%	5.33	**27.1%**	13	2	0		
2008	T	Zayante Creek	Quail Hollow	**38**	18	**7.3%**	**5.77**	12.4%	11	3	7		x
2008	T	Lompico Creek	Lompico bdg	57	**14**	31.8%	4.51	19.6%	12	1	0		
2008	T	Zayante Creek	Market bdg	**47**	18	23.8%	4.86	8.3%	15	1	2		
2008	T	Bean Creek	Locateli Rd.	**34**	**13**	**16.3%**	5.35	**40.8%**	**7**	5	6	x	x
2008	T	Bean Creek	Morgan Runs	51	19	61.5%	4.29	16.8%	14	0	3		
2008	T	Love Creek	Glen Arbor bdg	53	17	21.0%	5.03	7.0%	12	0	1		
2008	T	Boulder Creek	Hwy 9	**47**	**14**	60.4%	5.39	19.4%	**7**	3	2		
2008	T	Bear Creek	Eurella	50	18	49.8%	4.28	11.2%	14	0	0		
2008	T	Newell Creek	Rancho Rio Rd.	51	**15**	26.0%	4.68	9.1%	**8**	2	8		x
2008	T	Carbonera Creek	Carbonera Rd	**36**	**9**	26.4%	4.77	**39.3%**	**9**	4	4	x	
2008	T	Branciforte Creek	DeLaveaga	51	**14**	21.5%	4.99	21.2%	11	1	8		x
2008	T	Branciforte Creek	Shady Brook bdg	**49**	**16**	29.4%	5.21	15.1%	12	2	6		x
2008	T	Shingle Mill Creek	Above Hwy 9	**47**	**14**	**15.0%**	**5.49**	**36.6%**	**9**	6	6	x	x
2009	T	San Lorenzo River	Paradise	**46**	**10**	33.1%	**5.50**	**35.5%**	**8**	5	3	x	
2009	T	San Lorenzo River	city intake	**33**	**7**	**11.4%**	**6.63**	**71.1%**	**4**	6	6	x	x
2009	T	San Lorenzo River	RR bridge	**30**	**11**	**11.4%**	**6.04**	**53.0%**	**5**	6	5	x	x
2009	T	Bean Creek	Locateli Rd.	51	**14**	17.6%	4.57	17.3%	10	1	7		x
2009	T	Bean Creek	Morgan Runs	52	18	45.5%	4.59	17.5%	13	0	0		
2009	T	Carbonera Creek	Carbonera Rd.	**41**	**9**	25.7%	4.90	23.8%	**7**	3	3		
2009	T	Branciforte Creek	DeLaveaga	51	**15**	32.2%	4.44	11.2%	**8**	2	8		x
2009	T	San Lorenzo River	entrance bdg	**42**	**13**	**5.3%**	**5.77**	**41.3%**	**7**	6	4	x	
2009	T	San Lorenzo River	San Lo Way	51	19	38.5%	4.84	16.4%	12	0	2		
2009	T	Boulder Creek	Hwy 9	52	**16**	22.9%	5.25	20.6%	10	1	0		
2009	T	Bear Creek	Eurella	55	19	53.6%	3.64	13.4%	12	0	1		
2009	T	Zayante Creek	RR bridge	54	17	28.9%	4.92	14.5%	13	0	0		
2009	T	San Lorenzo River	Hwy 9 X	52	17	27.3%	5.48	23.5%	**9**	1	0		
2009	T	San Lorenzo River	E Lomond bdg	53	21	34.8%	4.79	14.1%	12	0	0		
2007	T	Big Sur River	Coyote Flat	**39**	**8**	**9.5%**	**5.78**	23.5%	**5**	5	6	x	x
2007	T	San Lorenzo R	RR bridge	**44**	**11**	**10.0%**	5.06	25.5%	**8**	4	5	x	x
2007	T	Bear Cr	Scout Camp	60	21	58.8%	3.76	13.1%	14	0	0		
2007	T	Zayante Creek	RR bridge	62	18	24.4%	4.86	20.4%	13	0	1		
2007	T	Scott Cr	Swanton	**31**	**9**	**1.5%**	**6.08**	**30.1%**	**6**	6	4	x	x
2007	T	Soquel Cr	Lower	**36**	**8**	**1.5%**	5.45	24.0%	**3**	4	2	x	
2007	T	Aptos Cr	Valencia	**41**	**6**	23.5%	**5.57**	**29.0%**	**4**	5	5	x	x
2007	T	Corralitos Cr	Hames	**47**	**12**	**6.7%**	**5.50**	**28.8%**	**8**	6	0	x	
2007	T	Arroyo Seco	Green Bridge	**41**	**11**	25.7%	**5.65**	**30.5%**	**4**	5	1	x	
2007	T	Santa Rosa Cr	High School	**44**	**10**	21.0%	4.72	20.5%	**4**	3	2		

Listing of taxa sediment tolerance ranked most-to-least by weighted average %FS based on patch-scale samples from San Lorenzo River region (n=60, 2008-2009 grid samples)

Taxa_Code	Total#Occuring	#ofSamples Occuring	Avg%FS	%GridFSMetric
Phaenopsectra	4205.43	24	36.21	49.18
Hygrobates	2447.45	22	30.84	47.09
Cladotanytarsus	58411.73	23	36.65	43.66
Oligochaeta	32817.56	57	29.35	42.59
Parakiefferiella	8258.70	40	33.22	41.44
Polypedilum_scalaenum	4820.46	23	32.49	41.36
Pisidium	575.14	22	32.17	40.26
Tanytarsus	59135.44	55	30.22	38.70
Serratella	2614.17	29	25.51	38.28
Ostracoda	1913.99	39	29.52	38.21
Tricorythodes	12569.59	45	28.99	38.17
Sperchon	3851.15	41	28.51	37.46
Microtendipes_pedellus	8487.98	26	31.48	37.23
Thiennemannimyia	3704.13	45	29.27	36.97
Antocha	997.60	24	35.23	36.92
Sperchonopsis	592.50	17	32.02	35.94
Skwala	552.68	17	28.19	34.64
Lebertia	2494.10	46	29.97	33.96
Neoplasta	326.12	16	31.70	33.26
Sphaeromias	455.94	21	30.41	33.13
Stempellinella	10726.10	47	29.08	33.10
Hydropsyche	1149.60	23	30.07	33.06
Micropsectra	20491.76	51	30.01	33.02
Parametriocnemus	6186.08	46	28.61	32.58
Rheocricotopus	4542.10	34	28.01	32.49
Dicranota	200.72	19	31.88	32.32
Heterotrissocladius_marcidus	1476.55	28	29.43	32.30
Optioservus_quadrimaculatus	7216.49	55	29.59	31.57
Siphlonurus	261.33	17	30.52	31.47
Hydra	422.67	17	30.77	31.23
Rheotanytarsus	4988.68	28	31.56	30.77
Cricotopus_Orthocladius	4247.50	36	28.51	30.59
Corynoneura	2791.16	44	28.78	30.39
Microtendipes_rydalensis	2418.67	25	25.94	30.23
Mucronothrus	592.33	21	30.31	30.08
Lepidostoma	16869.21	59	29.36	29.66
Brillia	5622.53	43	29.42	29.65
Sialis	922.40	28	27.22	29.63
Tvetenia_bavarica	1162.11	25	28.06	29.18

Atractides	2730.27	46	29.14	29.12
Centroptilum	3973.55	49	28.29	28.85
Polypedilum_tritum	3481.56	19	29.24	28.71
Synorthocladius	1325.87	28	29.60	28.54
Zavrelimyia	927.75	22	25.11	27.90
Isoperla	351.57	21	23.64	27.63
Baetis	26042.83	59	29.36	27.62
Neophylax	638.53	23	20.64	27.32
Timpanoga_hecuba	318.44	20	26.56	26.60
Polypedilum_laetum	3136.46	23	27.12	26.09
Cordulegaster_dorsalis	280.35	19	22.60	25.79
Torrenticola	3605.71	43	25.61	25.58
Narpus_angustus	422.44	29	25.49	25.42
Rhyacophila_betteni	1967.28	52	29.59	25.19
Psychoglypha	350.25	22	27.29	24.53
Fluminicola	832.00	24	29.34	24.35
Ephemerella_maculata	1942.50	42	27.11	24.35
Ceratopsyche	600.22	21	27.17	24.31
Paraleptophlebia	9762.59	51	28.06	24.13
Turbellaria	436.53	19	24.80	24.02
Physa	461.07	17	25.73	23.30
Optioservus_divergens	2377.64	19	24.26	23.27
Bezzia_Palpomyia	752.59	33	25.05	22.69
Eukiefferiella_claripennis	717.40	21	22.33	22.58
Micrasema	378.23	15	21.43	22.27
Simulium	11007.63	55	28.12	22.03
Glossosoma	266.11	15	22.16	22.01
Polypedilum_aviceps	3972.86	28	21.68	21.89
Suwallia	987.20	20	22.56	21.88
Malenka	12611.25	56	28.26	21.58
Wormaldia	1526.97	27	26.86	21.01
Zaitzevia	1074.89	26	21.20	20.42
Drunella_flavilinea	571.32	30	21.87	20.34
Diphetor_hageni	1689.35	24	24.29	20.17
Calineuria_californica	957.59	27	21.25	20.12
Apatania	754.02	18	20.06	18.88
Agapetus	2385.29	35	27.41	17.27
Epeorus	1057.02	27	21.44	16.44
Nixe	15668.02	54	27.62	16.05
Eubrianax_edwardsii	1074.07	25	20.54	10.78