Project Summary Report

Sediment TMDL Guidance for Central Coast Region of California and the San Lorenzo River: Physical Habitat and Biological Criteria for Deposited Sediments in Streams

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Overview and Goals

This summary project report provides an overview of results from combined studies of sediment deposition in streams from the San Lorenzo River region and more extensive surveys along the coastal and interior valleys of the central coast range mountains. These studies examined sediment levels in reference streams from watersheds with minimal levels of road and land use disturbance compared to test-streams with moderate to high levels of disturbance. Criteria for identifying sediment impaired conditions were derived both from the highest percentiles of sediments observed the reference streams and from changes in biological indicators at differing sediment levels. The results from these complementary studies of physical and biological effects of sediment are detailed in companion reports, and are synthesized in this project summary. These two companion reports together make up the FINAL report deliverable for Contract 07-125-130

Setting expectations for acceptable levels of sedimentation was based on the approach used in the USEPA Ecological Assessment of Western Streams and Rivers (Stoddard et al. 2005), which defined conditions above the 90th percentile of sediment-stress measures at reference sites as “most-disturbed”, between the 75th and 90th percentiles “moderately disturbed”, and below the 75th percentile conditions would be considered as meeting standards for being “undisturbed”. These levels may also be thought of in regulatory terms as “not supporting”, “partially supporting”, and “supporting” of numeric standards based on the reference range. For the central coast studies reported here, this approach is based on 39 reference streams. In addition to this approach, changes in biological indicators across the observed range of sediment deposition in all stream surveys (45 additional test streams for 84 total), were used to evaluate whether there are thresholds in sediment levels above which biological communities suffer severe losses in diversity and/or abundance of sensitive species [*integration task (f) below*]. In these studies we used altered community structure among benthic invertebrates as the primary indicators, along with more limited data on abundance of steelhead (anadromous rainbow trout) in the San Lorenzo River.

The goals of the study were as follows (re-stated from contract 07-125-130):
(a) document responses of benthic communities to sediment deposition
(b) establish physical habitat features representing disturbed levels of sediment deposition
(c) document potential biological impairment thresholds for sediment
(d) refine taxa-specific tolerance rankings and values for sediment effects
(e) determine sediment relation to salmonid abundance
(f) integrate results of San Lorenzo study with central coast region data set

Study Design and Methods

Streams were selected for the purposes of this study to reflect a range of exposure to watershed land surface disturbances to erosion from both natural and land-use sources (Table 1, and Figures 1-3). Streams with ≤3 km/km^2 riparian area roads and ≤10% combined human land use (some exceptions) were defined as reference. Stream reach surveys were conducted in May and June of 2007, 2008 and 2009, and emphasized measurement of sediment deposition features at different scales (as points on transects, as patches in quadrat grids, and as large deposition features such as bars), and geomorphic features of channels that could influence how particles were transported and deposited under bankfull flow conditions (refer to separate reports for details on methods used). Sediment was partitioned in terms of different size classes as follows (in mm): F (fines, <0.25), S (sand, 0.25-2), G (gravel, 2-8 and 2-16 classes), P (pebble, 16-64), C (cobble, 64-256), and B (boulder and bedrock, >256). Though F and S were measured as classes, all others were measured in terms of intermediate axis dimension, enabling calculation of a median particle size (D50) for all substrates measured in the channel. Some particle classes were combined as sediment deposition measures (FS, FSG<8 or FSG<16 for fines and sand combined with the smallest gravels or all gravels). Relative bed stability and excess fines were also used as expressions of sedimentation, related to the observed particle composition of a streambed compared to what would be expected from the flow energy capability of a channel to transport particles, and how reference streams compare to test streams (refer to physical report for methods). [*task (b)*]

Land use types and areas covered were measured for each stream using GIS, and were partitioned for the entire catchment of streams, just the riparian zone (100 m on either side of the channel), or only the local area of the reach (to 500 m upstream). In this way, the influence of land use at different spatial scales could be related to sediment deposition observed in each stream. Different models of erosion and soil loss were also used to predict the load of sediments from the upstream watersheds into the stream study reaches. These models provided a means of testing how observed sediment deposition in streams might be related to the cumulative amount predicted to be entering a stream. Output of predicted sediment loads were normalized to compare streams by dividing the load by the length of stream channel over which the load could be distributed or deposited, and the power at the reach when bankfull flows could transport sediment.

Along with the physical habitat and substrate features measured at each stream, samples of benthic aquatic invertebrates were also taken. Sampling method used was the standard SWAMP reachwide composite benthos protocol, but this was supplemented by recording the fine and sand counts present on a 25-point grid placed over each sample location prior to collecting. An additional sampling protocol was to collect replicate samples from depositional bars at each site, also using a grid frame to measure fine and sand cover present. Biological indicators from these samples could then be examined in relation to the cover of deposited sediments across different streams, both at the reach-scale of sediment over the entire reach, and the patch-scale of sediment occurring just at localities where invertebrate samples were taken. [*task (a)*]

In 2009, within the San Lorenzo drainage at 20 sites repeated from 2008 surveys, we conducted electroshocking surveys where both steelhead rainbow trout and non-native crayfish were collected, counted and measured. This provided another set of biological data to assess the influence of bedded sediments on large native and non-native aquatic species that can have important roles in aquatic food webs. [*task (e)*]

Study Results

There were significant differences in sediments between reference and test stream groups, with more fines and sand at test streams, measured at either the transect or grid-scale (Figures 4 and 5). The test streams where combined land use disturbance and road densities were greater than in reference streams, also showed increased levels of sediment in proportion to these land use activities. The minimum levels of sediment (FSG<8) found in streams increases with both greater combined human land use (Figure 6), or road density within the riparian zone (Figure 7). Quantile regression on the 10^{th} percentile of these sediment distributions showed that the minimum amount of sediment found in stream beds increases 4 to 5 percent for each 10% increase in combined land use or each km/km^2 of road density.

Sediment load models predict higher amounts of sediment loading in the disturbed landscapes of test streams than compared to reference streams, and these loads are show a clear relationship to observed sediment deposition (Figures 8 and 9). These models also show that as the predicted load increases, so does the minimum level of sediment present. The FOREST model predicts an average annual normalized load (divided by upstream channel length and local reach power index) of 18.4 Mg at reference sites, increased 2.2X to 40.2 Mg load at test streams. AGWA predicts a similar relative increase of 2.6X from 10.3 to 26.3 Mg of sediment in reference and test streams, respectively.

Criteria for establishing standards can be based on the highest stressor levels observed within the distribution of reference sites, assuming these are due to a combination of natural causes and the low levels of disturbance present at reference sites selected according to a least-disturbed condition approach (Stoddard et al. 2006). Taking the 75^{th} and 90^{th} percentiles of sediment levels observed at reference sites (as done for the Western Stream Assessment, Stoddard et al. 2005), the criteria for 7 measures of bedded sediment can be depicted as bar charts of ranges representing regulatory standards (Figure 10). This shows, for example, that combined percent fines and sand (FS) meet standards for any level below 35.5% (green), but that between 35.5 and 42% FS any stream is only <u>partially supporting</u> of habitat quality (yellow), and >42% FS streams would be categorized as <u>not supporting</u> of habitat quality with regard to the %FS measure of sedimentation (red). [*task (b)*]

The relation of biological indicators to sedimentation show gradual increases in the relative abundance of tolerant taxa with increased sediment cover, but as limits are reached, thresholds were observed for losses in diversity where the most sensitive groups of taxa start to disappear (Figure 11). The percent tolerant taxa increase gradually with increased %FS, but diversity in the number of sensitive taxa drops rapidly at 30% as shown in the deviance reduction (Figure 11), a statistical measure of the changepoint in a response variable over an environmental gradient (Qian et al. 2003). This was observed also for total diversity (Figure 12) with the best resolution of the changepoint found where sediments were measured at the same local scale as where the invertebrate collections were taken (patch- rather than reach-scale). [*tasks (a) & (c)*]

The limits imposed on diversity indicators shown at about 30% FS corresponds to the sediment levels of 30-40% FS where most indicators at all sites fall below the criterion 25^{th} percentile of reference sites (horizontal dashed lines in Figures 11 and 12). Patch-scale samples taken on depositional bars from streams in both the Coast Range and Sierra show statistically significant losses of total and EPT (mayflies, stoneflies and caddisflies) diversity over the range 25-40% (Figure 13), representing a similar range for the overall loss of biological integrity as seen in the Central Coast data alone (both at reach-scale and patch-scale grid samples). [*task (f)*]

The changes in overall community metrics (such as diversity and tolerance) over sediment gradients can also be applied to individual taxa. Weighting the relative abundance of commonly observed taxa by the sediment cover where they occur can be used to provide a summed product ranking of taxa that ranges from aversion to tolerance of sediment (Table 2). Using this ranked list, developed from both reach-scale and patch-scale relations of common invertebrates (present at >20% of streams sampled), the taxa found in coastal streams can be grouped into indicator groups that are tolerant or somewhat tolerant, sensitive or somewhat sensitive, and intermediate with respect to their responses to sediment. Midges and non-insect invertebrates dominate the tolerant taxa, and the EPT dominate the sensitive end of the spectrum (though there are cross-over exceptions to this). [*task (d)*]

Using a more limited data set from the San Lorenzo River drainage (20 sites), another finding was that the abundance of steelhead was reduced in streams with more than about 6% fines cover (Figure 14). In addition to this effect on the dominant native fish of this river, further increases in fines or fines and sand also appeared to benefit the density and size of non-native crayfish present at these sites (Figure 14). [*task (e)*]

Conclusions

GIS analysis of land use disturbance and sediment load models show that sedimentation in stream beds increases where stream catchments are exposed to greater erosion, and these sediment deposits may exceed criteria for impairment based either on the condition of reference streams or thresholds of degraded biological integrity. The amount of fine and sand sediment exceeding these limits is in the range of about 30-40% fine and sand cover. Leading to these threshold levels are reductions in the relative abundance of sensitive benthic invertebrate indicators (increased relative abundance of tolerant forms), while fine particles alone (>6% cover) may limit the abundance of steelhead trout and elevate the numbers of invasive crayfish in some coastal streams.

Stream power is important in exerting local controls on the dynamics of sediment transport and deposition, resulting in channels of low power (smaller and/or with lower gradients) being most susceptible to accumulation of sediment deposits. Even though fluvial forces set limits, with added land use, roads, and loads, streams can achieve no better than ever-increasing levels of sediment as low power streams are incapable of transporting these excess sediments. There is an apparent rising floor of sediment that builds and persists in these disturbed channels, leading to poor habitat quality, losses of invertebrate biological integrity, fewer native steelhead, and more non-native crayfish.

The critical range for loss of biological integrity at about 30-40% FS compares to about 35-42% FS from estimates of reference sediment levels alone at 75th to 90th percentiles that may be regarded as partial-to-not supporting of habitat quality (yellow-to-red zones of Figure 10). This range for biological degradation observed for coast streams was also substantiated in the responses seen from patch-scale samples taken on depositional bar formations in both central coast and Sierra Nevada streams (Figure 13). Taken together, physical and biological criteria identify the range of 30-40% FS as a numeric target for sediment [*tasks (a), (b), (c), and regional data integration task (f), in part*]

Effects were most readily observed where the scale of sediment measurements was the same as where invertebrates were collected. Field procedures for invertebrate sampling should therefore incorporate use of a quadrat frame for counts of fine and sand particles where reach-wide benthos samples are collected. Such data may be used to supplement information on taxa-specific sediment tolerance. The table of sediment-indicator taxa may be used to show whether streams have been altered by sediment or retain taxa that are sensitive to sediment pollution. Relative abundance of these different taxa in any sample from coastal streams can be examined as a probe to gauge how the stream community has been affected by sediments.

Regional differences between the Sierra and Coast exist primarily in reference-based distribution standards. For Sierra streams, these are more restrictive (lower levels of %FS for example at 75th/90th percentiles) because this region has lower amounts of sediment present in reference streams, owing to the differences in geology and less erodible terrain than in coastal watershed dominated by sedimentary rock formations (separate report on this prepared for the SWAMP TMDL program). These differences are consistent with the need for application of standards in an appropriate geographic context. Large-scale studies such as the Western Stream Assessment for example (Stoddard et al. 2005), report stressor indicators separately for 10 different regions of mountains, xeric landscapes, and interior plains ecoregions (Sierra and central coast in this treatment fall in separate regions). [*task (f)*]

In streams with spawning steelhead, habitat limitation may be most related to fine sediment cover. Above 6% fines we observed mostly low levels of abundance compared to less fine sediment cover. Using the reference habitat criteria, partial-to-not supporting fines are above the range 8-15%, and other studies have concluded that >5% fines limits aquatic vertebrates in western streams (Bryce et al. 2008), and that salmonid egg and fry survival is reduced above a range of 5-8% (Beschta and Jackson 1979). The San Lorenzo River data here are based on few surveys, so further studies would be useful in resolving the level of fines that form specific limits for steelhead, but these initial results are in line with other studies. Compounding the effects of fines on steelhead is that fines or fines and sand in the San Lorenzo also support elevated abundance of non-native crayfish in these streams. Crayfish are opportunistic consumers and scavengers, and particulate organic matter fraction of fines may be used a food resource that enhances the abundance of these animals. They also consume the food resources of resident native invertebrates and because of their larger size may significantly alter the food web, displace or even consume smaller invertebrates, and disrupt natural ecosystem processes. [*task (e)*]

Recommendations:

- Use multiple reference-based standards for different measures of sedimentation to improve certainty in judgments of impairment, and combine with biological criteria that show threshold for loss of biological diversity in the 30-40% FS range
- Screen streams of low power (less than an index value of 3 to 4) as the most vulnerable to degradation from sediment accumulation
- Adopt patch-scale sampling of fines and sand (using quadrat frames) during collection of reach-wide benthos samples in order to detect conditions that may exceed limits on biological integrity (30-40% FS)
- Separate standards for fines (above the 5-10% range) may be necessary for protection of coastal streams used by steelhead (rainbow trout)
- Repeated sampling at sites or stream segments of concern may be necessary to determine if both physical and biological metrics of sediment impairment are exceeded, and expanded sampling of new reference condition streams could be useful in reinforcing the numeric criteria established in this study
- Where problems with sediment are documented to exist, use physical and biological protocols to monitor effectiveness of any remediation practices used to control sediment sources (from roads, land use disturbances)
- Use the numeric criteria outlined here to list or de-list sites that are under consideration on the 303(d) list

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Beschta, R.L. and W.L. Jackson. 1979. The intrusion of fine sediment into a stable gravel bed. Journal of the Fisheries Research Board of Canada 36:204-210.

Bryce, S.A., G.A. Lomnicky, P.R. Kaufmann, L.S. McAllister, and T.D. Ernst. 2008. Development of biologically based sediment criteria in mountain streams of the western United States. North American Journal of Fisheries Management 28:1714-1724.

Qian, S.S., R.S. King, and C.J. Richardson. 2003. Two statistical methods for the detection of environmental thresholds. Ecological Modelling 166:87-97.

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Herbst, D.B., R.B Medhurst, S.W. Roberts, and J.W. Moore. 2011b. Development of biological indicators and targets to guide sediment TMDLs for streams of the central coast region of California and the San Lorenzo River.

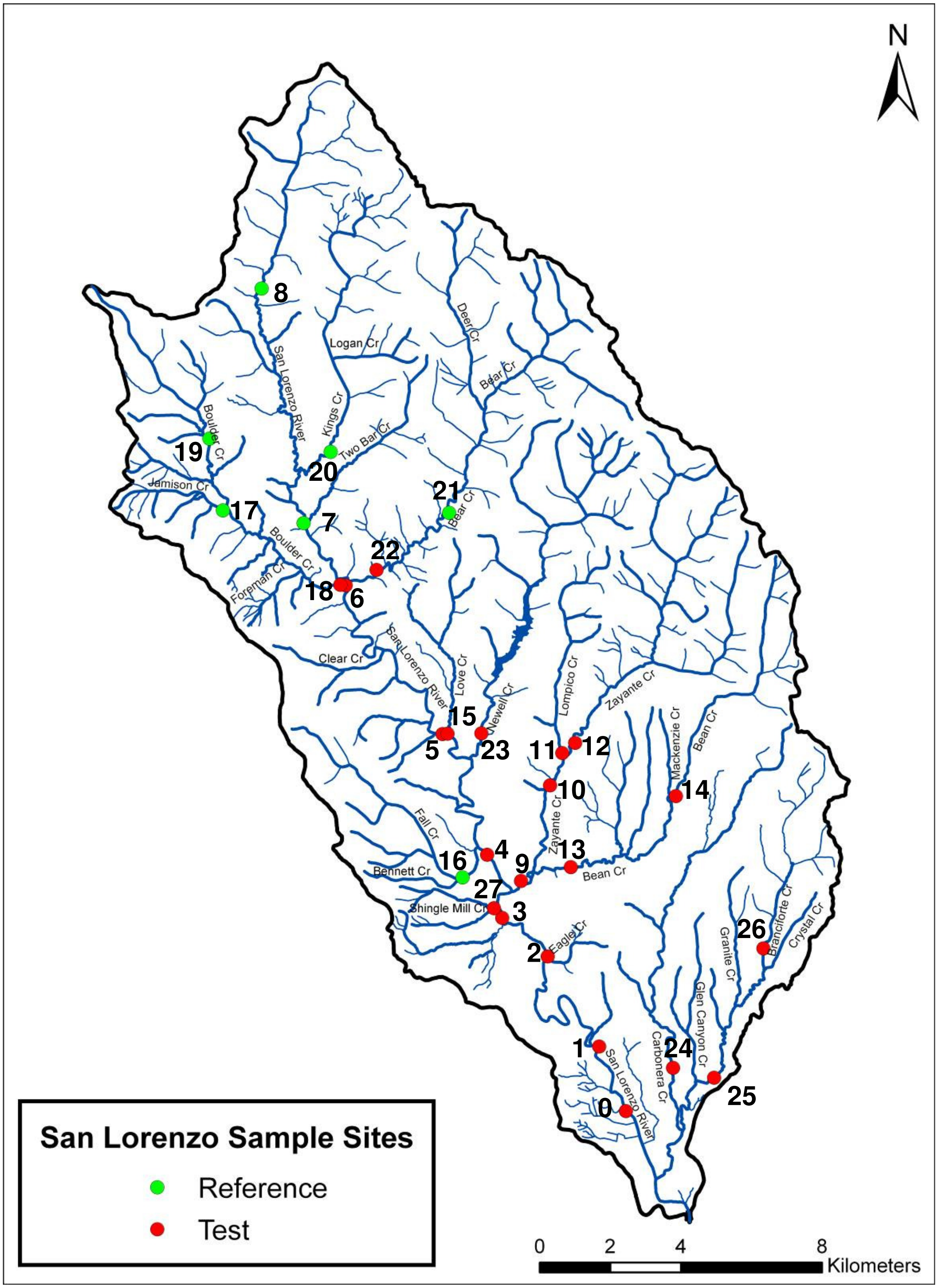


Figure 1. San Lorenzo River watershed and bioassessment monitoring stations for sediment TMDL development (2008 & 2009). Reference selection based on primary screen of watersheds with <10% human land use, and secondary on buffer road density <3 km/km^2 (see text). Site numbers correspond to the code listings in Table 1.

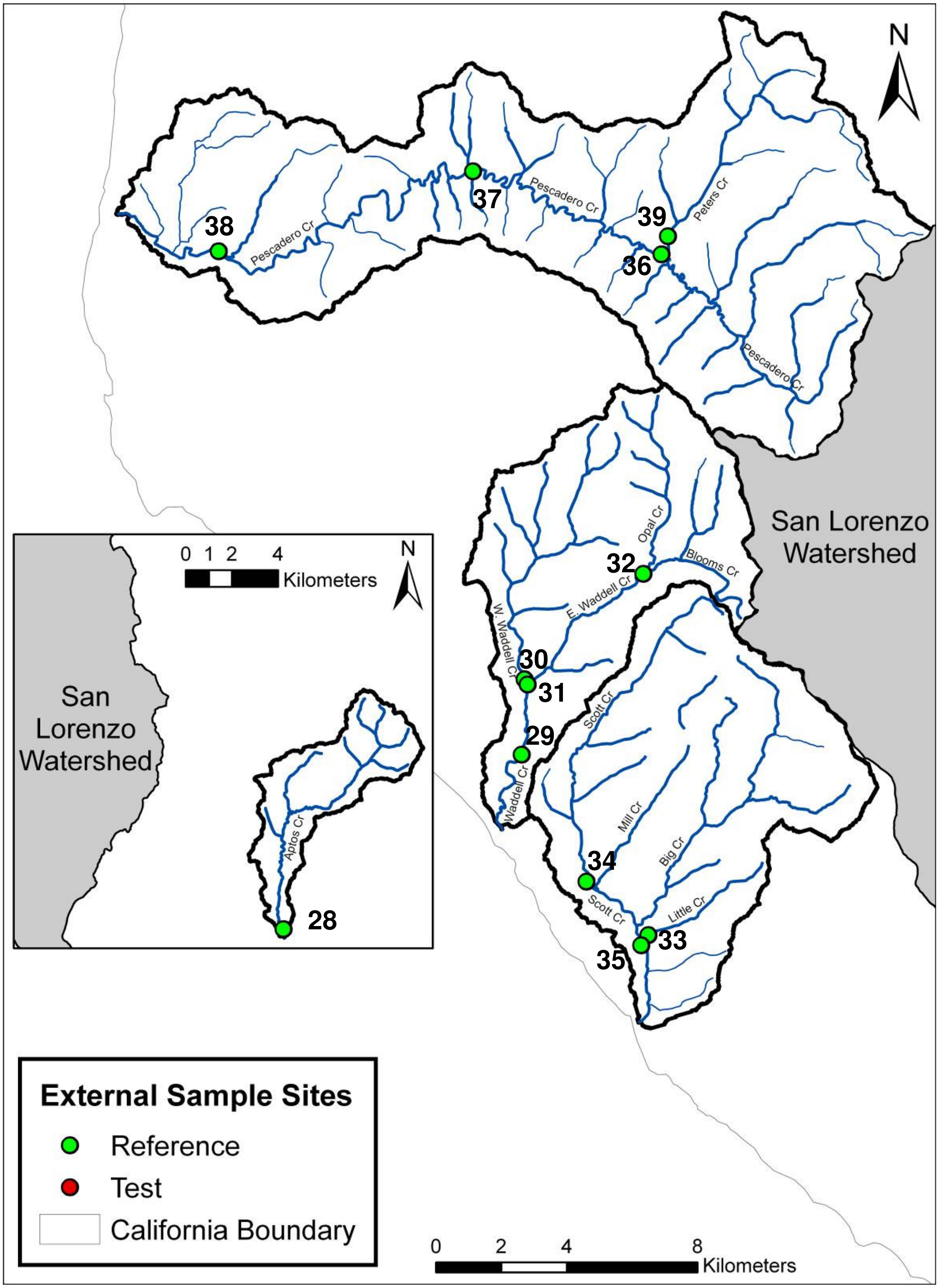


Figure 2. External watershed study sites for the San Lorenzo River regional assessment (2008 & 2009). Includes Aptos, Scott, Waddell, and Pescadero Creeks (gray area the boundary of the San Lorenzo). Site numbers correspond to the code listings in Table 1.

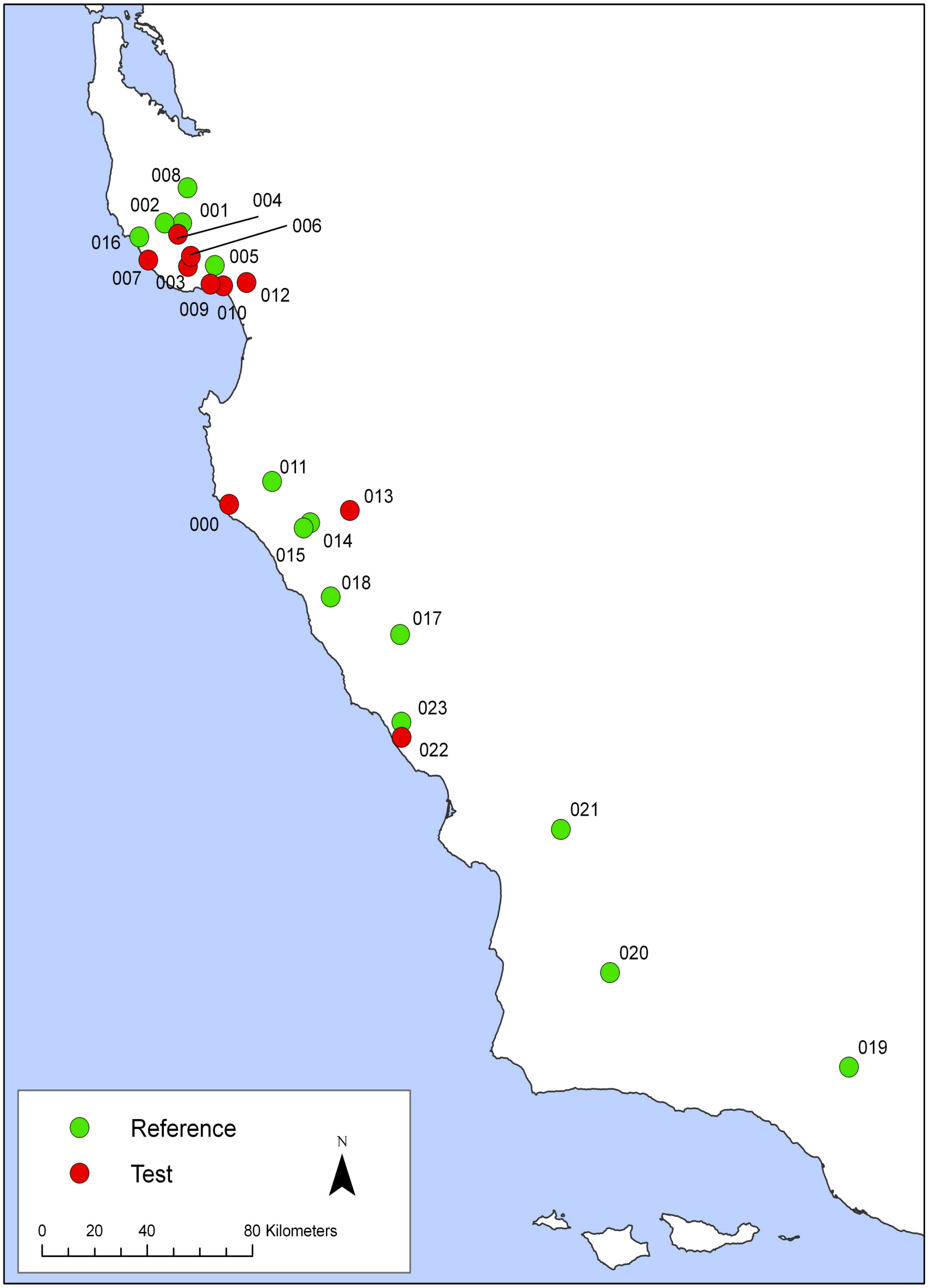


Figure 3. Sites surveyed throughout the Central Coast Region during May 2007. Code numbers correspond to stream name listing in Table 1.

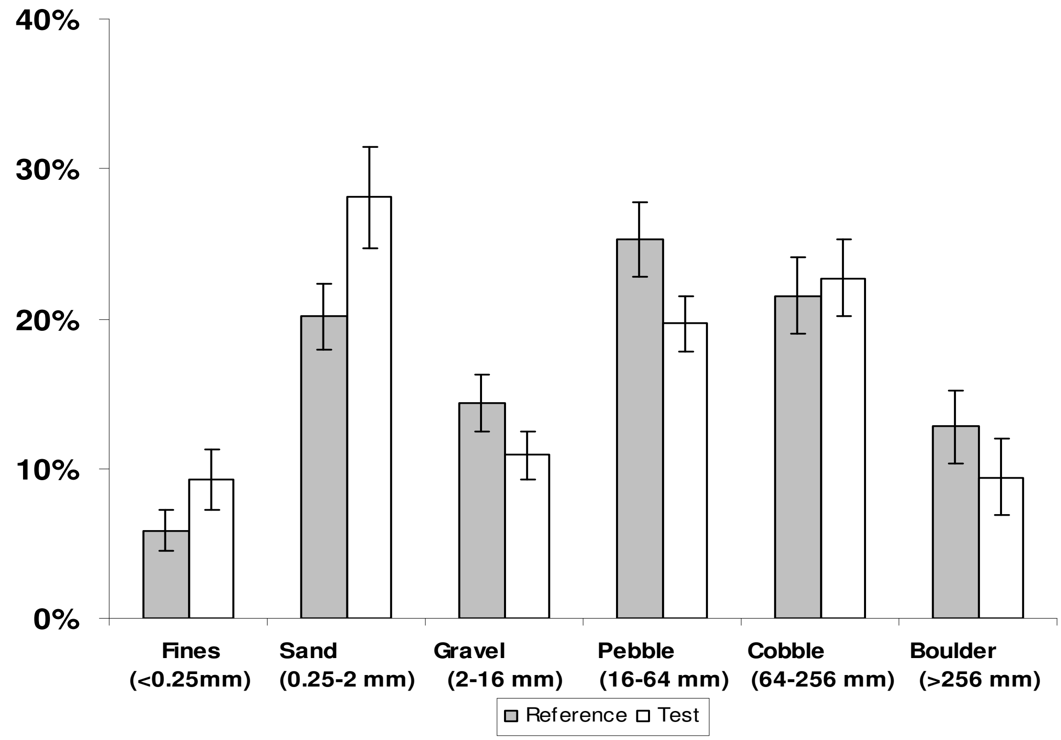


Figure 4. Average particle size distributions from transect point counts for 84 central coast stream surveys. Error bars show 95% confidence intervals, equivalent to t-tests of significance of differences ($p<0.05$ if bars do not overlap paired means).

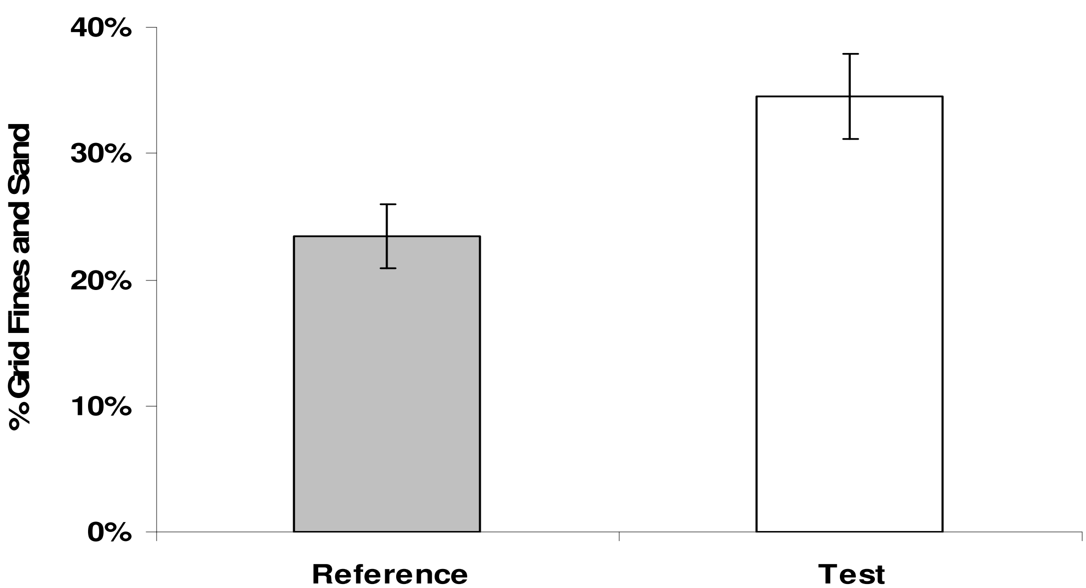


Figure 5. Percent Fines and Sand from grid counts of 84 central coast stream surveys. Error bars show 95% confidence intervals, equivalent to t-tests of significance of differences ($p<0.05$ if bars do not overlap paired means).

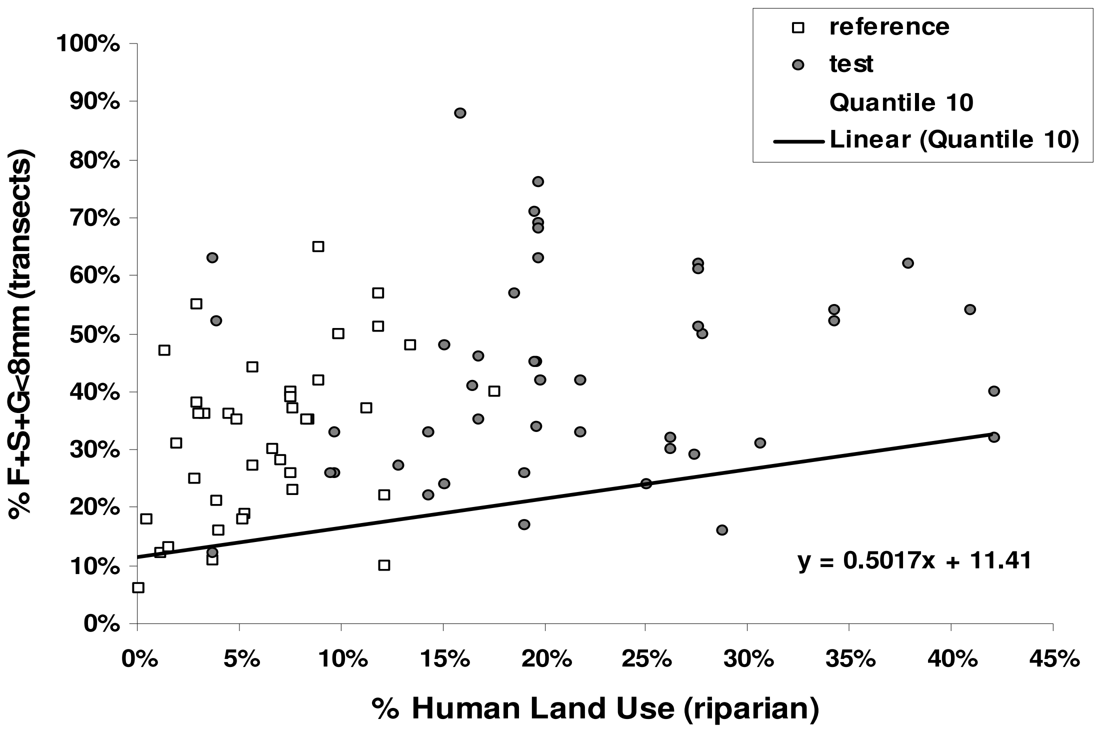


Figure 6. Influence of increased combined human land use cover on sediment deposition (%FSG<8mm) showing quantile regression of the 10th percentile.

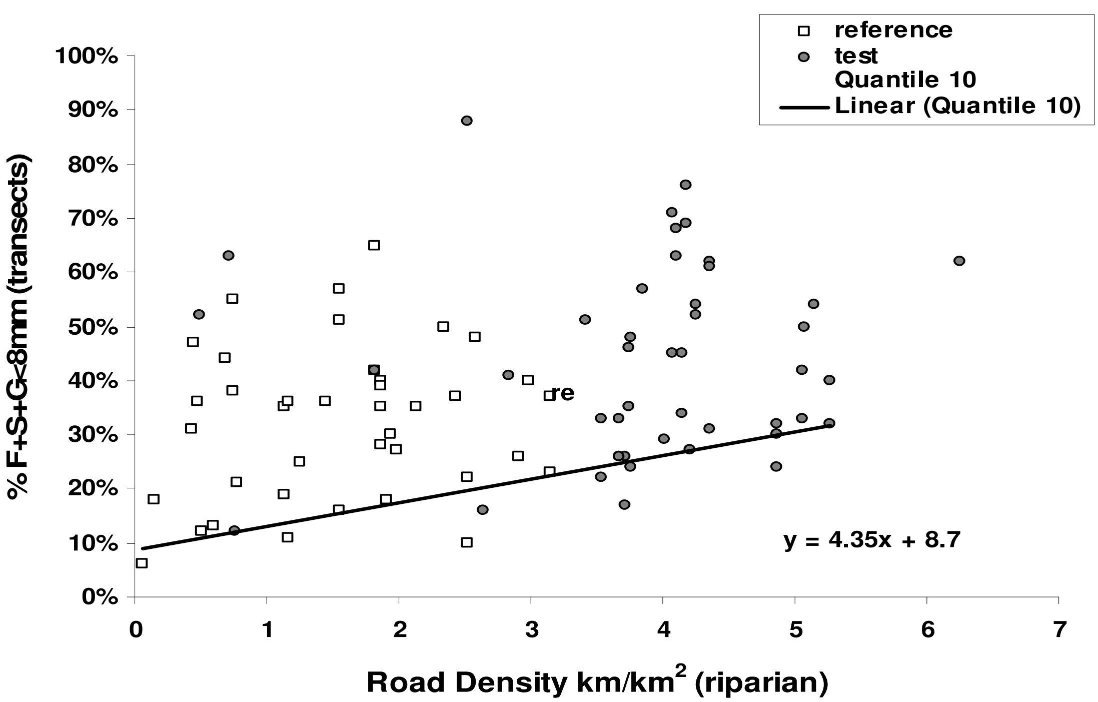


Figure 7. Influence of increased road density on sediment deposition (%FSG<8mm), showing quantile regression of 10th percentile (excluding the far right point).

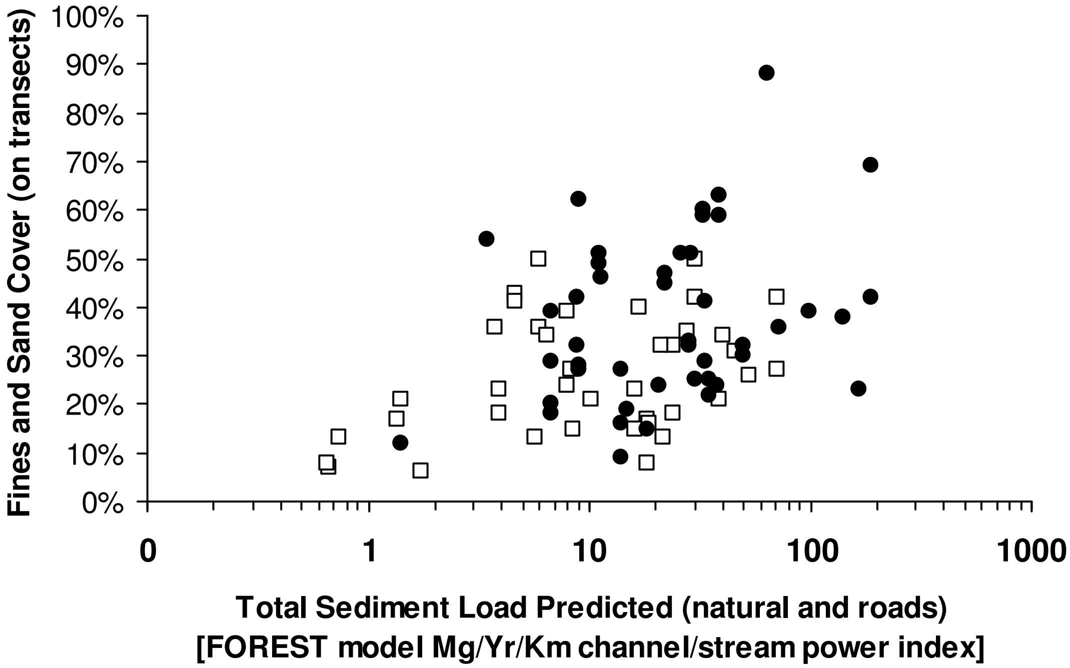


Figure 8. Predicted normalized load of sediments from both natural and road sources in relation to observed levels of fine and sand deposition in reference (open squares) and test (filled circles) streams. From FOREST model (FORest Erosion Simulation Tools).

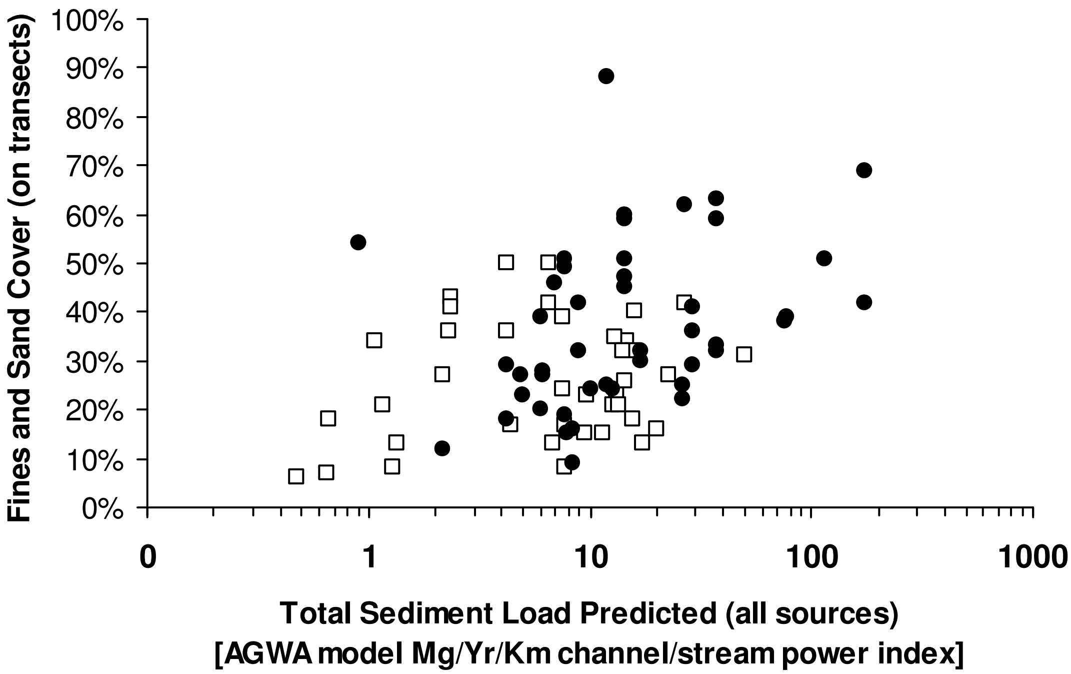


Figure 9. Predicted normalized load of sediments from all sources in relation to observed levels of fine and sand deposition in reference (open squares) and test (filled circles) streams. From AGWA model (Automated Geospatial Watershed Assessment).

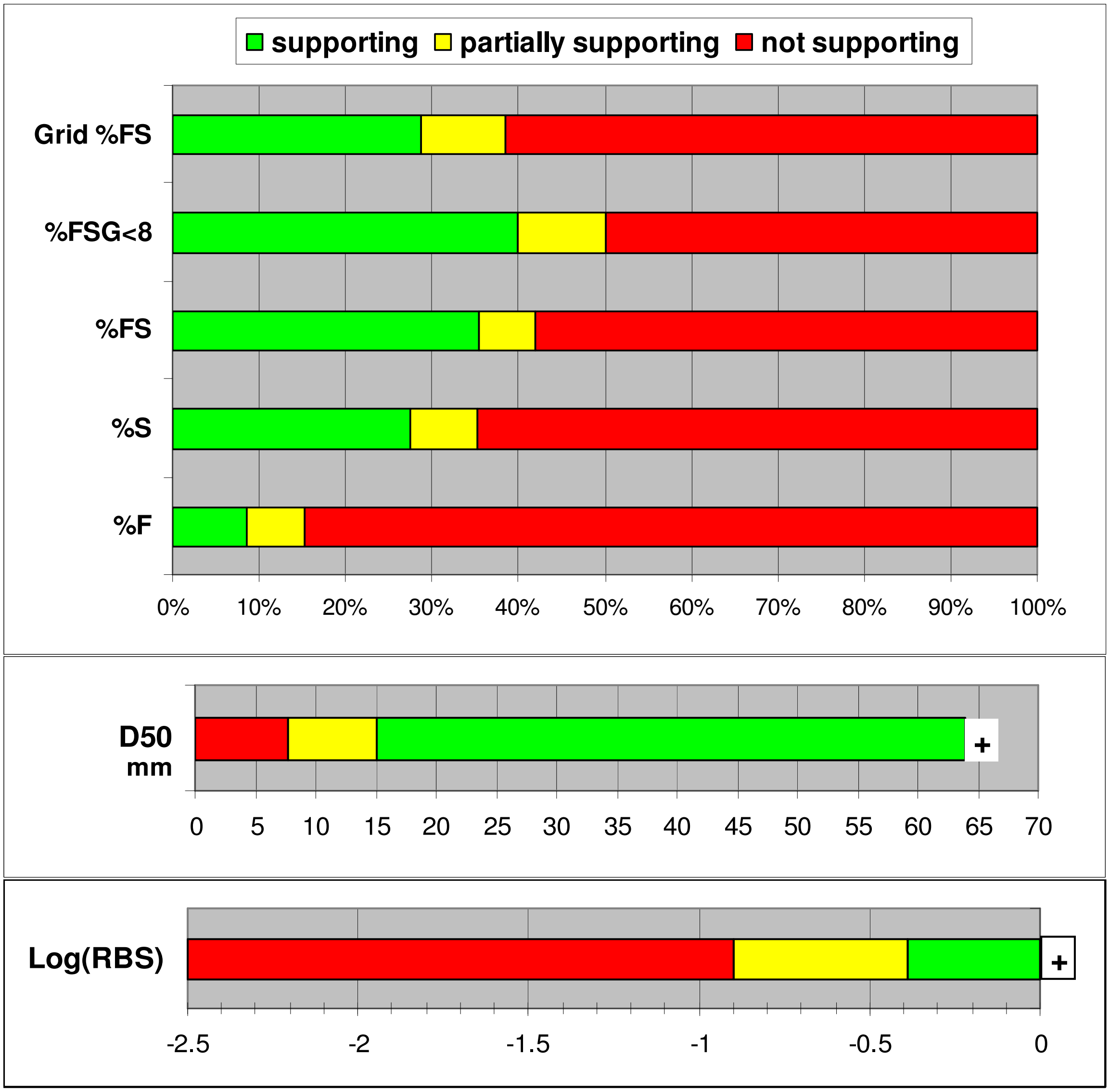


Figure 10. Ranges for the distribution of 7 measures of sediments at reference streams in the Central Coast Region (n=39) that provide criteria for sediment impairment beyond the 90th percentile of conditions (red= not supporting), between the 75th and 90th percentiles (yellow= partially supporting), and below the 75th percentile (green= supporting).

F=fines, S=sand, G=gravel (<8 mm size fraction), Grid FS = fines and sand counts from grid quadrats placed at 20 sampling locations including those where invertebrates were collected (patch-scale samples), D50 is the median particle size from the 100 point-counts of substrata in each survey reach, and Log(RBS) is the log of relative bed stability (as defined in the physical habitat companion report) – a measure of the ratio of observed to expected D50 particle size, where negative log values all show particles smaller than expected (i.e., where sediments are accumulating).

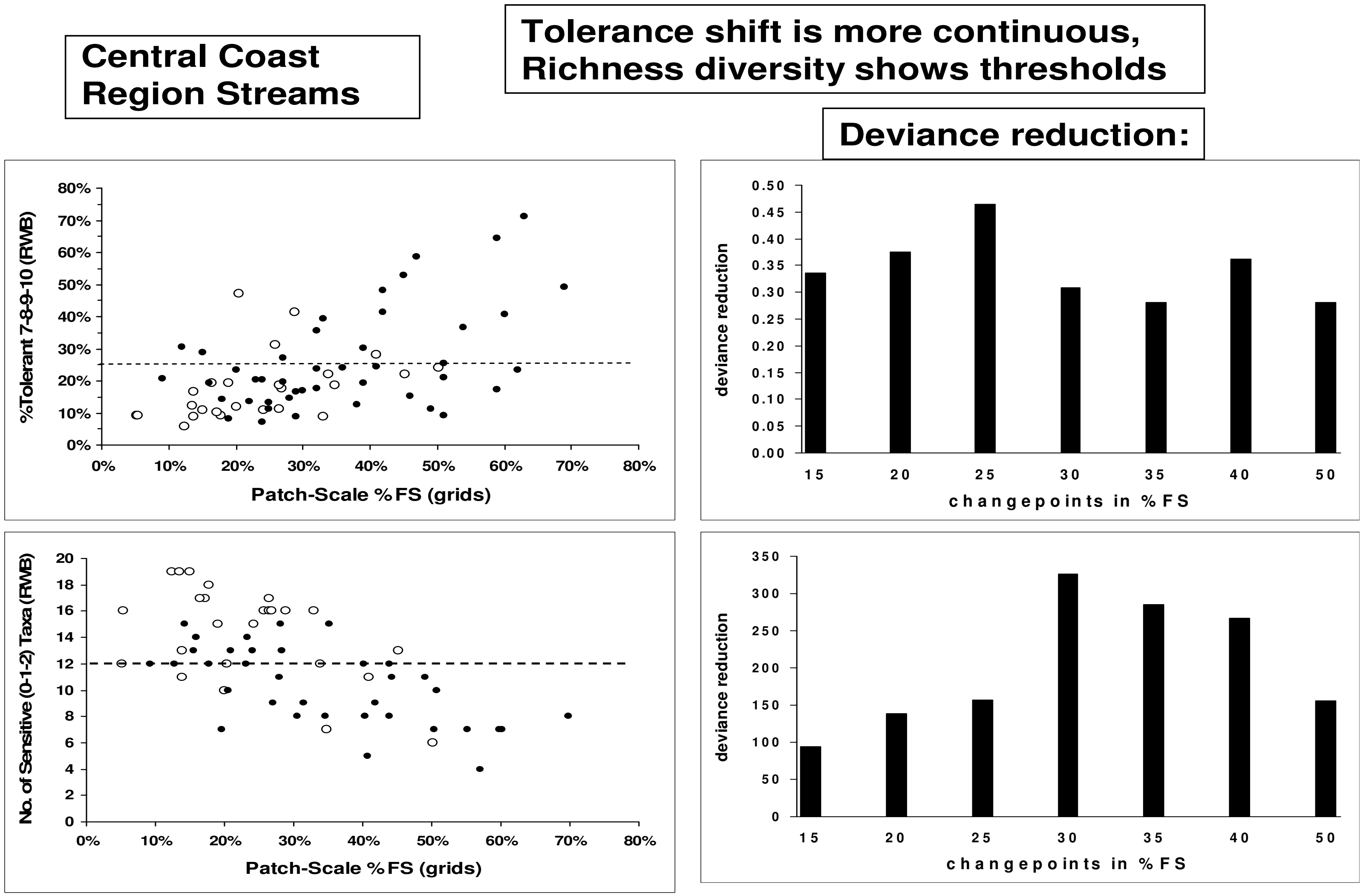


Figure 11. Tolerance measures gradual changes in abundance, but diversity or richness shows where taxa disappear with higher FS.

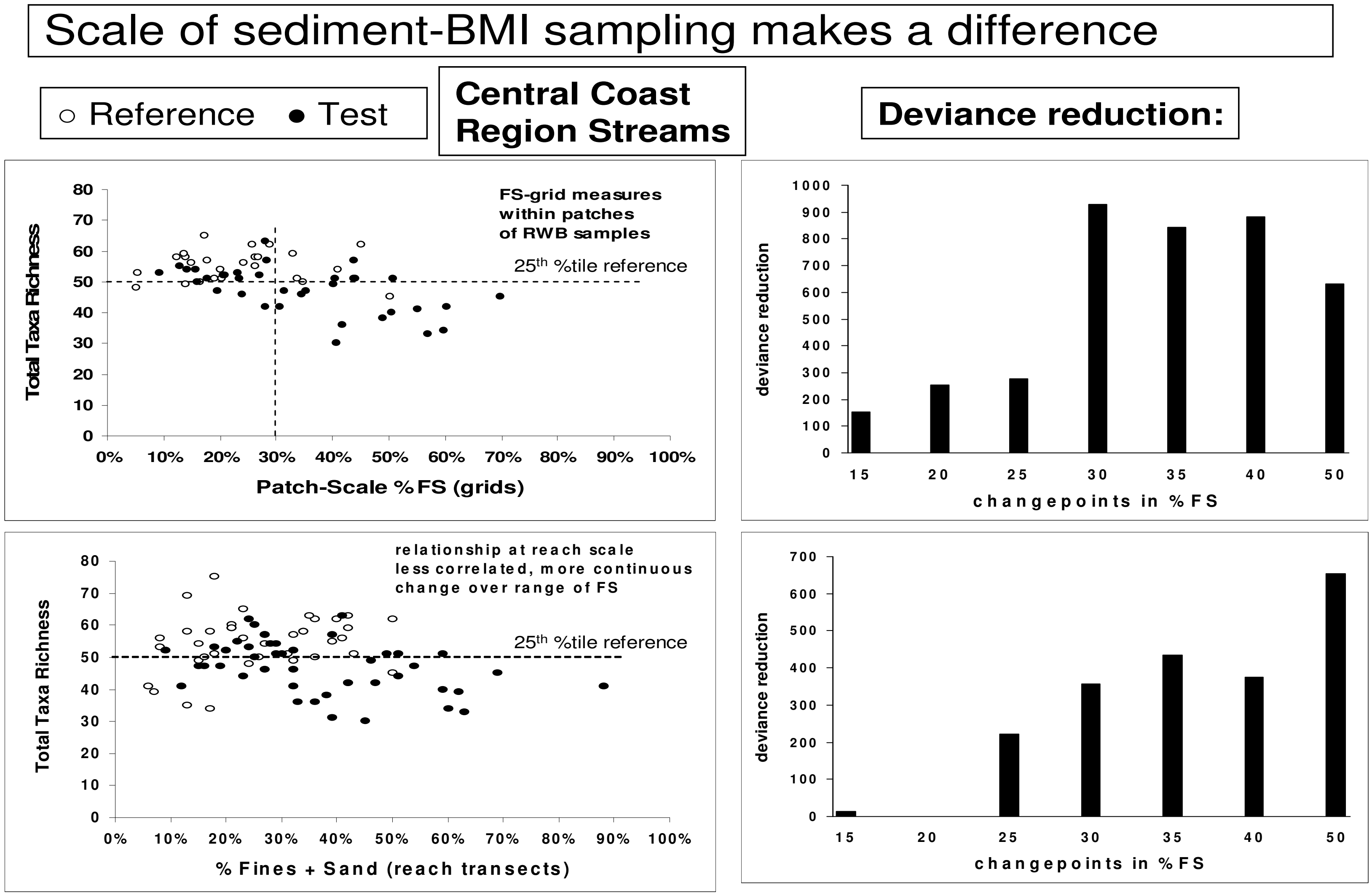


Figure 12. Improved resolution of spatial scale relation (patch vs. reach) of sediment to response allows clearer definition of threshold.

At the patch-scale, from samples taken on depositional bars, the threshold appears to be in the range of 25-40% FS (Sierra & Coast combined)

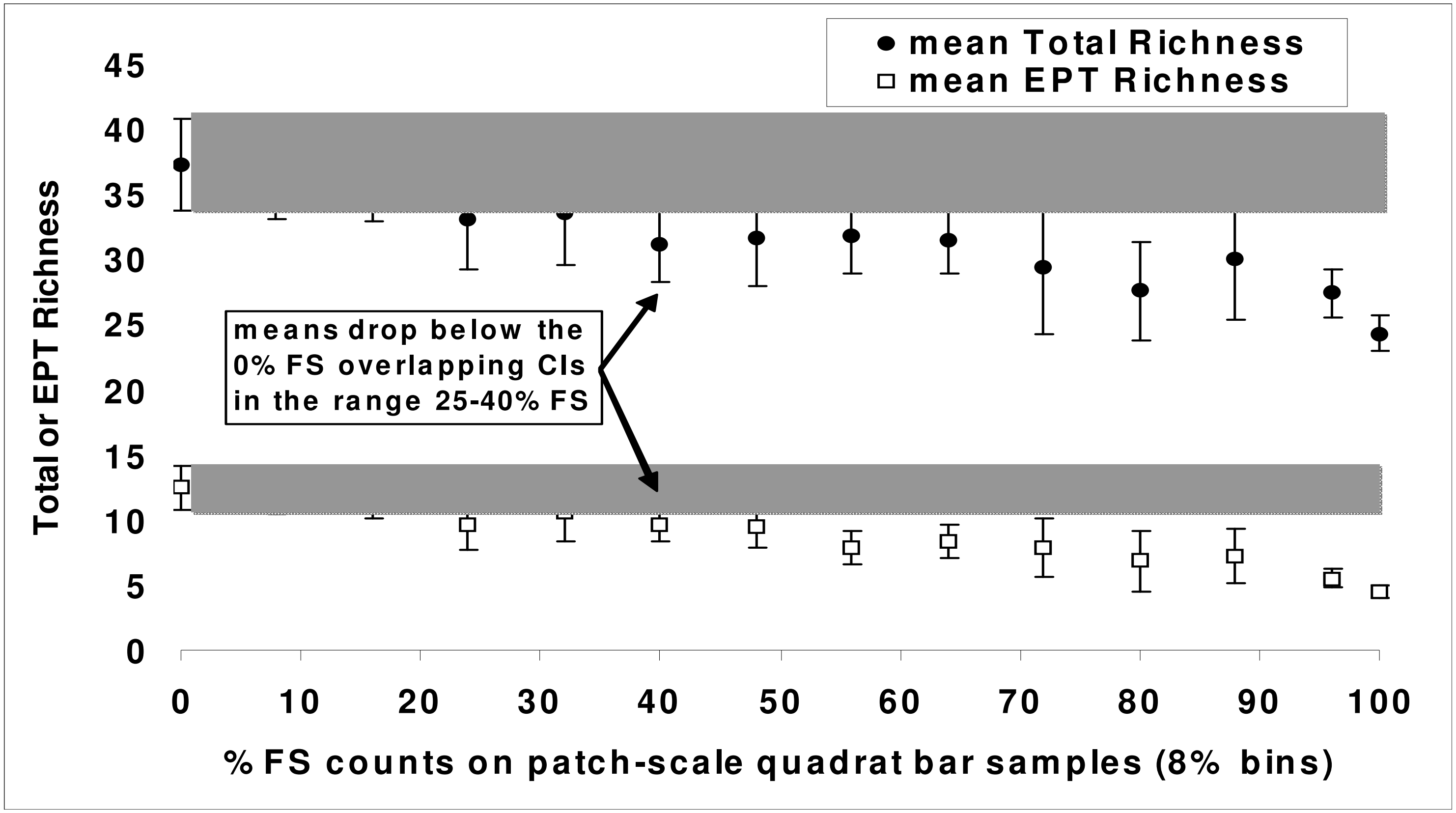
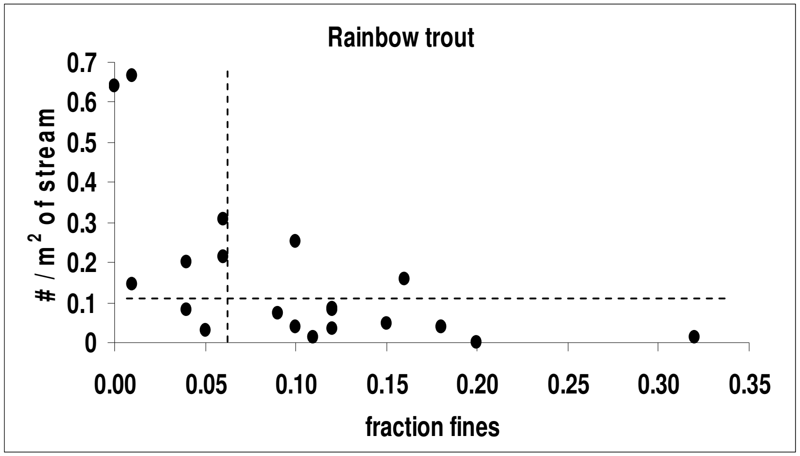


Figure 13. Combined samples at the patch-scale from Coast and Sierra show threshold of diversity loss in the range of 25-40% FS. Significant difference from richness levels observed in the absence of FS (at 0) is shown where means drop below grey 95% CI error.

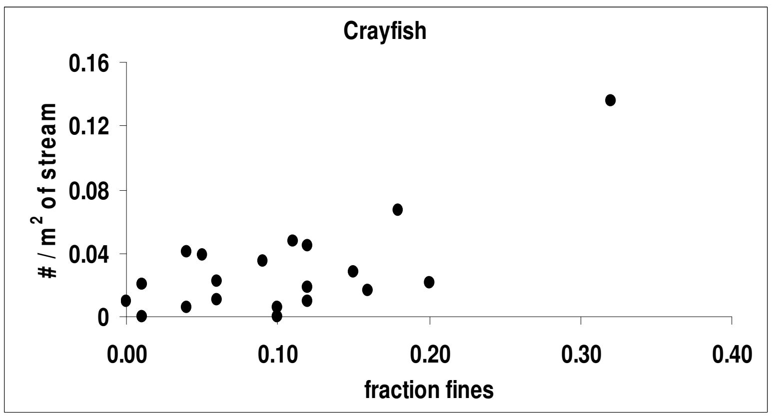


San Lorenzo River: 2009 surveys

As the fraction of fines increase, there is a loss in the abundance of native steelhead and an increase in non-native invasive crayfish.

Above 6% fines, steelhead trout numbers are low, and as fines and/or sand cover increases further, so does the number and size of crayfish.

Steelhead are regarded as key species for conservation, but crayfish exploit and deplete resources to the detriment of native invertebrates. Together these sediment-mediated changes may degrade natural ecosystem processes in the river.



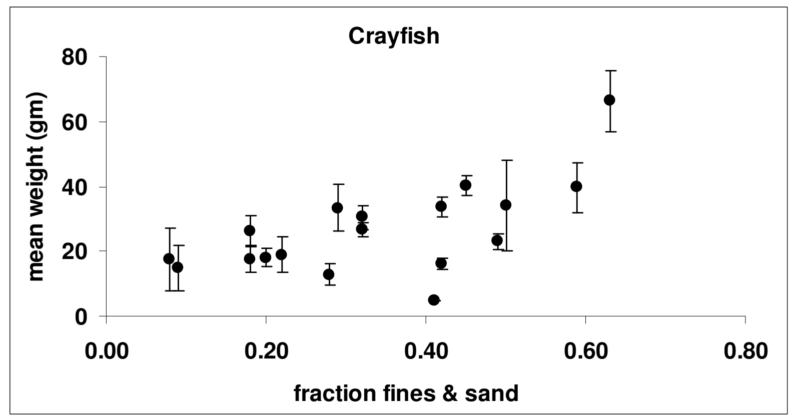


Figure 14. San Lorenzo River surveys from 2009 showing the influence of fines or fines and sand on the abundance native steelhead trout and non-native crayfish.

Table 1. Listing of the 40 study sites (R=reference site, T=test or dose site) used in developing geomorphic and biological indicators for the San Lorenzo River sediment TMDL (last 12 sites listed are in adjacent watersheds). **Sites also surveyed in 2009.

Code & Stream Name (Reference or Test)	Catchment Area (km^2)	Reach Slope (%)	Lat.	Long.	Elev. (m)	Human Land Use	Riparian Road Density (km / km^2)	Alley Site Code	TMDL Listed?
0 San Lorenzo River (T) above city intake**	276.40	0.16%	36.99	-122.03	3	14.71%	4.18	0b	Pathogens
1 San Lorenzo River (T) Paradise park**	274.48	0.65%	37.01	-122.04	8	14.58%	4.15	1	Pathogens
2 San Lorenzo River (T) lower HC park**	264.61	0.22%	37.03	-122.06	63	14.27%	4.10	3	Pathogens
3 San Lorenzo River (T) below HC bridge**	256.22	0.03%	37.04	-122.07	68	14.08%	4.07	4	Pathogens
4 San Lorenzo River (T) below San Lo Way bridge**	181.31	0.30%	37.06	-122.08	73	11.41%	3.74	6	Pathogens
5 San Lorenzo River (T) above Hwy 9**	149.96	1.36%	37.09	-122.09	90	9.82%	3.76	7	Pathogens
6 San Lorenzo River (T) above E.Lomond bridge**	135.34	1.52%	37.13	-122.12	120	9.29%	3.54	9	Pathogens
7 San Lorenzo River (R) above Brimblecom**	52.22	0.78%	37.14	-122.13	156	6.69%	2.52	10	Pathogens
8 San Lorenzo River (R) lower Castle Rock SP**	20.44	1.16%	37.20	-122.15	182	7.25%	1.82	12a	Pathogens
9 Zayante Creek (T) above RR bridge**	70.10	1.12%	37.05	-122.06	71	19.25%	4.86	13a	Sediment
10 Zayante Creek (T) above Quail Hollow Rd	43.26	0.09%	37.07	-122.06	79	15.77%	5.07	13c	Sediment
11 Lompico Creek (T)	7.15	1.29%	37.08	-122.05	108	21.44%	4.36	n/a	Pathogens
12 Zayante Creek (T) below Zayante market bridge	29.12	0.97%	37.09	-122.05	108	8.68%	4.21	13d	Sediment
13 Bean Creek (T) at Locatelli Rd**	25.22	0.38%	37.05	-122.05	92	23.37%	4.36	14a	Sediment
14 Bean Creek (T) above Morgan Run Rd**	10.02	0.70%	37.07	-122.02	143	15.03%	5.05	n/a	Sediment
15 Love Creek (T)	7.93	0.91%	37.09	-122.09	90	14.22%	4.01	n/a	Sediment
16 Fall Creek (R) **	12.78	1.73%	37.05	-122.08	78	9.15%	1.55	15	Sediment
17 Jamison Creek (R)	4.35	1.68%	37.15	-122.16	231	5.00%	2.14	n/a	No
18 Boulder Creek (T) below Hwy 9**	29.71	1.06%	37.13	-122.12	133	10.10%	3.72	17a	Sediment
19 Boulder Creek (R) Hwy 236 marker 4.0	13.00	0.55%	37.16	-122.16	243	10.47%	2.98	n/a	Sediment
20 Kings Creek (R) **	20.04	1.39%	37.16	-122.12	157	2.75%	1.87	19a	Sediment
21 Bear Creek (T) Eurella**	41.97	0.52%	37.13	-122.11	140	10.64%	3.67	18a	Sediment
22 Bear Creek (R) above treatment plant**	38.93	0.69%	37.14	-122.09	149	10.03%	3.15	18b	Sediment
23 Newell Creek (T)	4.07	0.97%	37.09	-122.08	83	27.56%	5.15	16	Sediment
24 Carbonera Creek (T) **	17.84	0.32%	37.00	-122.02	17	51.02%	5.27	20b	Pathogens
25 Branciforte Creek (T) Delaveaga park**	20.67	0.77%	37.00	-122.00	27	16.49%	4.25	21a	Sediment
26 Branciforte Creek (T) below Shady Brook bridge	10.02	1.32%	37.03	-121.99	53	12.13%	3.42	21b	Sediment
27 Shingle Mill Creek (T)	1.72	3.14%	37.04	-122.07	70	27.77%	6.26	n/a	No

External Watersheds – Table 1 continued									
Stream Name (<u>R</u>ef or <u>T</u>est)	**Catchment Area (km^2)**	**Reach Slope (%)**	**Lat.**	**Long.**	**Elev. (m)**	**Human Land Use**	**Riparian Road Density (km / km^2)**	**Alley Site Code**	**TMDL Listed?**
28 Aptos Creek (R) **	28.66	1.80%	36.98	-121.91	10	3.55%	0.75	3*	Sed + Path
29 Waddell Creek (R)	61.70	0.72%	37.11	-122.27	0	3.67%	1.14	n/a	No
30 W. Waddell Creek (R)	24.69	0.70%	37.14	-122.27	25	1.86%	0.44	n/a	No
31 E. Waddell Creek (R) above confluence	30.72	0.90%	37.13	-122.27	25	4.48%	1.55	n/a	No
32 E. Waddell Creek (R) above treatment plant	26.66	1.54%	37.16	-122.23	51	4.64%	1.45	n/a	No
33 Little Creek (R)	5.10	5.17%	37.06	-122.23	11	0.85%	0.45	n/a	No
34 Scott Creek (R) upper tributary	23.00	0.32%	37.08	-122.25	22	2.31%	0.68	n/a	No
35 Scott Creek (R) below Little Creek	71.75	0.53%	37.06	-122.23	7	1.71%	0.47	n/a	No
36 Pescadero Creek (R) above Cloverdale bridge	139.92	0.47%	37.25	-122.37	6	6.63%	2.34	n/a	Sediment
37 Pescadero Creek (R) at Oakland YMCA	101.32	0.77%	37.28	-122.28	61	5.39%	1.91	n/a	Sediment
38 Pescadero Creek (R) below Sequoia trail	75.94	0.64%	37.25	-122.22	104	5.62%	1.98	n/a	Sediment
39 Peters Creek (R)	25.47	1.06%	37.26	-122.22	112	8.59%	2.91	n/a	No

Table 1. Continued – Central Coast Streams used in combination with San Lorenzo studies to expand geographic coverage.

Code Stream Name	Site Name	GPS Lat	GPS Long	Slope (%)	Elev (m)	Stream Order	Area (km)	Roadedness (km/sqkm)	% Human Land Use	Reference or Test
000 Big Sur River	Coyote Flat	36.28084	121.83337	0.27	13	3	146.323	0.72	1.7	Test*
001 Kings Cr	County Land	37.16	122.12448	0.58	166	3	20.1339	1.87	2.8	Reference
002 San Lorenzo R	Upper Camp Campbell	37.16358	122.13559	0.29	166	3	30.0276	2.59	8.7	Reference
003 San Lorenzo R	Cowell Park - below RR bridge	37.03078	122.05637	0.19	64	4	287.644	3.85	13.3	Test
004 Bear Cr	Scout Camp	37.13113	122.1049	0.85	154	3	39.1257	3.67	10.2	Test
005 Soquel Cr	Upper	37.07835	121.94168	0.47	51	3	83.4642	2.43	10.0	Reference
006 Zayante Cr	Above Graham Hill Bridge	37.0499	122.06515	0.61	73	3	70.4259	4.86	19.3	Test
007 Scott Cr	Swanton Ranch - CalPoly	37.04361	122.22637	0.06	4	3	77.3532	0.49	1.9	Test*
008 Stevens Cr	Above Reservoir	37.28111	122.07458	1.67	172	3	36.9522	1.86	5.9	Reference
009 Soquel Cr	Lower	36.97832	121.95666	0.23	9	3	107.279	2.83	15.1	Test
010 Aptos Cr	Below Valencia Confluence	36.97499	121.90204	0.29	10	3	63.6867	2.53	19.1	Test
011 Carmel R	Bluff Camp	36.36161	121.65597	1.52	378	3	87.6195	0.06	0.1	Reference
012 Corralitos Cr	Above Hames	36.99028	121.80366	1.03	79	3	56.2302	2.65	19.8	Test
013 Arroyo Seco R	Above Green Bridge	36.28072	121.32317	0.56	114	4	628.546	0.76	2.2	Test*
014 Arroyo Seco R	Above day use area	36.23549	121.48767	0.70	250	4	285.694	0.51	0.8	Reference
015 Tassajara Cr	Horse Pasture trail crossing	36.21855	121.51468	1.60	318	3	69.7122	0.59	0.6	Reference
016 Waddell Cr	Above Alder Camp	37.11528	122.26983	0.17	13	4	62.0289	1.14	3.6	Reference
017 San Antonio R	Above Interlake Bridge	35.89391	121.09031	0.22	267	3	559.572	1.93	7.0	Reference
018 Nacimiento Cr	Below Campground	36.003	121.38885	1.06	475	2	22.518	1.17	1.7	Reference
019 Sespe Cr	Lion Campground	34.56228	119.16647	0.94	925	4	221.383	0.78	1.9	Reference
020 Sisquoc R	Above Dam	34.84222	120.1663	0.34	195	3	731.027	0.15	0.4	Reference
021 Salinas R	Above Pozo CDF Station	35.29372	120.38835	0.28	425	3	125.605	1.17	1.4	Reference
022 Santa Rosa Cr	Behind High School	35.56669	121.06738	0.66	25	3	56.4444	1.82	6.7	Test*
023 San Simeon Cr	Above Fence	35.61448	121.07036	1.73	48	3	34.2216	1.26	1.6	Reference

*Sites that met reference criteria but were excluded because of local disturbance factors, so were classified as test sites. Arroyo Seco above green bridge excluded as a large gravel quarry exists upstream, Scott Crk excluded due to local agriculture and tidal influence, lower Big Sur River excluded because of historic mudflows and channel dredging/clearing after the Marble Cone fire and winter storm surges of sediment and debris, and Santa Rosa Creek excluded due to development within the reach.

Sediment Tolerance and Sediment Aversion:
Abundance of common taxa across a range of %FS measured at different scales (patch-to-reach) used to calculate weighted averages to give a list of indicators

Data set from central coast streams (for taxa present in ≥20% of streams, and 2 of 3 data sets)

Sediment Indicator Groups for Common Central Coast Taxa (wieghted average Fines and Sand)				
Tolerant	**Moderately Tolerant**	**Intermediate**	**Moderately Sensitive**	**Sensitive**
Parakiefferiella	Phaenopsectra	Thiennemannimyia*	Serratella*	Turbellaria-flat worms
Hygrobates	Polypedilum_scalaenum	Parametriocnemus	Cricotopus_Orthocladius	Physa
Cladotanytarsus	Tanytarsus	Lepidostoma	Microtendipes_rydalensis	Micrasema
Oligochaeta	Tricorythodes	Atractides	Torrenticola	Diphetor_hageni
Heterotrissocladius_marcidus	Lebertia	Sperchon*	Paraleptophlebia	Ceratopsyche
Brillia	Hydra	Baetis*	Bezzia_Palpomyia	Polypedilum_aviceps
Antocha	Corynoneura	Ephemerella_maculata	Rheocricotopus	Epeorus
Neoplasta	Centroptilum	Mucronothrus	Rheotanytarsus	Cinygmula
Paracladopelma	Ostracoda	Thienemanniella_xena*	Synorthocladius	Zapada
Limnesia	Microtendipes_pedellus*	Hemerodromia*	Agapetus	Calineuria_californica
Sphaeromias	Stempellinella	Simulium*	Eubrianax_edwardsii	
Siphlonurus	Micropsectra	Hydroptila	Tvetenia_bavarica	
	Optioservus_quadrimaculatus	Testudacarus	Rhyacophila_betteni	
	Polypedilum_tritum	Gumaga	Suwallia	
	Zavrelimyia	Paratanytarsus	Drunella_flavilinea	
	Hydropsyche			
	Sialis			
These taxa derived from quartile rankings of weighted average scores from three central coast data sets of %FS at different scales.				
*denotes those taxa for which rankings were in both the highest and lowest quartiles and so are uncertain (mostly intermediate); possible multi-species responses				

Table 2. These common sediment-indicator taxa are based on the weighted average of invertebrate abundance and the %FS found in 3 sources of data: FS at the reach scale (84 surveys), FS at the patch-scale from grids where samples were collected (60 San Lorenzo region surveys), and from patch-scale quadrat samples taken on bars (24 central coast surveys). Combining quartiles from these data sets, and ranked 1-4 (lowest to highest weighted average quartiles), red group is most tolerant (4), yellow group moderately tolerant (3), white group intermediate (mixed 2/3 or 1/4), green group moderately sensitive (2), and the blue group most sensitive (1).

San Lorenzo River / Central Coast Recommended Sediment Numeric Targets

	Recommended Numeric Targets To Support Beneficial Uses	Recommended Numeric Targets to Support Preliminary 303d Listing (lower priority)	Recommended Numeric Targets To Support 303d Listing (high priority)	SWAMP Standard Method / Scale (reach, patch, facies resolution)	Reference
Sediment Indicators		**75/25**	**90/10**		
1. Percent Fines (F) on transects	<8.5%	8.5 – 15.2%	>15.2%	Reach	Sediment Report (P 19)
2. Percent Sand (S) on transects	<27.5%	27.5 – 35.3%	>35.3%	Reach	Sediment Report (P 19)
3. Percent FS on transects	<35.5%	35.5 – 42.0%	>42.0%	Reach	Sediment Report (P 19)
4. Percent FSG<8mm on transects	<40.0%	40.0 – 50.2%	>50.2%	Reach	Sediment Report (P 19)
5. D50 median particle size	>15 mm	7.7 – 15 mm	>7.7 mm	Reach	Sediment Report (P 19)
6. Percent patch-scale grid FS	<28.8%	28.8 – 38.5%	>38.5%	Patch	Sediment Report (P 19)
7. Log RBS (relative bed stability)	>–0.39	-0.39 – -0.90	<–0.90	Reach	Sediment Report (P 19)
8. Percent Fines (steelhead)	<6.0%	6- - 10%	>10%	Reach	Project Summary (p. 6-7)
9. Percent cover of FS (BMI limits)	<30%	30 – 40%	>40%	Reach or Patch	Project Summary (p. 5-7)
Biological Indicators		**75/25**			
1. Total Richness	>50.0	<50.0	* *	Reach and/or Patch	Biological Report (P 29)
2. EPT Richness	>16.5	<16.5	**	Reach and/or Patch	Biological Report (P 29)
3. % EPT	>16.7%	<16.7%	**	Reach and/or Patch	Biological Report (P 29)
4. Biotic Index	<5.48	>5.48	**	Reach and/or Patch	Biological Report (P 29)
5. Percent Tolerant	<26.3%	>26.3%	**	Reach and/or Patch	Biological Report (P 29)
6. Sensitive Number	>9.5	<9.5	**	Reach and/or Patch	Biological Report (P 29)
7. Crayfish # and Size	No target		~>25%FS	Reach	Biological Report (P 14)
**Biological metric and sediment indicator exceedances: if greater than half of the Sediment Indicators and greater than half of the Biological Indicators are exceeded, then that reach is considered impaired [requiring TMDL if repeated assessment confirms exceedances]					
BMIs = benthic macroinvertebrates					