Benthic invertebrate responses to patch and reach-scale sediment deposition and the relation of land use and roads to sedimentation

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Detection of sediment supply effects on stream habitat and benthos

Many complexities:

- sediment transport is a natural process of streams, characterized by high temporal and spatial variability
- anthropogenic influence is often diffuse (non-point), and complex to characterize and link to stream responses
- stream hydrology is coupled to sediment dynamics, and land use changes are likely to influence both
- sediment supplies & responses may be acute and/or chronic and vary in duration, frequency, and severity
- effects of sediment transport vs. deposition vary as a function of stream gradient, stream power, delivery source, and timing of flux/re-suspension
- other effects from landscape disturbance may be difficult to separate from sedimentation (nutrients, riparian…..)

Questions and Study Objectives

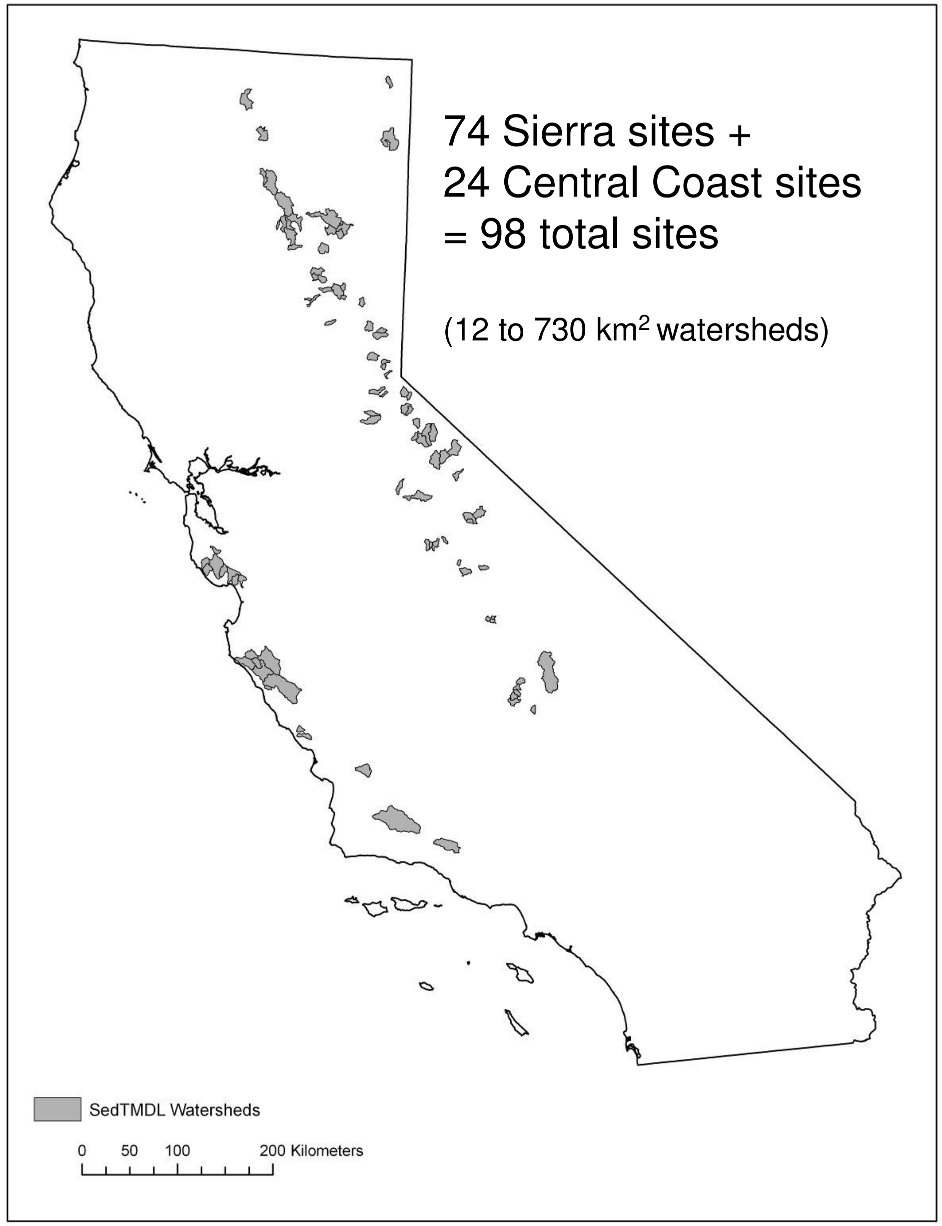
- What is the relationship of the macroinvertebrate community and metrics to both reach-scale and local-scale variation in sediment deposition?
- What is the influence of land use disturbance and road density on sediment deposition?
- Can we use this information to develop general guidance on sediment TMDLs based on the depositional environment?

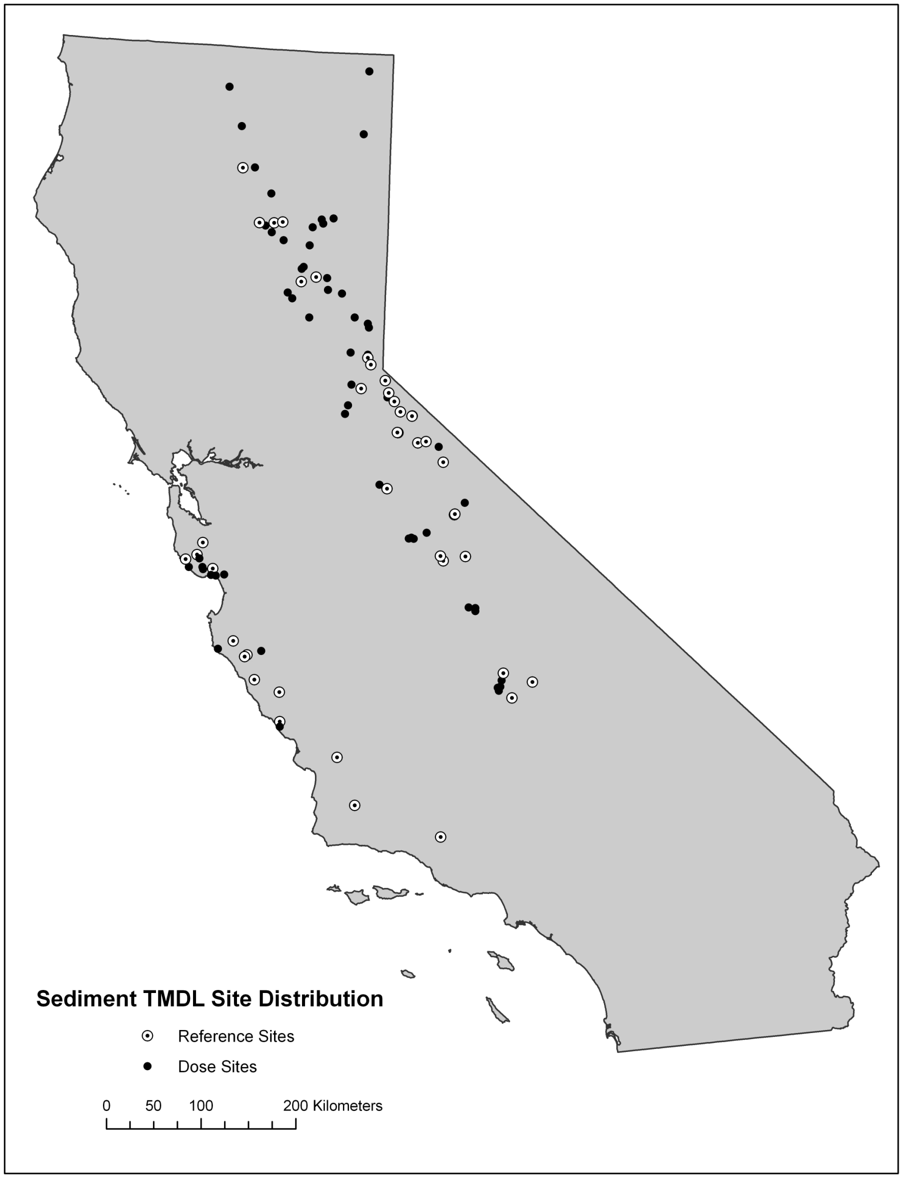
Site Selection:

To ensure sites were similar in hydrology and fluvial geomorphology, we used the following criteria:

- 2 ° - 4 ° Perennial
- <2 % Slope
- Riffle/Pool Geomorphology
- Alluvial
- Depositional bar formations
- No upstream dams

Sierra: 3000-8000 feet
Coast: above tidal influence
up to 3300 feet





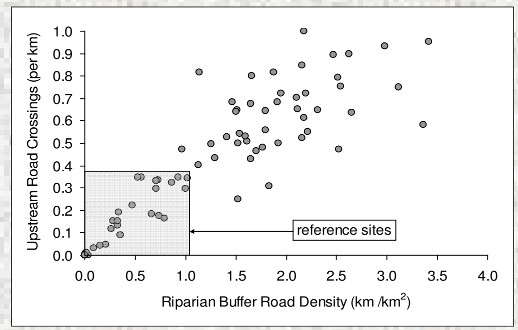
Reference / Test Designation:

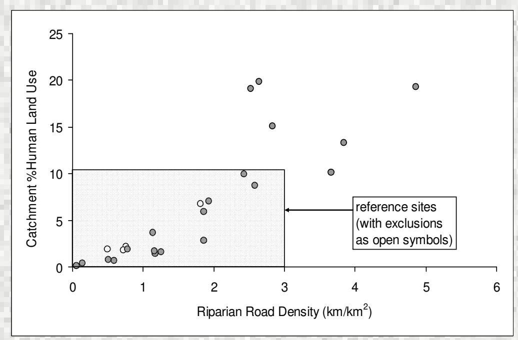
Sierra:

- Riparian Road Density <1.0 km/km²
- <0.4 Road Crossings/stream km
- 29 Reference; 45 Test

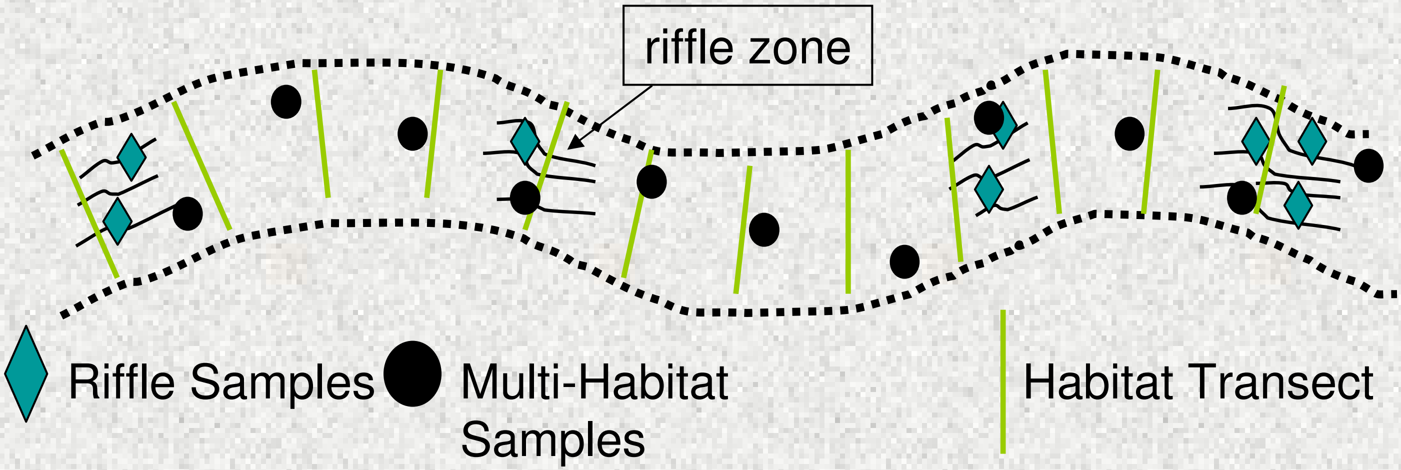
Coast

- Riparian Road Density <3.0 km/km²
- <10% human land uses within catchment
- 14 Reference; 10 Test



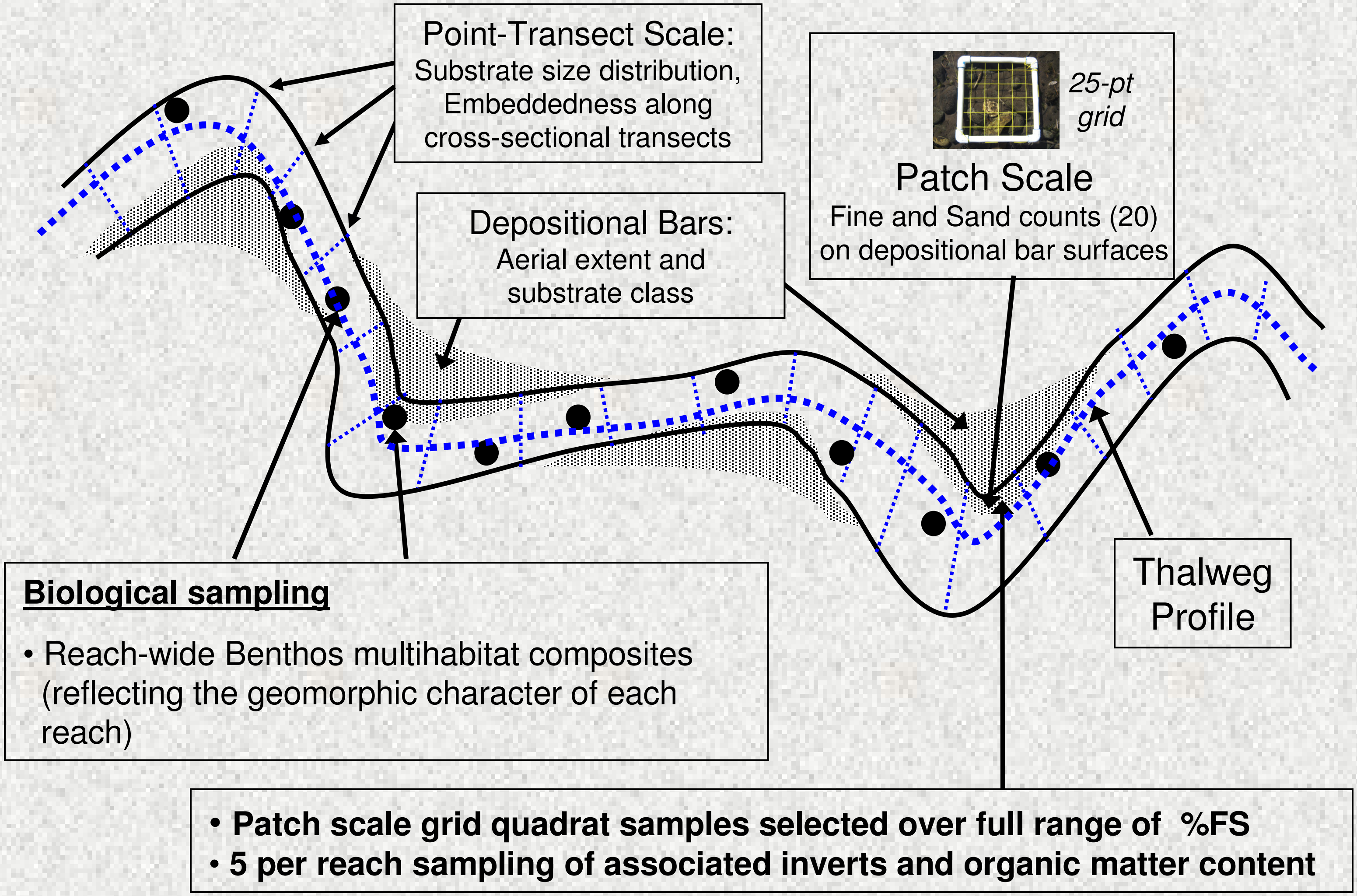


Reach survey: Samples are taken from randomized locations (within riffles OR at multi-habitats along a typical 150 m reach length) and then combined as a composite collection representing the reach

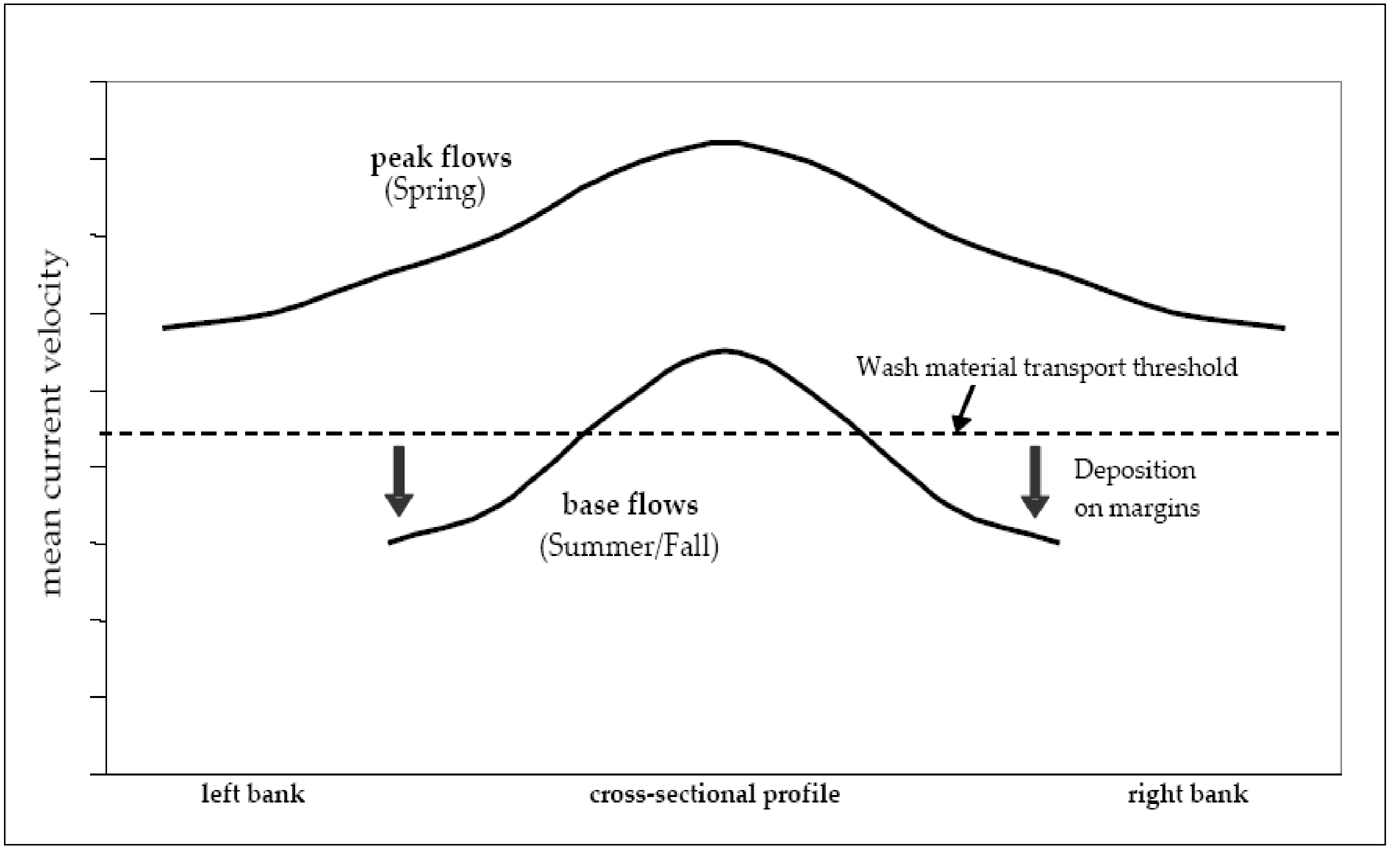


- Physical habitat surveys are conducted at repeated transects along the reach such that measures of substrate particle size distribution or percent fines-sand-gravel are reach-wide average values
- >> Associating the biological collections with the physical measures are therefore “fuzzy” – they are limited by the lack of correspondence between the habitats from which bugs are collected, and where habitat is measured

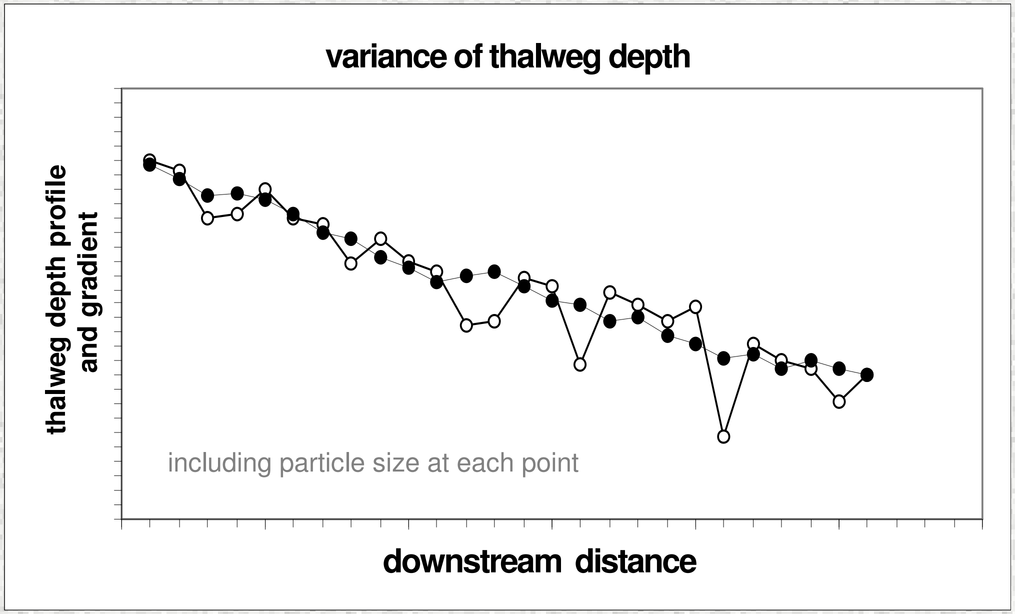
Field Measures of Sediment Deposition and Geomorphology



Idealized cross-section profile of transport and deposition: surveys of depositional margin zones under moderate to base flow conditions



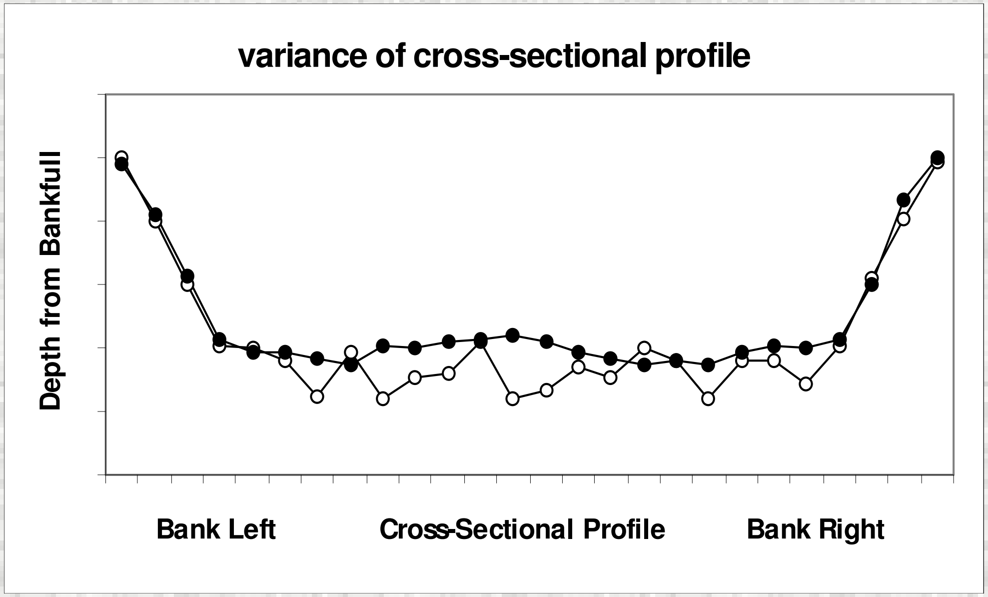
Thalweg and Cross-Section Profiles



How would we expect these features to change with increase in sediment deposition?

More homogeneous profile (as in filled symbols)

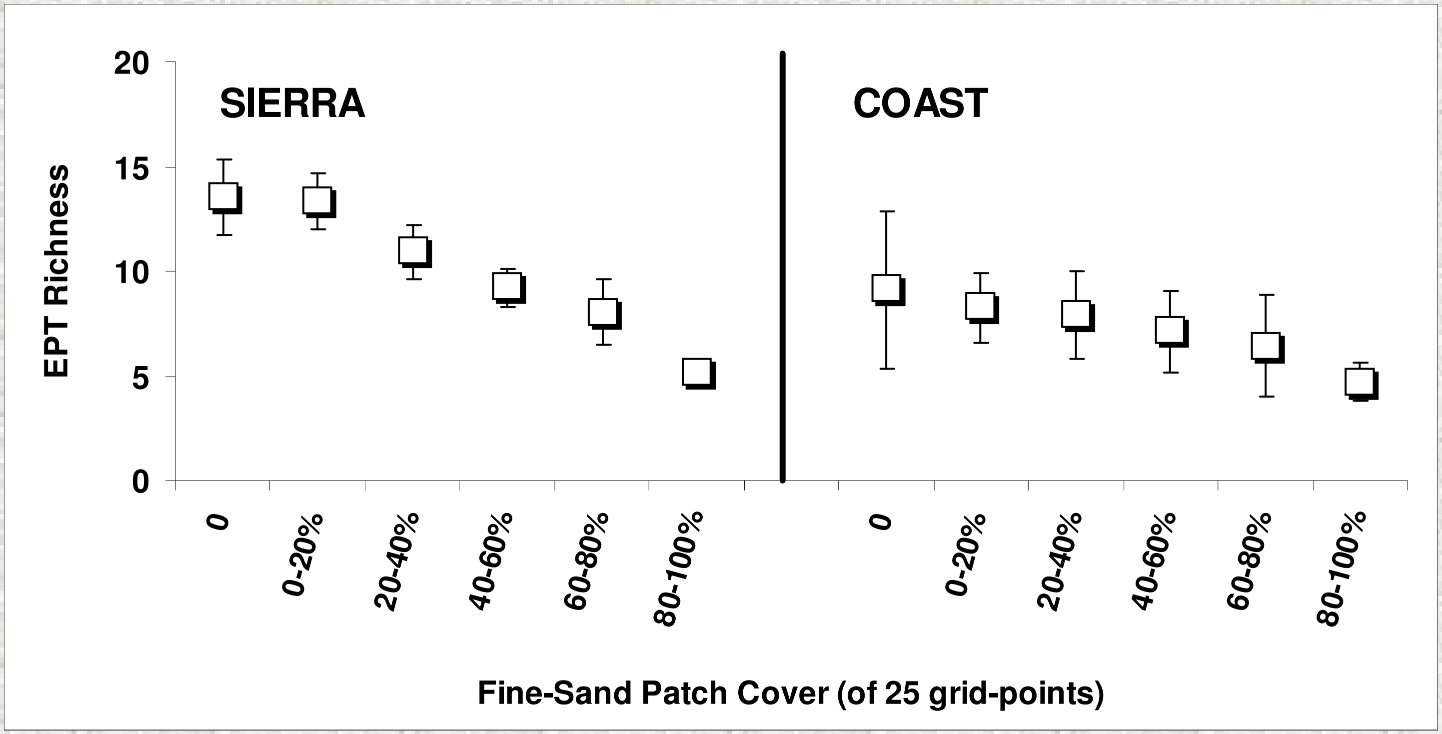
Bartley and Rutherford 2005 Riv. Res. Appl. 21:39-59 demonstrate utility in measuring reach-scale geomorphic and habitat diversity as affected by sediment



Patch Scale Sampling:

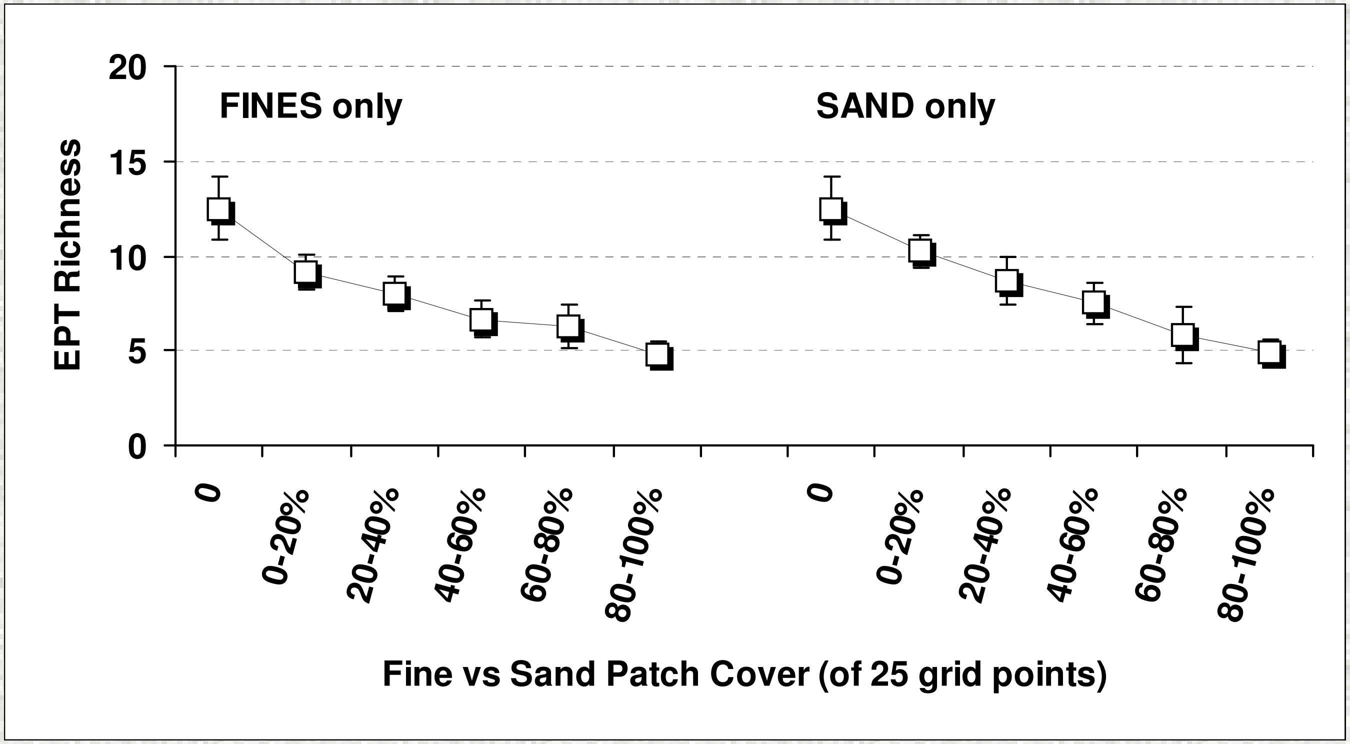
- Macroinvertebrate sampling at 5 quadrats each site: Selected to cover low to high range of FS local-scale deposition

Patch-scale differences between Sierra Nevada and Coast Range for EPT richness



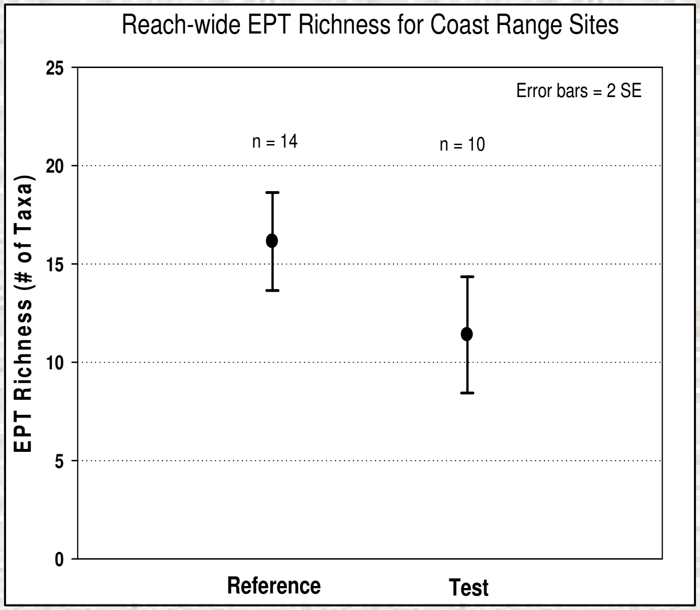
Lower scope for response in coast range streams evident in fewer EPT taxa even without FS cover, and though EPT decline over the dose range, overlapping 95% CIs indicate no significant reductions until >80% FS (variation does not yet integrate influence of FPOM & CPOM)

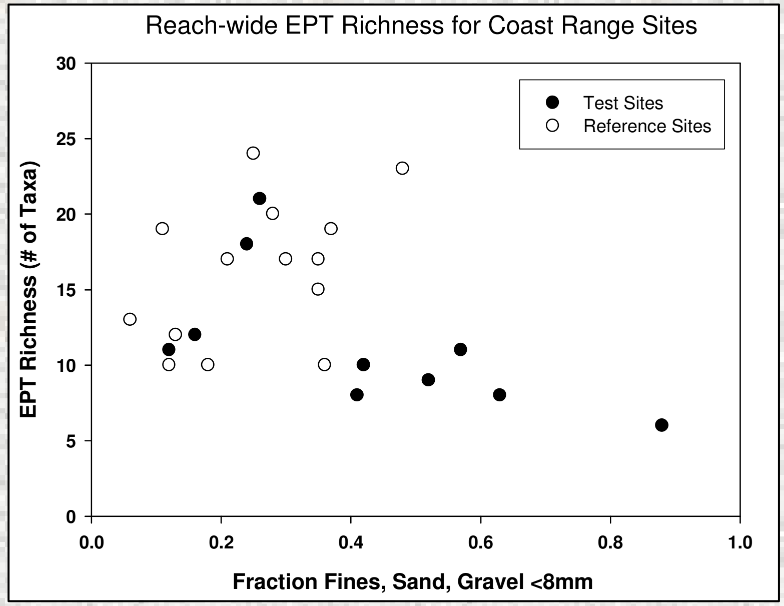
Patch-scale differences between fines and sand



For Sierra and Coast combined, EPT decline significantly more with initial increase in fines than with sand, but then produce Comparable reductions in richness as F or S cover increases to higher levels

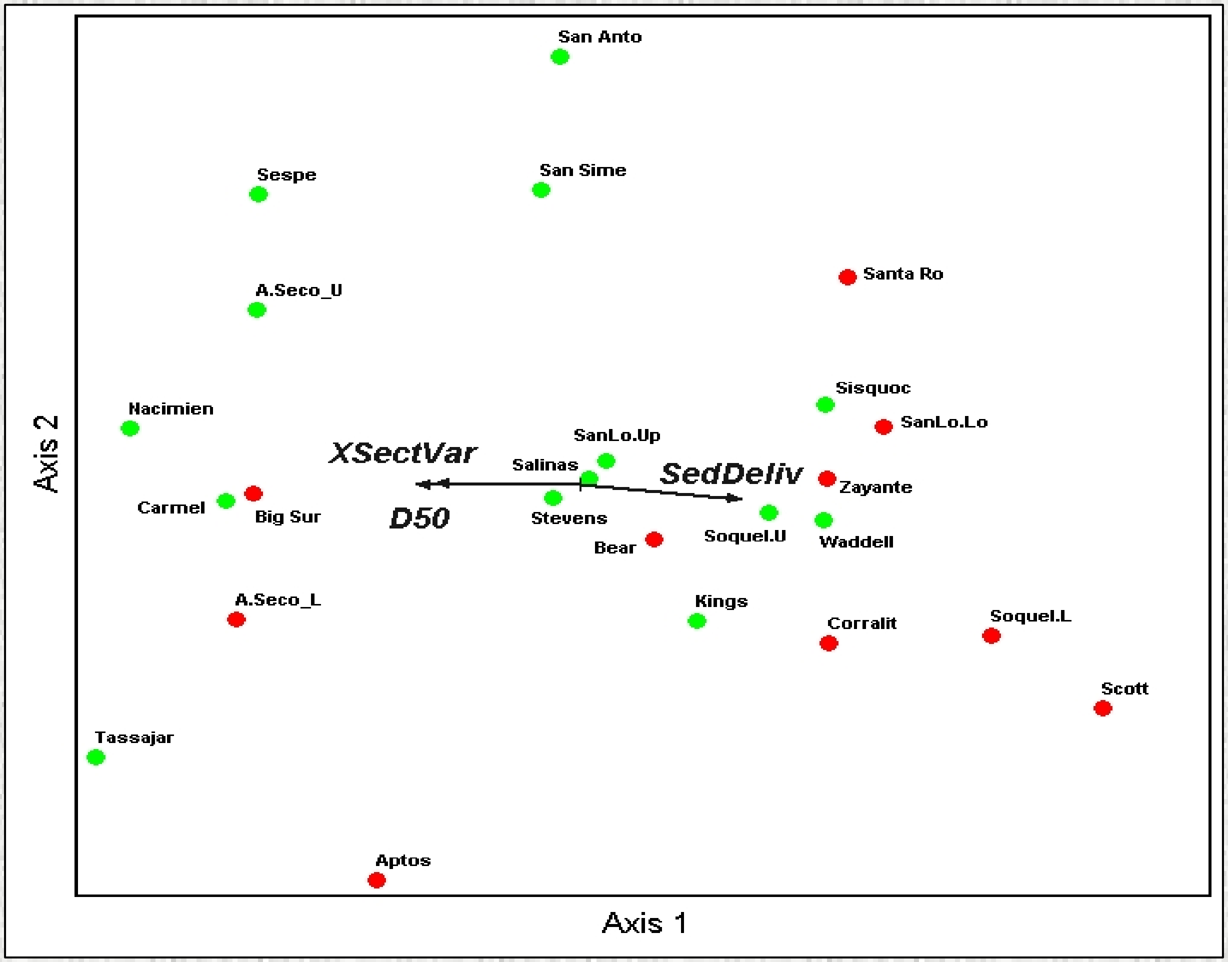
Reach-scale differences in coast stream EPT between Reference and Test and in relation to FSG fraction





- Significantly fewer EPT in test than reference sites
- Greater probability of EPT reduction above FSG >40%

- Reach-scale data from Sierra not yet incorporated



NMDS Ordination

Axis 1 correlations

D50 median particle size	-.571
X-Section Variability	-.539
Rheotanytarsus	-.746
Tanytarsus	-.554
Micropsectra	-.448
Phaenopsectra	-.634
Thienemannimyia	-.615
Tvetenia bavarica	-.531
Sediment Delivery Model	+.564
Oligochaeta	+.834
Optioservus	+.419

Community ordination separates many R from T as a function of particle size gradient, infilling of X-sect profile, and modeled sediment load

Landscape Analysis

Objectives:

• Examine the relationship between stream sedimentation and landscape pattern.

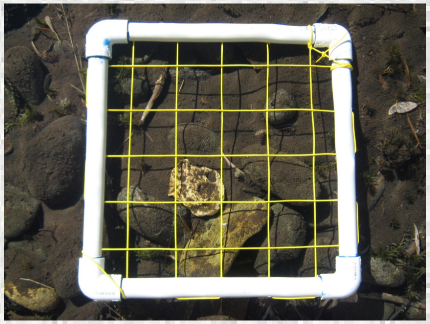
• Determine if differences in observed sediment deposition can be explained by landscape-scale measures of disturbance.

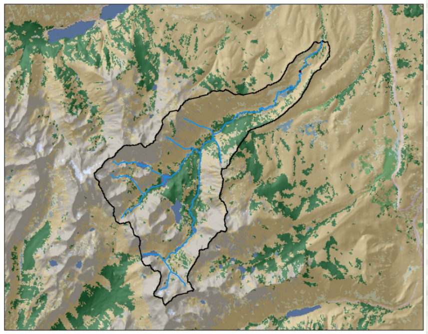
Questions:

1) Are there differences in field-based sediment deposition measures between reference and test populations?

2) Which landscape features (natural and anthropogenic) best explain differences in observed sediment deposition?

3) What scale of analysis provides the best relationship between landscape disturbance and observed sediment deposition?

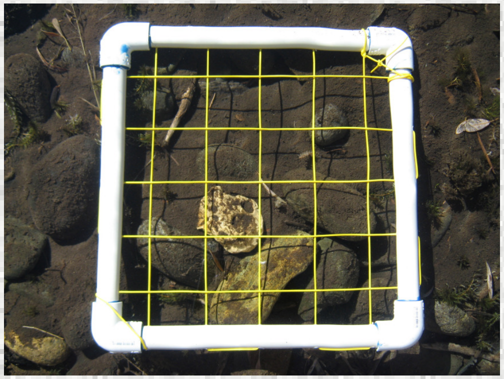




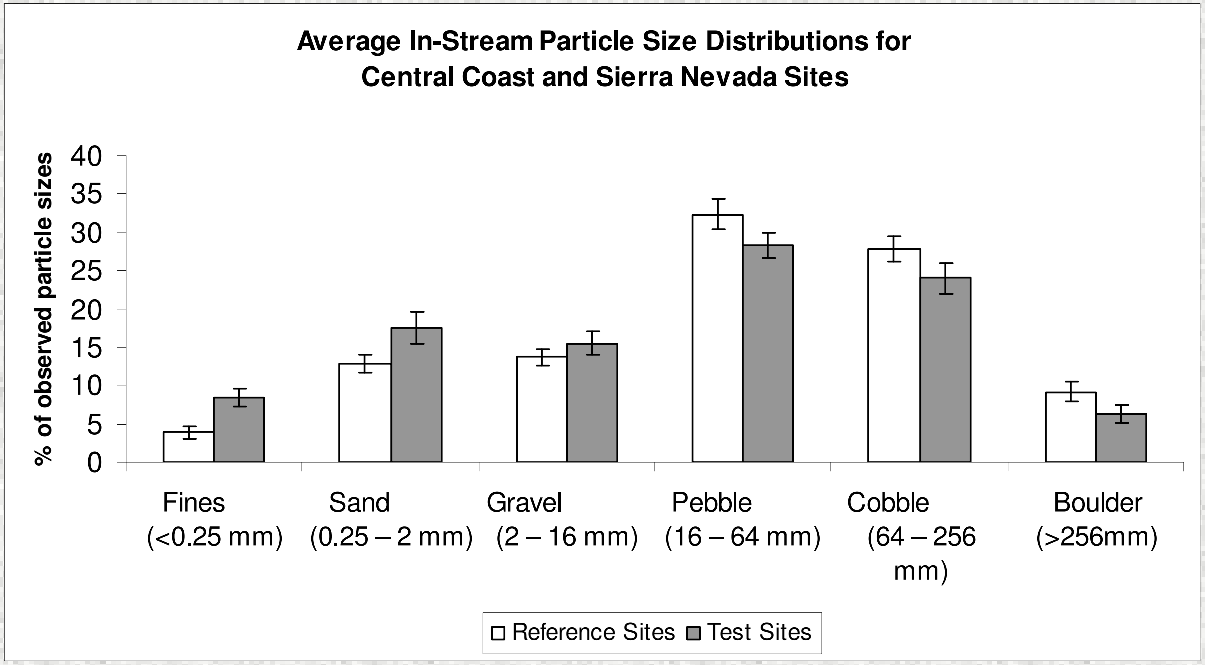
Reference (Natural) Vs. Test (Disturbed) Sites

Variable	Predicted Response	Observed Response	P
% Fines (<0.25mm)	"+"	"+"	0.0004
% Fines & Sands	"+"	"+"	0.0010
% FSG <16mm	"+"	"+"	0.0008
% FSG <8mm	"+"	"+"	0.0049
Thalweg Variability	"-"	"-"	0.0142
X-section Variability	"-"	"-"	0.0033
Geomean	"-"	"-"	0.0032
Relative Bed Stability	"-"	"-"	0.0124
D50	"-"	"-"	0.0037
Excess FS	"+"	"+"	0.0006
Excess FSG 8mm	"+"	"+"	0.0005
Excess FSG 16mm	"+"	"+"	0.0054

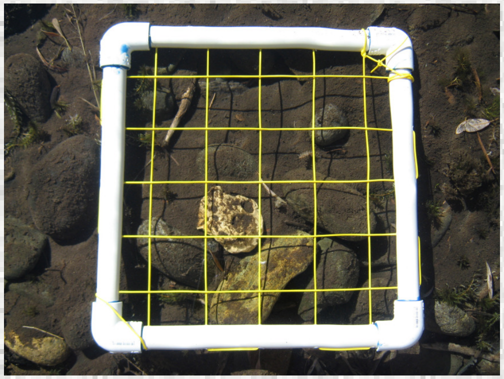
- Statistically significant differences in many sediment deposition measures between reference and test sites



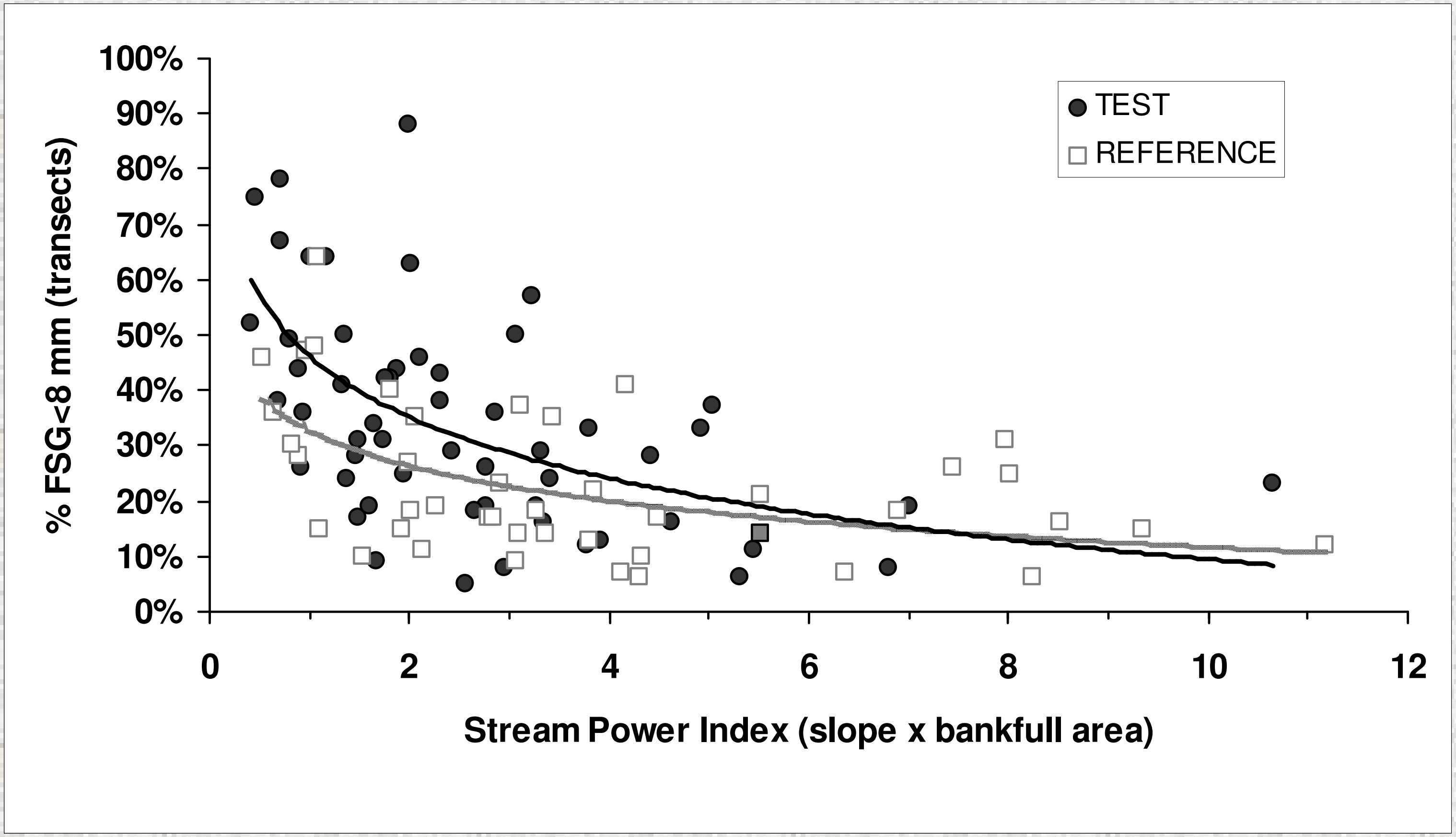
Reference (Natural) Vs. Test (Disturbed) Sites



- Test sites have higher percents of fines and sand
- and lower percent of pebble, cobble, and boulder



Reference (Natural) Vs. Test (Disturbed) Sites



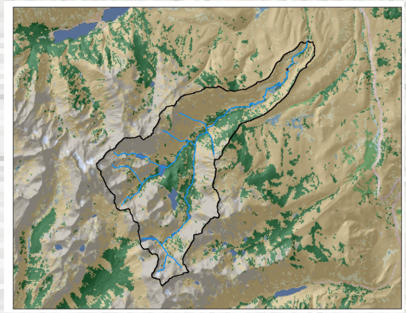
- Landscape disturbance shifts the relationship between stream power and stream bed sediment deposition
- Test sites with low to moderate Stream Power have 5-20% more fine, sand, and gravel-sized sediment compared to Reference streams of similar power

Individual Landscape Analysis Measures and Observed Sediment Deposition

Spearman Rank Correlation Coefficients

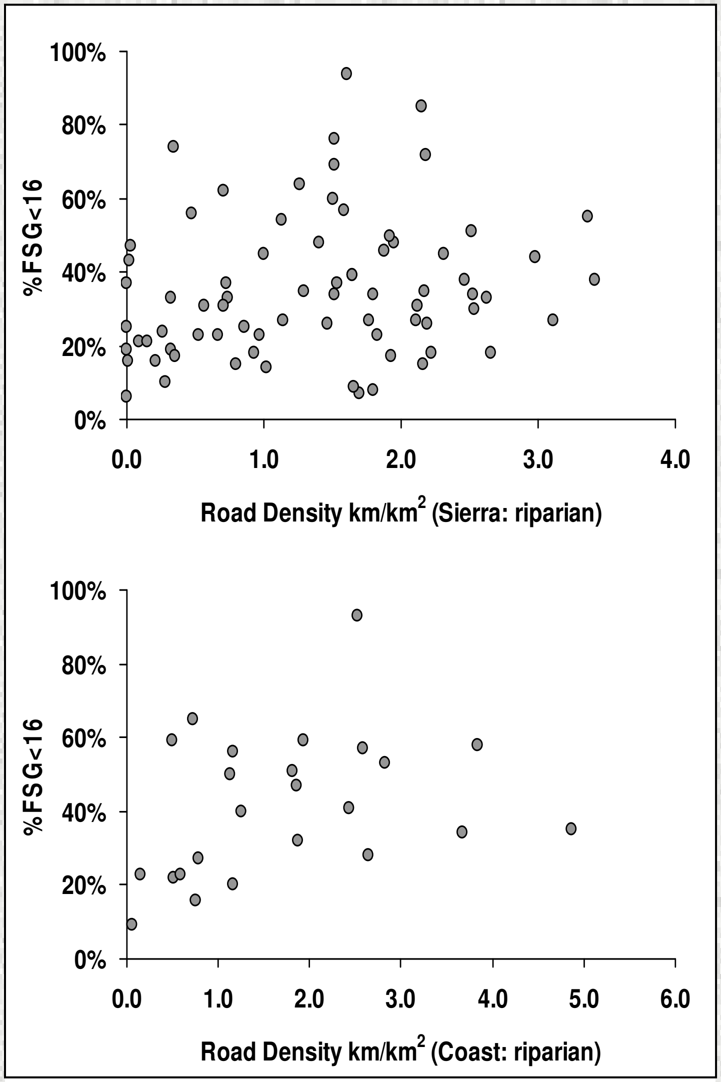
Road Measures	*Sierra*	*Coast*
Road Density - %FSG < 8 mm	0.227	0.378
Road Xings - %FSG < 8 mm	0.527	0.271

Land Cover Measures	*Sierra*	*Coast*
Human Land Cover - %FSG < 16 mm	-0.061	0.472
Natural Vegetation - %FSG < 16 mm	0.154	-0.481

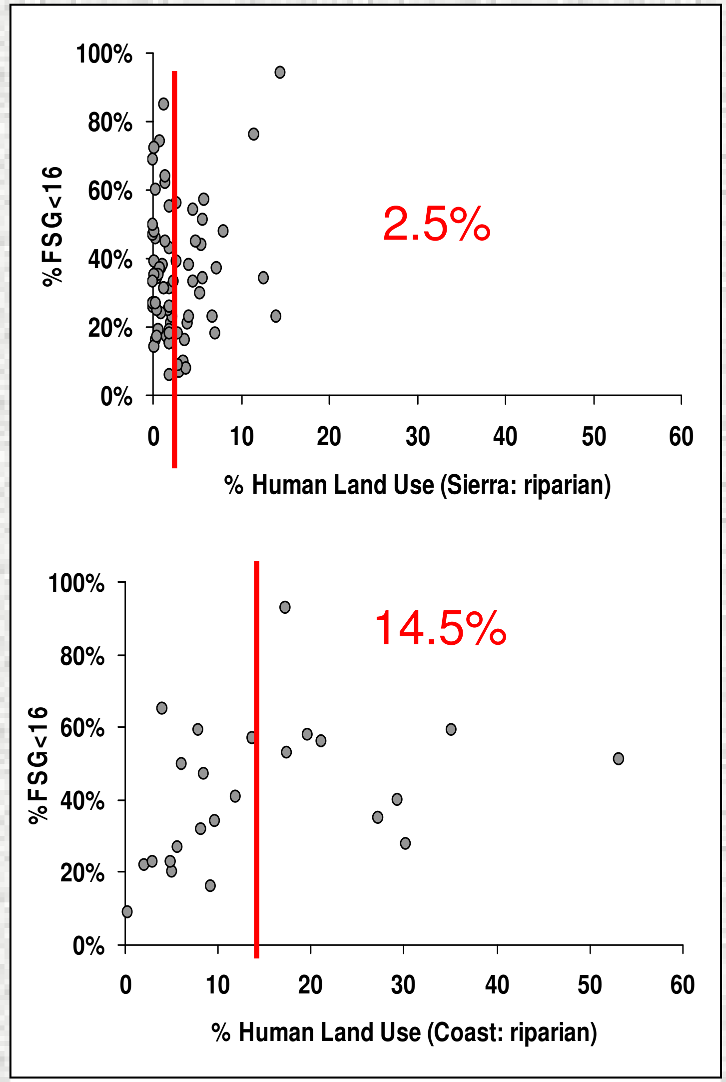


- In both the Sierra and Central Coast sites, landscape measures incorporating roads have stronger relationships to sediment deposition measures.
- Land Cover data had strong correlations for the coast, but very poor correlation for the sierra.

Road Density

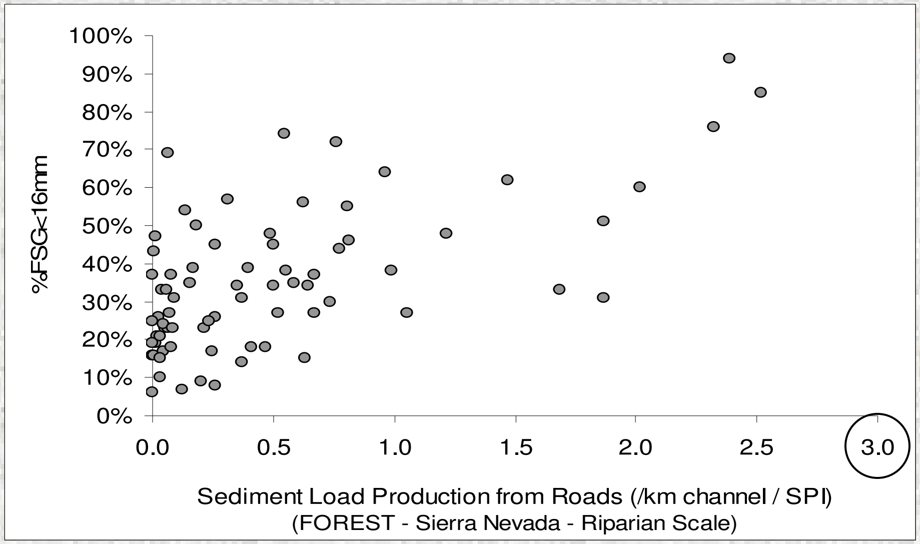


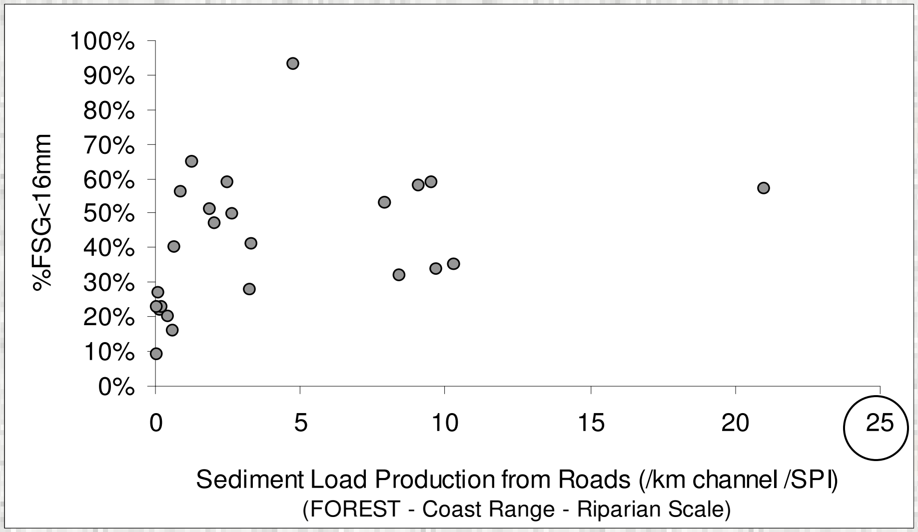
Human Influence Land Cover



Sediment Models and Observed Sediment Deposition

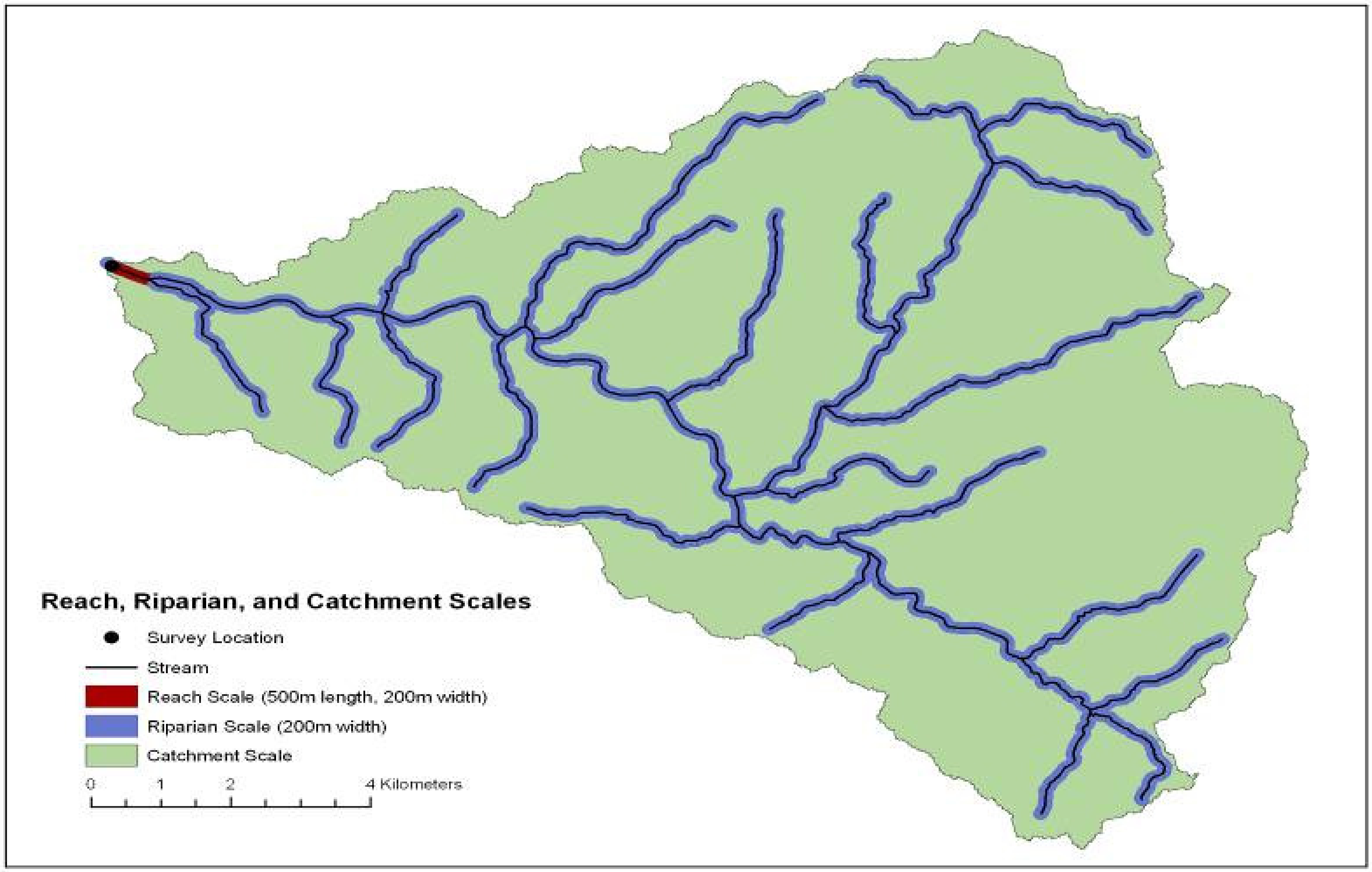
- Sediment Models derived from USLE.
- use input of both natural and human derived causes of erosion



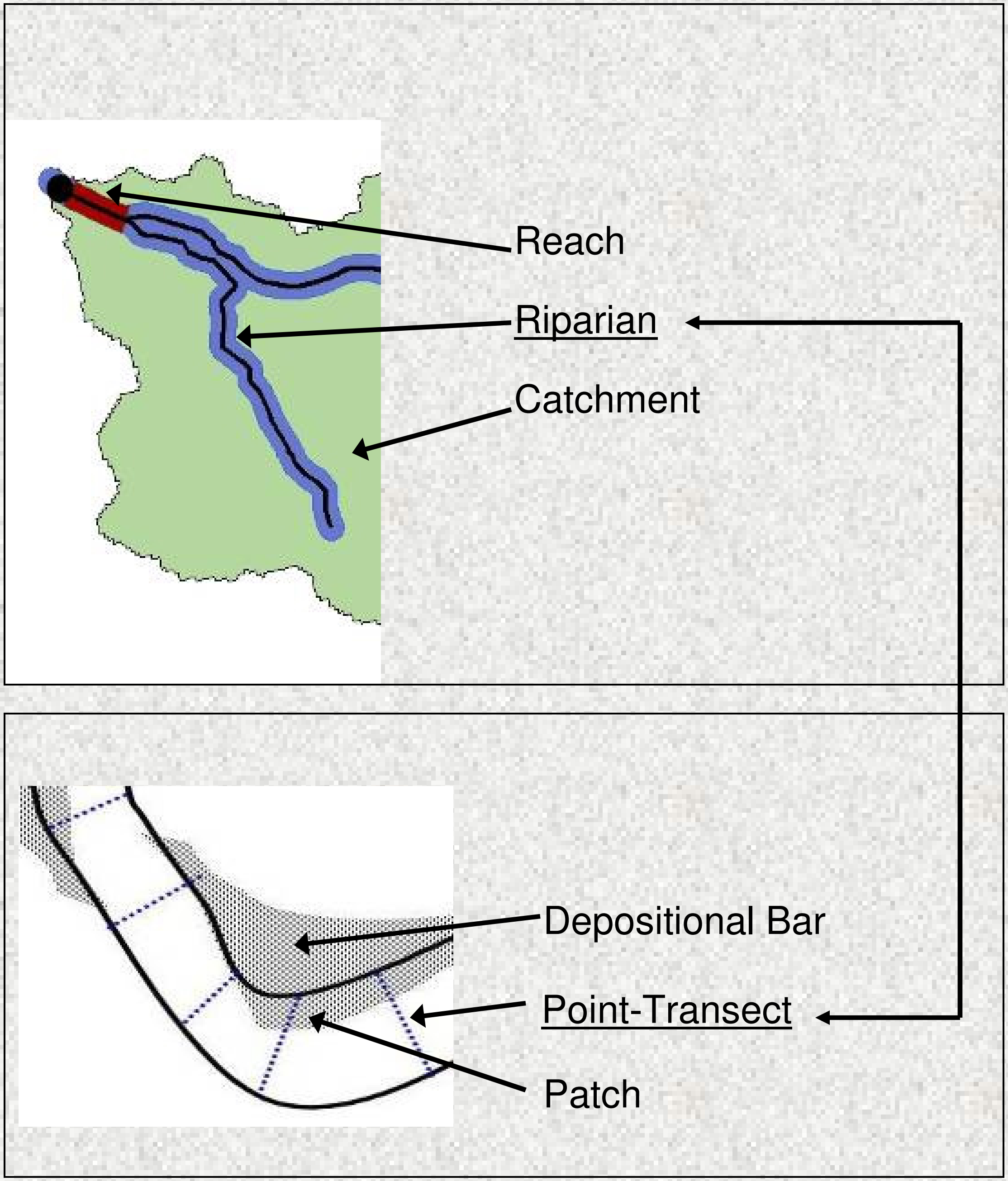


FORest Erosion Simulation Tools (FOREST)

Landscape Analysis Scales:

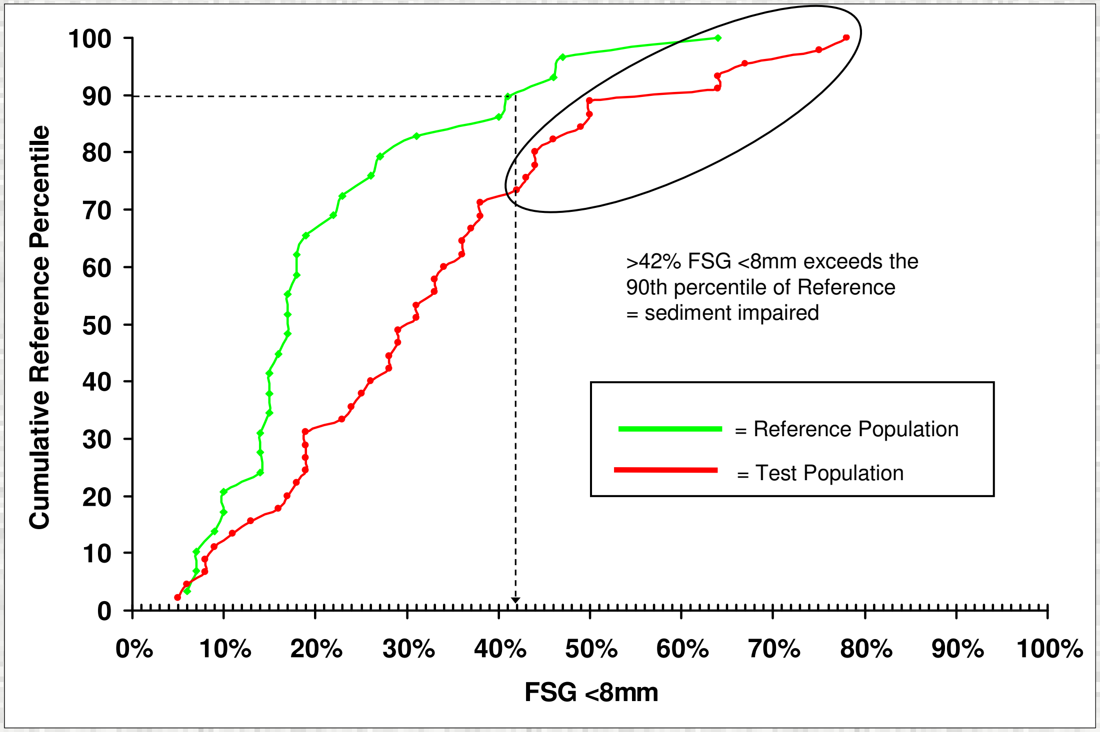


What scale of analysis provides the best relationship between landscape disturbance and observed sediment deposition?



We found the best relationship between landscape disturbance measures at the riparian scale and sediment deposition measures at the point-transect scale

Can we use this information to develop general guidance on sediment TMDLs based on the depositional environment?



Sediment Indicator	Sierra	Coast
%FS	29	
%S		28
%FS		34
%FSG<8mm	42	37
%FSG<16mm	49	57
D50 (mm)	15.1	15
Geometric Mean (mm)	10.9	9
X-Sect. Variability Index	2.8	
Embeddedness	19	
Relative Bed Stability	0.33	0.41
%Excess FS	13	12
%Excess FSG<8mm	19	12
%Excess FSG<16mm	20	
%Patch-Grid FS	77	
%Thalweg FS		49
%Thalweg FSG		78

Conclusions:

- Decreased EPT diversity at both patch- and reach-scales is associated with increased sedimentation that can be linked to erosion due to land use and roads disturbance.
- Sediment impairment criteria can be defined based on the exceedence of the 90^{th} percentile of the reference distribution (additional reference data needed to enhance reliability)
- Determining the appropriate landscape analysis to use in order to assess stream sediment conditions depends on the characteristics of the local landscape.

  For mostly forested landscapes, roads are the most important source of disturbance. For landscapes with more heterogeneous land cover, erosion and sedimentation sources should account for urban land use covers as well as roads.

- Reaches with low stream power may be most susceptible to accumulation of sediment deposits that impair biological integrity.