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Assessing Relative Bed Stability and Excess Fine Sediments in Streams

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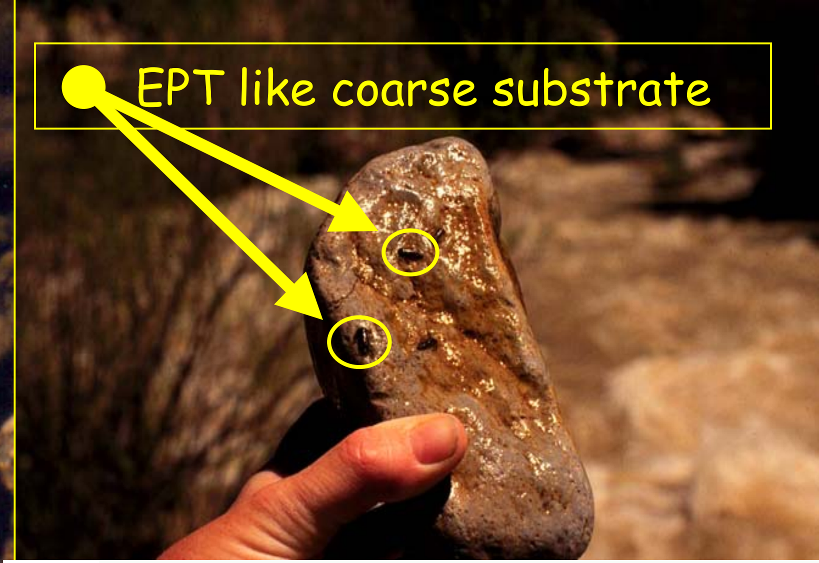
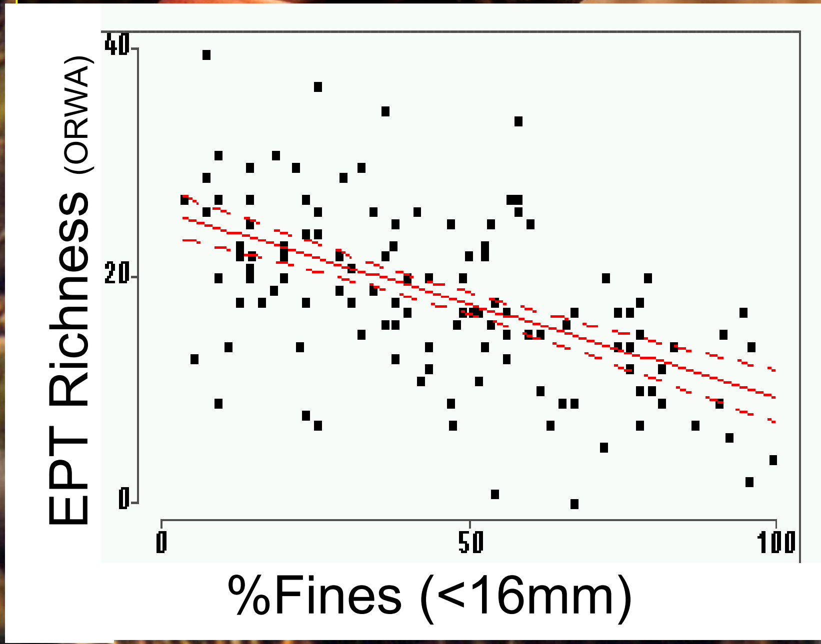
Substrate:
- Important determinant of habitat quality for aquatic biota.
- One of the habitat attributes most commonly altered by humans.





Fine particles fill spaces between larger particles, reducing water circulation, habitat space and diversity for invertebrates, benthic fishes, and spawning habitat for other fishes.

Why the RBS Approach?

There is abundant evidence that changes (particularly increases) in the amount of stream bed fine sediment are deleterious to biota.

We need a way to factor out natural variability to determine the amount of fine sediment excess (or deficit) attributable to human activities.

Our approach must be practical for States and Tribes to use in their ambient monitoring programs.

-----------Stream Size ------------>

------ Gradient --------->

LANDSCAPE CONTEXT

strongly controls stream discharge, sediment supply, channel morphology and streambed particle size

STREAM SUBSTRATE SIZE

- Bed particle size depends on interplay between supply and transport.

  (Wilcock, P. 1998. *Science* 280:410-412)

- Increased supply of fine sediment from erosion should cause fining of the bed.

  (Dietrich, W., et al. 1989 Nature 340:215-217)

<u>Relative Bed Stability (RBS)</u>

Compare:

Observed substrate diameter

with critical (mobile) diameter at bankfull flow (*Dingman, 1984, Fluvial Hydrology*), adapted for substrate diameter class count data and complex, reach-length channels:

$$\mathbf{RBS = D_{gm} / D^*_{cbf}}$$

Quantifying Components of RBS

- Observed $\mathbf{D_{gm}}$ or D_{50} --- from Field Wolman pebble count.

- $\mathbf{D^*_{cbf}}$ = Bankfull Critical (mobile) diameter, estimated by equating :

Bankfull Bed Shear Stress ($\rho g R^*_{bf} S$**)**, controlled by:

+ Channel slope (**S**)
+ Adjusted Bankfull Hydraulic Radius ($\mathbf{R^*}_{bf}$)
  + Bankfull Depth
  - Residual pool depth
  - Large wood volume

Critical Shear Stress $\theta(\rho_s-\rho)gD$, influenced by:

+ Particle Diameter (D)
+ mass density of particles in water $(\rho_s-\rho)$
. shape, exposure, size variance (θ)

Algebra for Deriving D^*_{cbf}

- Bankfull Shear = $\rho g R_{bf} S$
- Critical Shear = $\theta(\rho_s - \rho) g D$
- Equate $\rho g R_{bf} S = \theta(\rho_s - \rho) g D$
- Rearrange:

$$D^*_{cbf} = (\rho g R_{bf} S) / [\theta(\rho_s - \rho) g]$$

- Substitute values:

$$D^*_{cbf} = 13.7 \, R_{bf} S$$

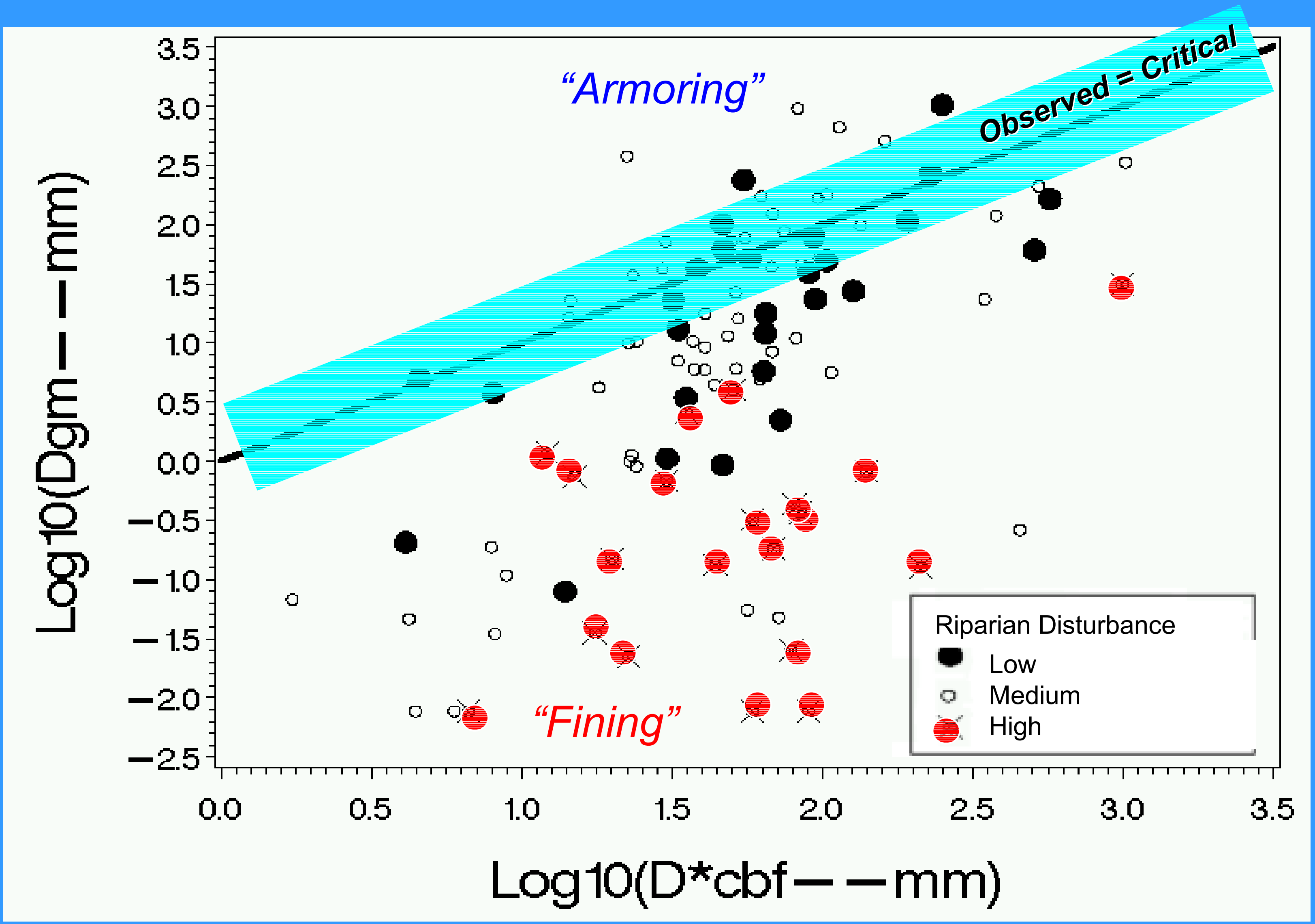
Expected Streambed Particle Size

Over time, streams adjust transport to match sediment supply.

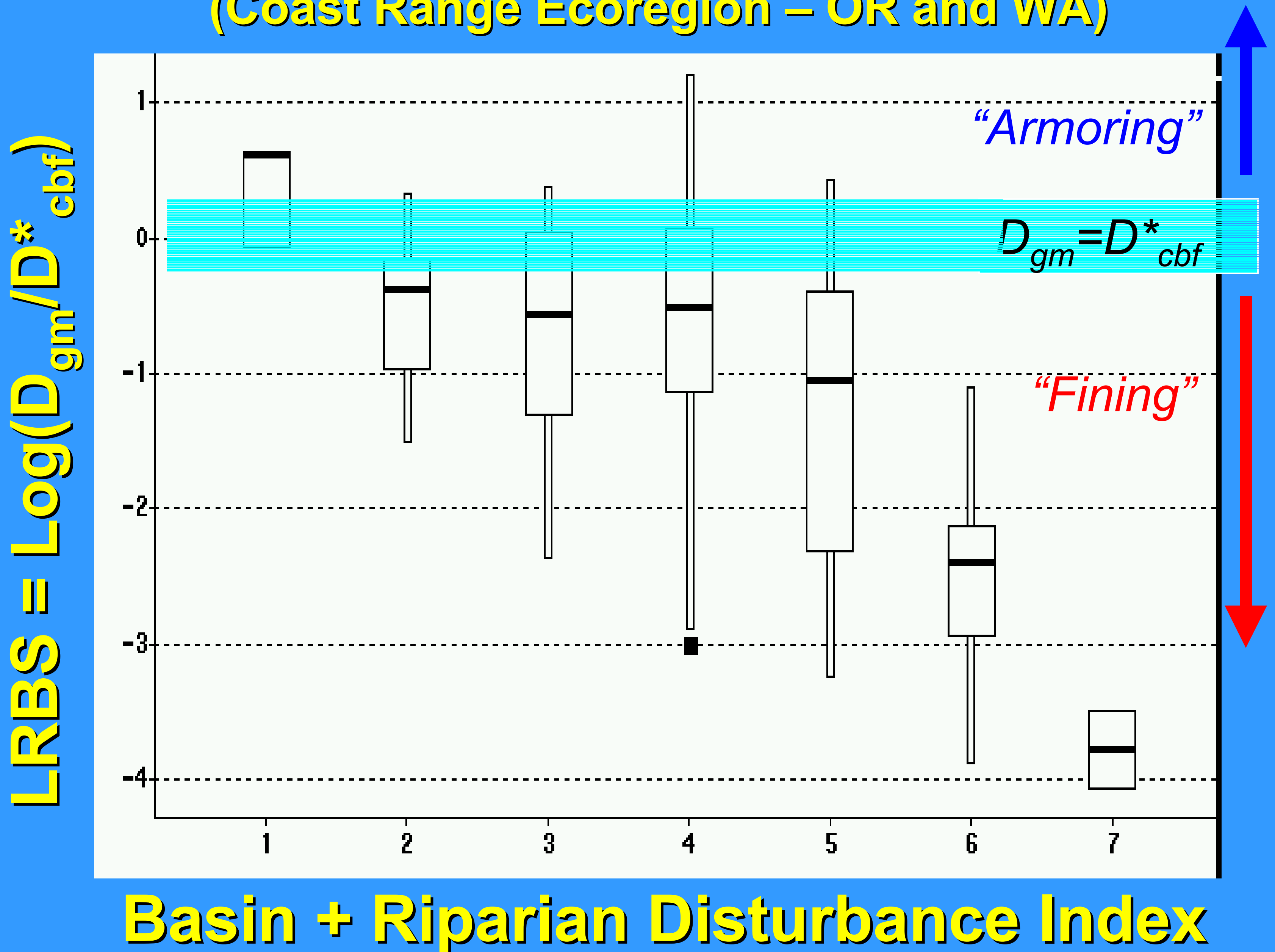
Where transport limited by competence, Bed substrate D_{gm} in minimally disturbed streams should tend towards D^*_{cbf}, the size the stream is capable of moving as bedload at bankfull.

RBS = D_{gm}/D^*_{cbf} should tend towards 1.0 in reference sites ($Log_{10}RBS=0$)

Bed Surface Particle D_{gm} vs Adjusted D^*_{cbf}
(104 Oregon and Washington Coast Range Streams)

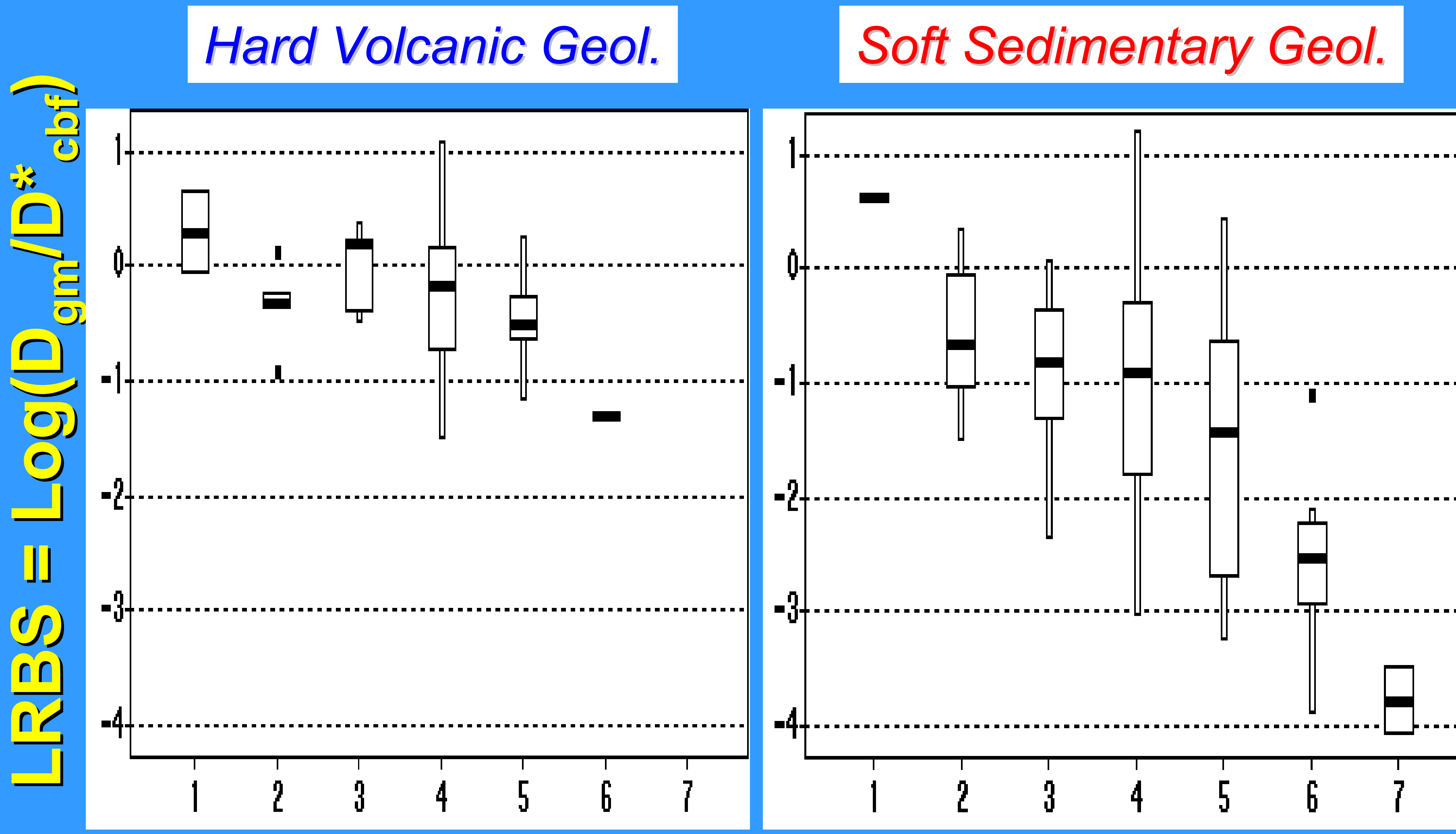


Relative Bed Substrate Stability vs Disturbance (Coast Range Ecoregion – OR and WA)



Relative Bed Substrate Stability vs Basin-Riparian Condition

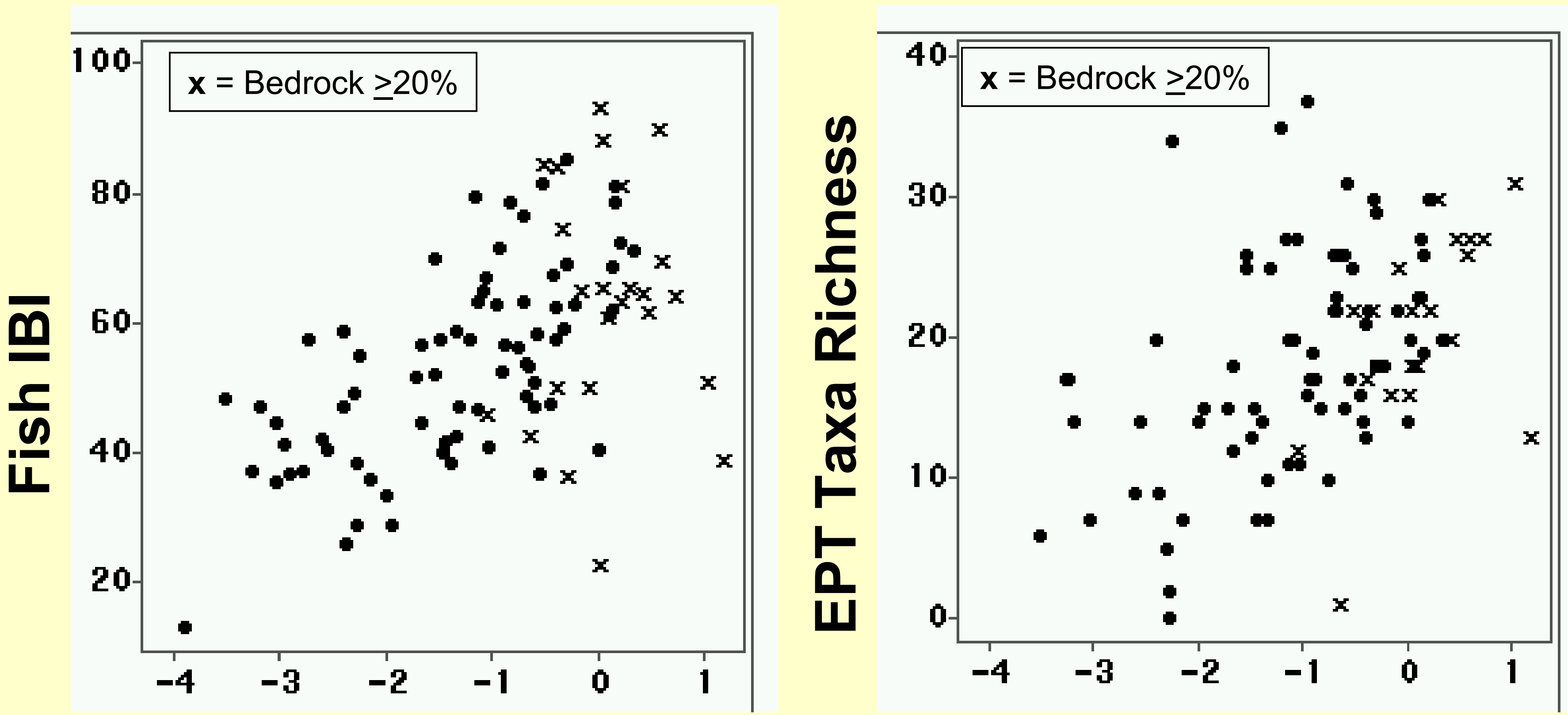
(Coast Range Ecoregion – OR and WA)



Basin + Riparian Disturbance Index

Do Biota Care about Relative Bed Stability ?

(Data from OR/WA Coast Range REMAP '94-'95)



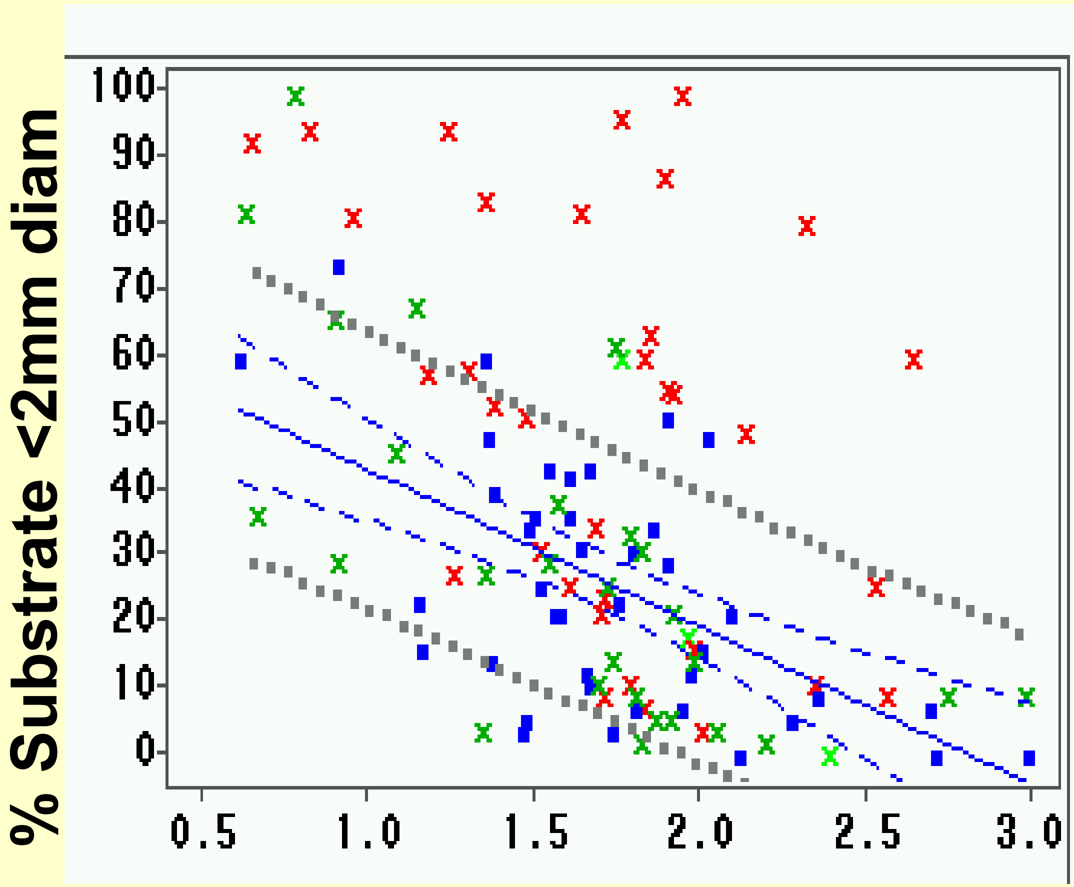
RBS: $\mathrm{Log}(D_{gm}/D^*_{cbf})$

Calculate % Excess Sand+Fines

(OR/WA Coastal REMAP 107 sites 1994-1995)

1. Regress %SaFn (<2mm diam) against Dcbf for reference sites (Blue) - - showing 90% CI; 80%Prediction Interval
2. Calculate deviations for all sites
3. Positive deviations are % Excess Sand and Fines.
4. Negative deviations are % Deficit Sand and Fines.
5. How do these values relate to RBS?

Basin+Riparian Disturbance:Low Med High

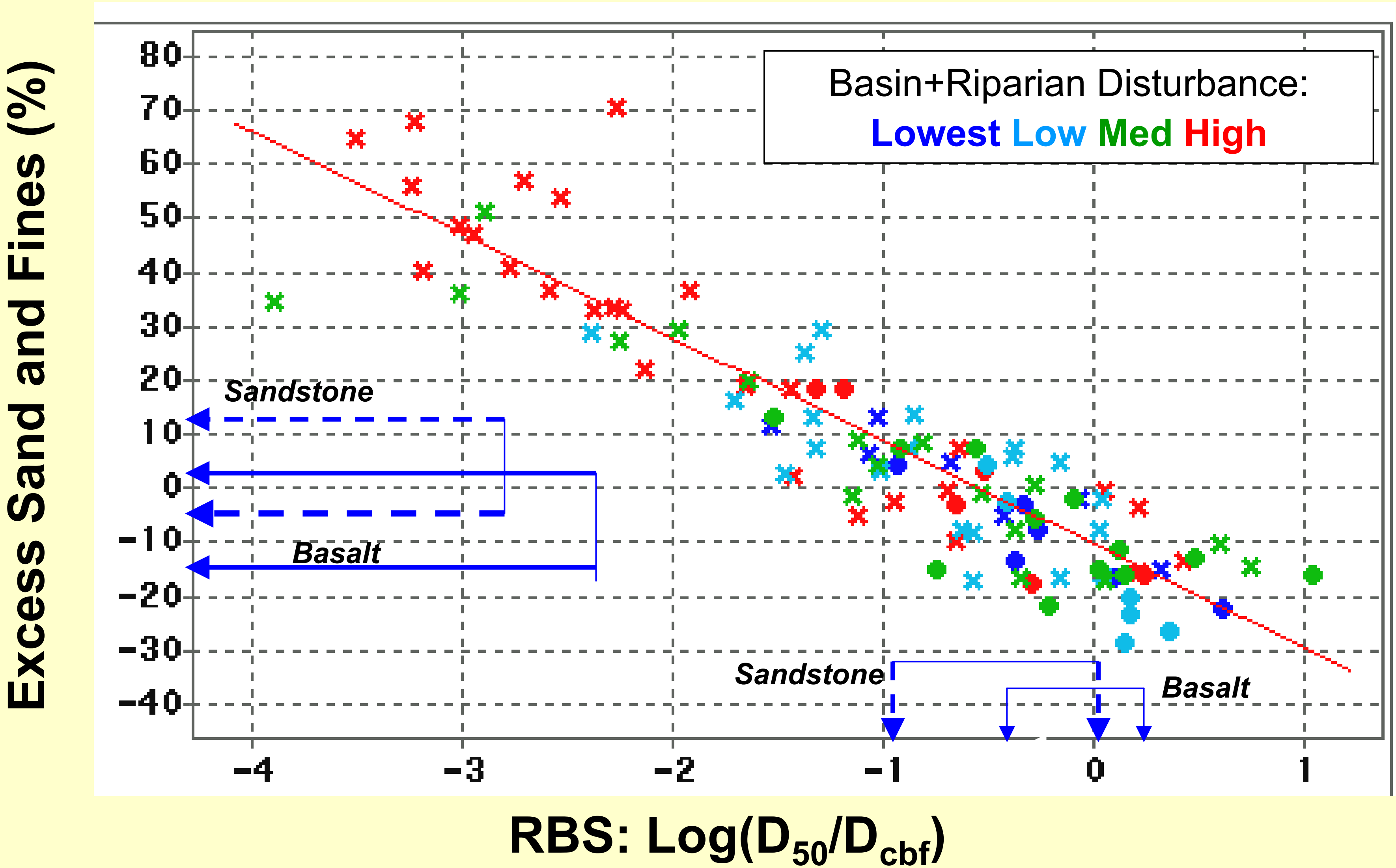


$Log_{10}(D_{cbf})$

Relate % Excess Sand+Fines to RBS

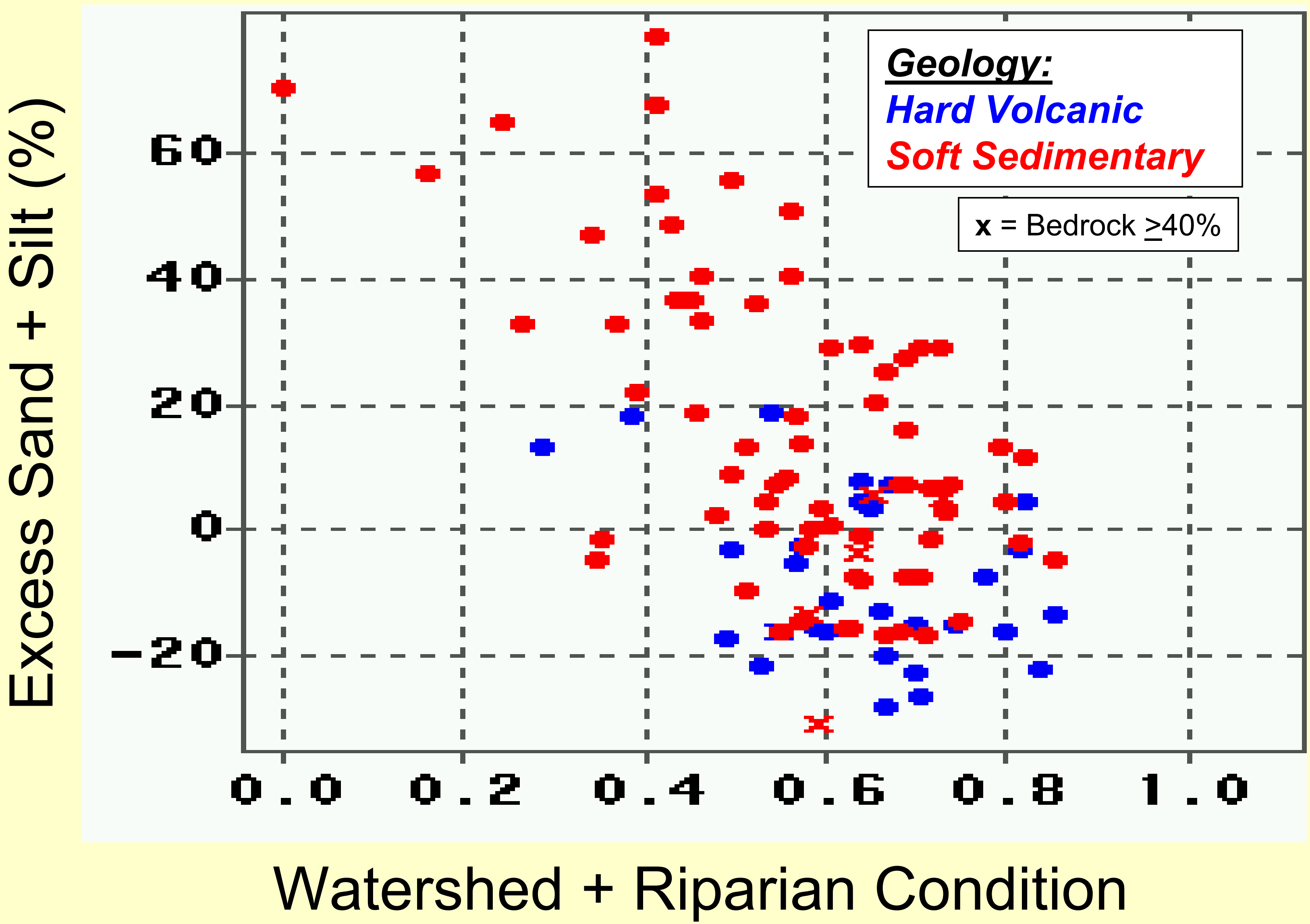
OR/WA Coastal REMAP (107 sites 1994-1995)

IQR of Ref sites in Blue, Lithology: Sandstone = **x** Basalt = •



Excess Sand + Fines vs Watershed + Riparian Condition

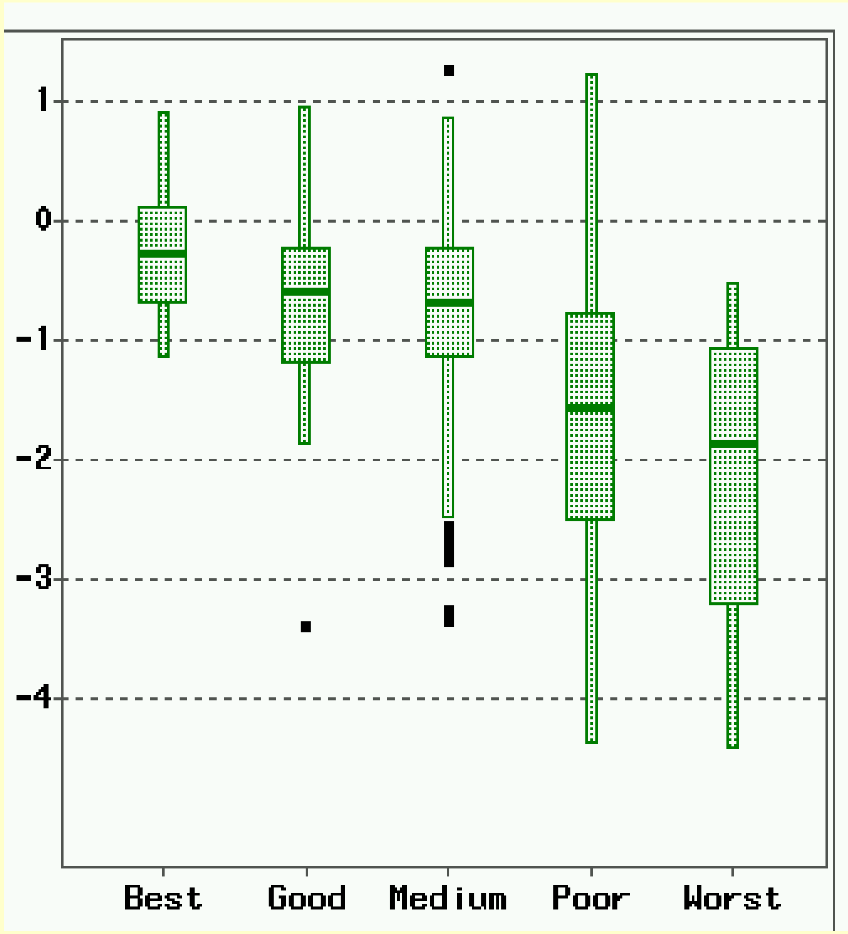
(Coast Range Ecoregion – OR and WA)



Does RBS approach work anywhere else?

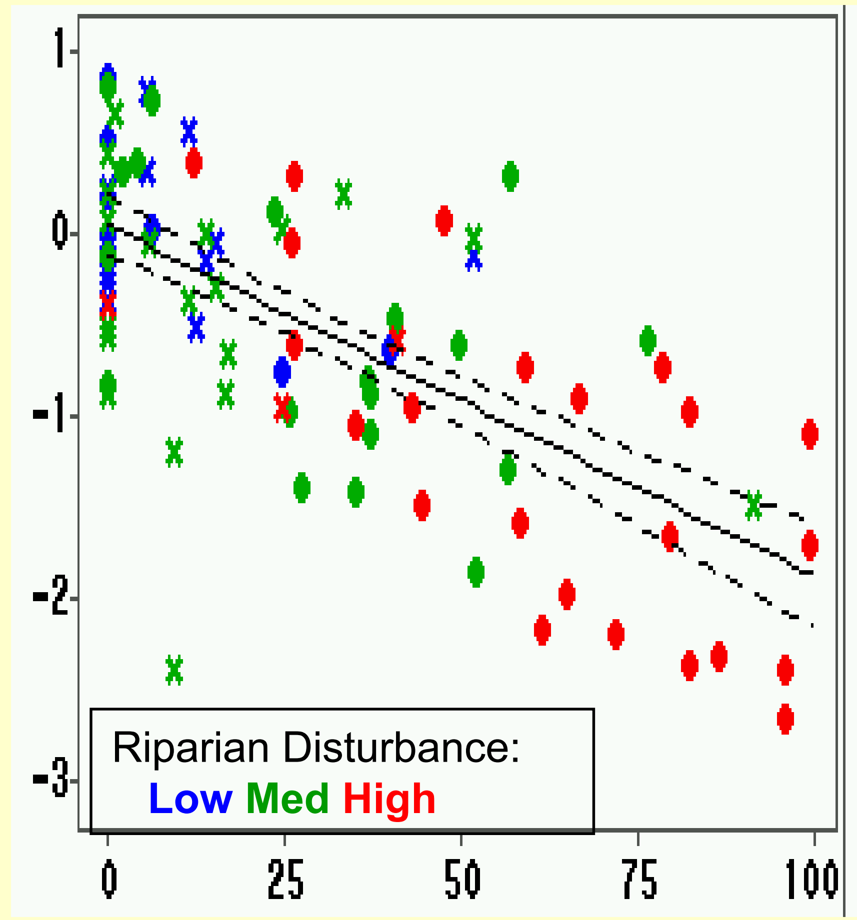
Relative Bed Substrate Stability (RBS) versus Human Disturbance

EMAP-West (n=900, 12 States)



Riparian Condition Class

Mid Atlantic Ridge (X) Valley (.)(n=84)

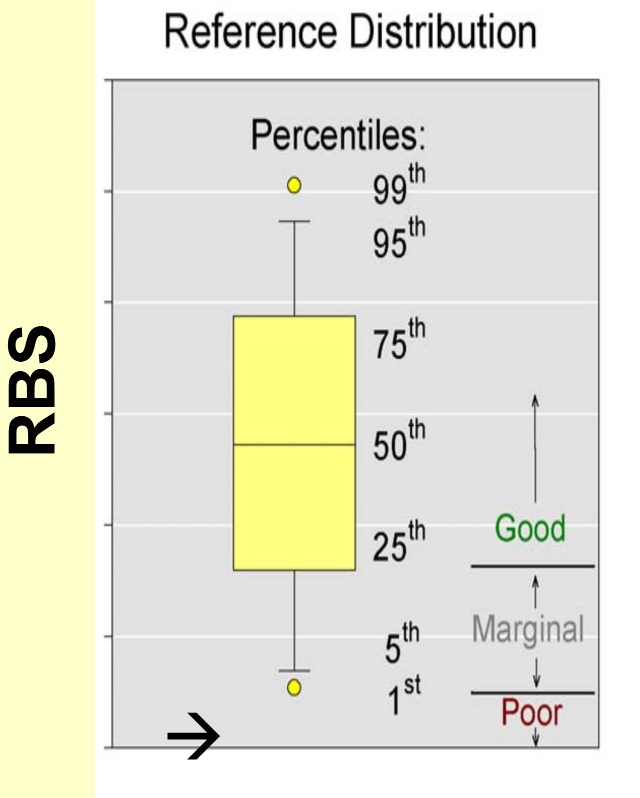


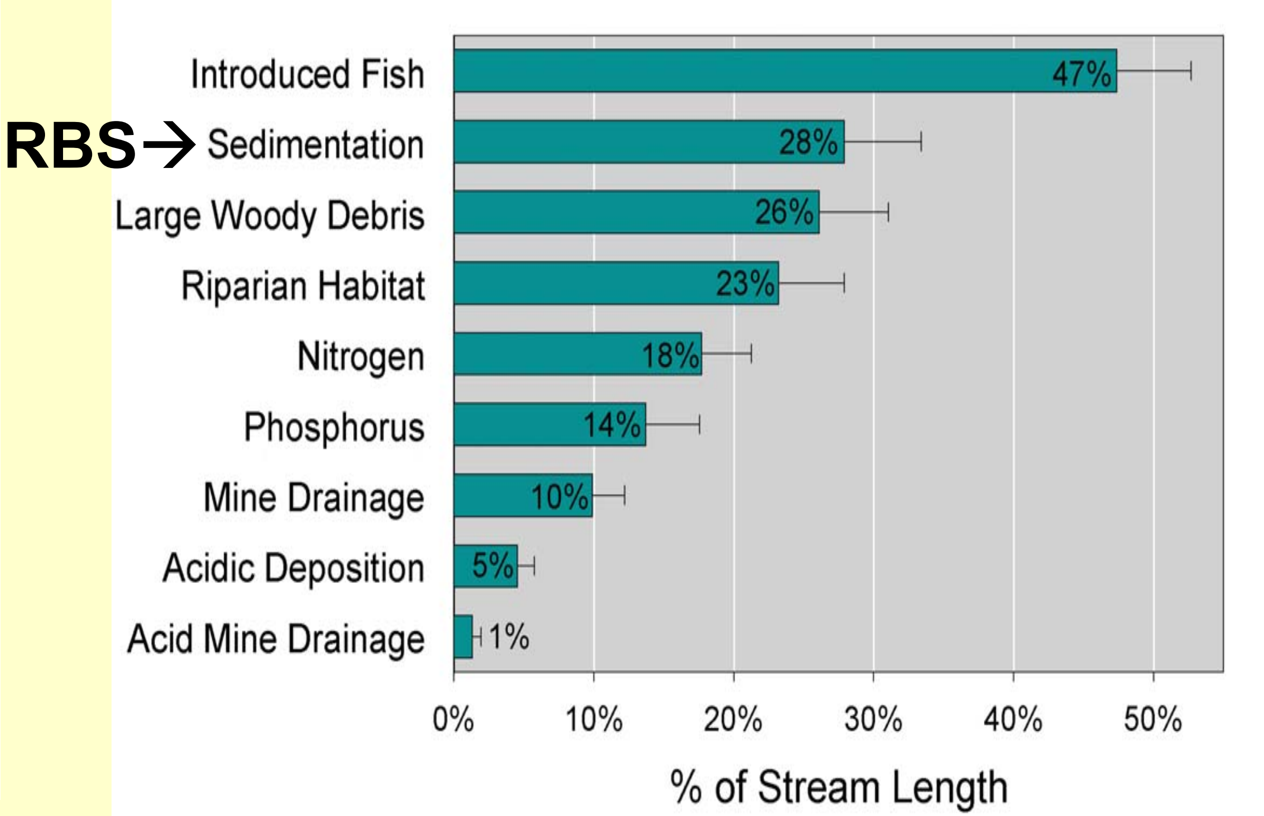
Basin Land Use Disturbance (%)

How Has RBS Approach Been Used in "Real Life"?

- Regional Assessment (305b Context)
- Site Impairment (303d Context)

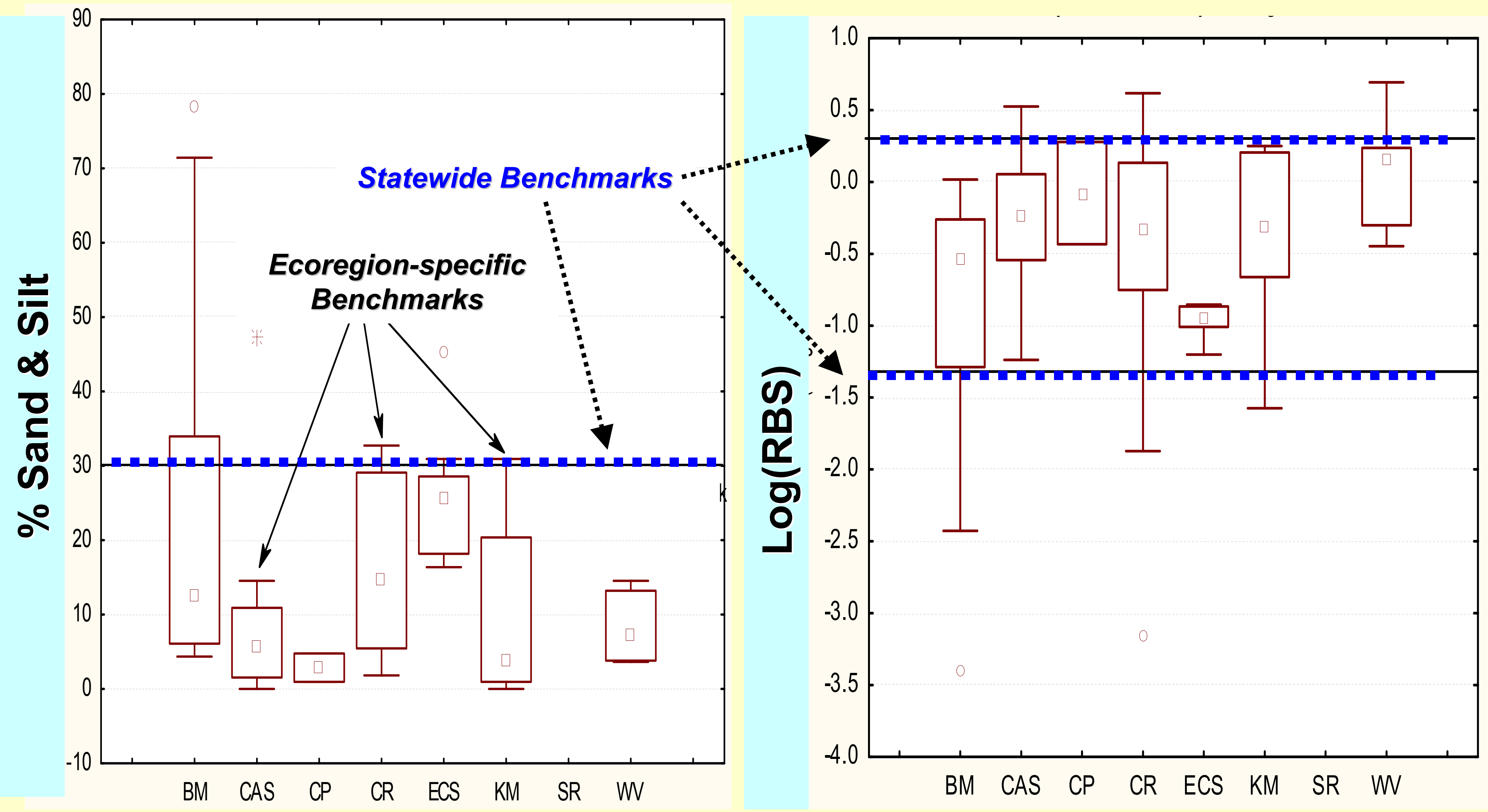
How has RBS been used to evaluate condition of streams?



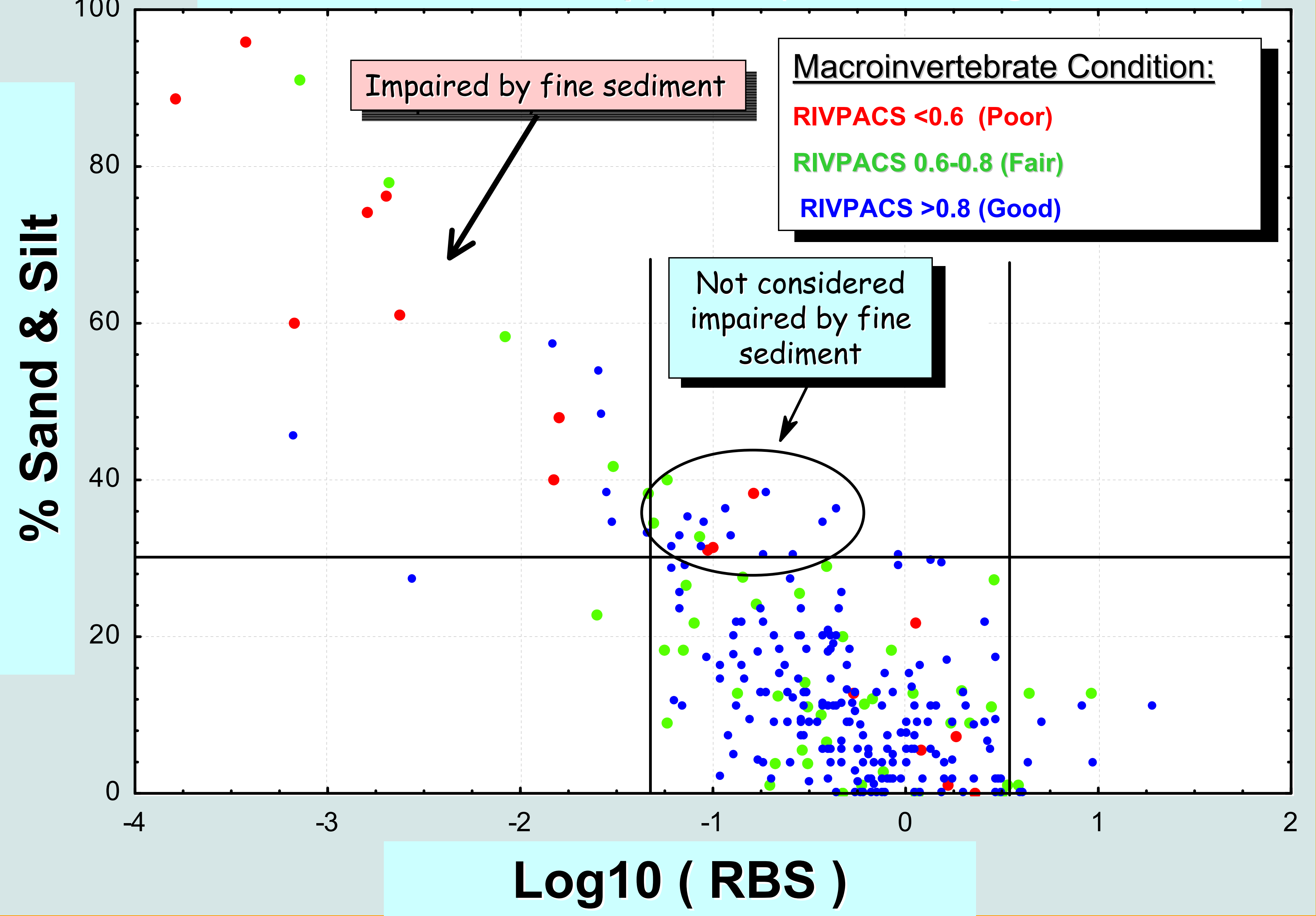


<u>Mid-Atlantic Highlands Assessment and draft Mid Atlantic Integrated Assessment</u>: Regional Population Estimates of the relative extent of major stressors on stream condition. Each bar represents the proportion of stream length in poor condition for that stressor, with 90% confidence intervals around each estimate. Criterion for poor condition: RBS < 1st percentile of ecoregionally-specific reference sites. (in Piedmont/Coastal Plain: -2.0; in remainder of Region, -0.9)

Ecoregion-specific Benchmarks for Fine Sediment and Relative Bed Stability based on Ecoregional Reference Sites *(from D. Drake, Oregon DEQ, 2004)*



Sediment Benchmark Approach (D. Drake, Oregon DEQ, 2004)

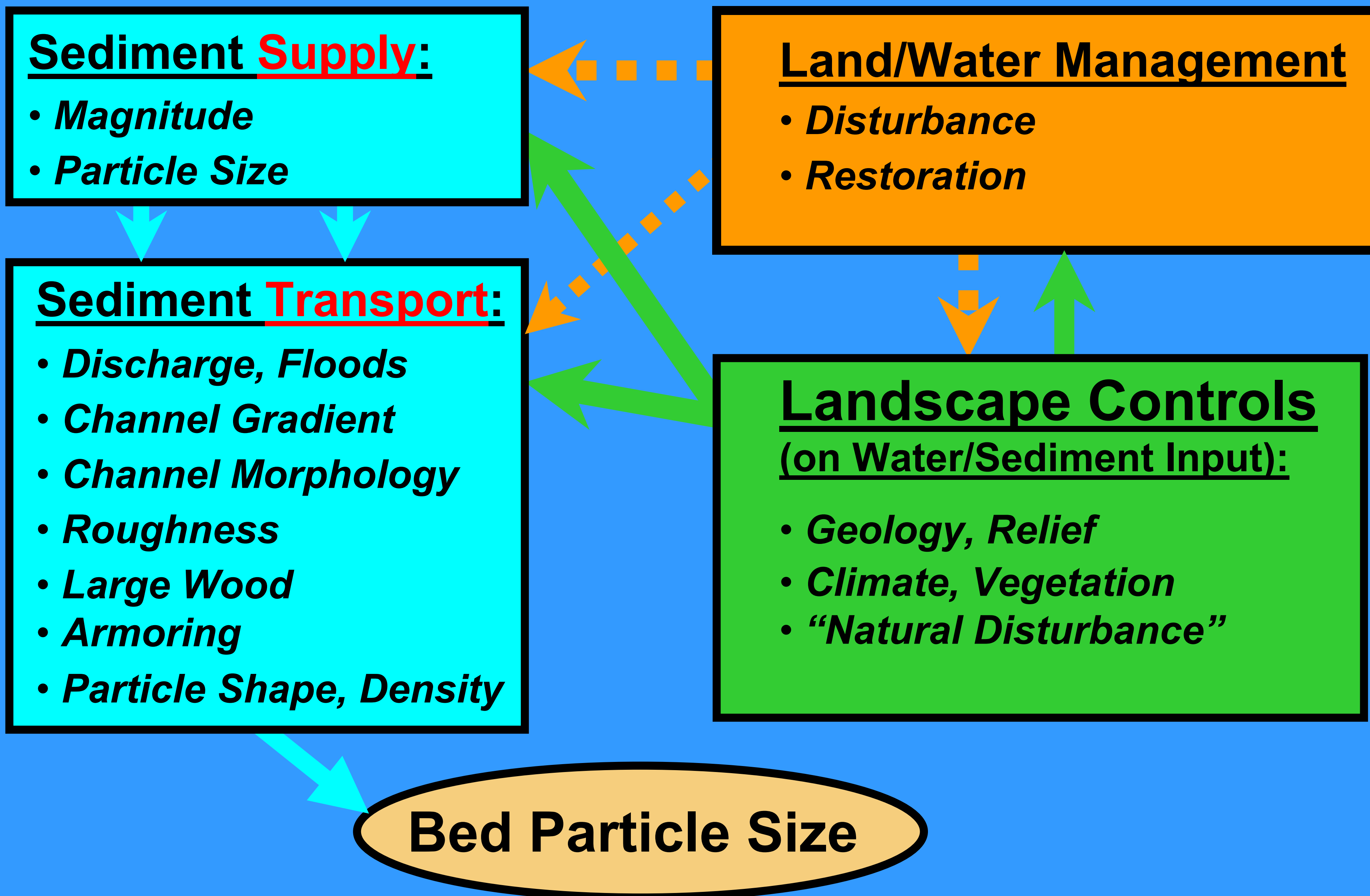


SUMMARY

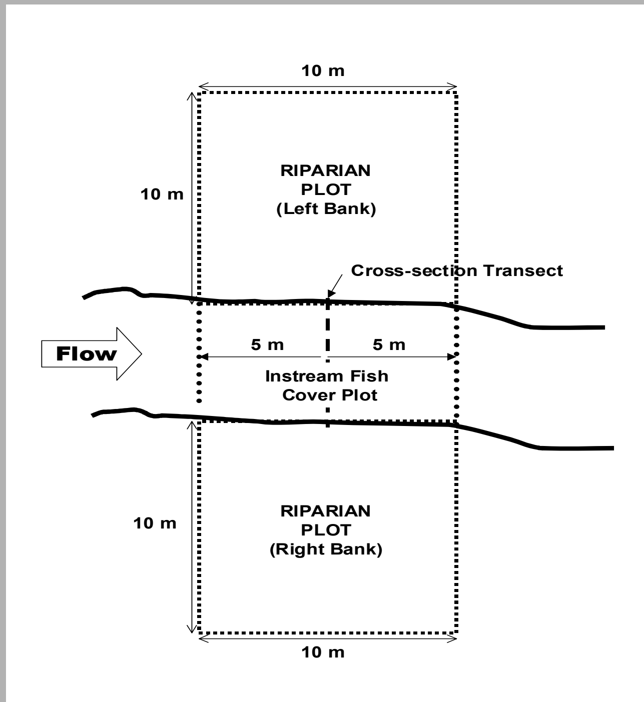
- Watershed erodibility and human disturbances influence sediment supply.
- Stream size, stream slope, and channel form control bed sediment transport.
- RBS is biologically relevant, and can be used to set expectations for mean substrate size and %fines in stream beds.
- RBS can reveal “excess” sedimentation of in streams disturbed by human activities.
- RBS approach is practical for ambient monitoring programs.

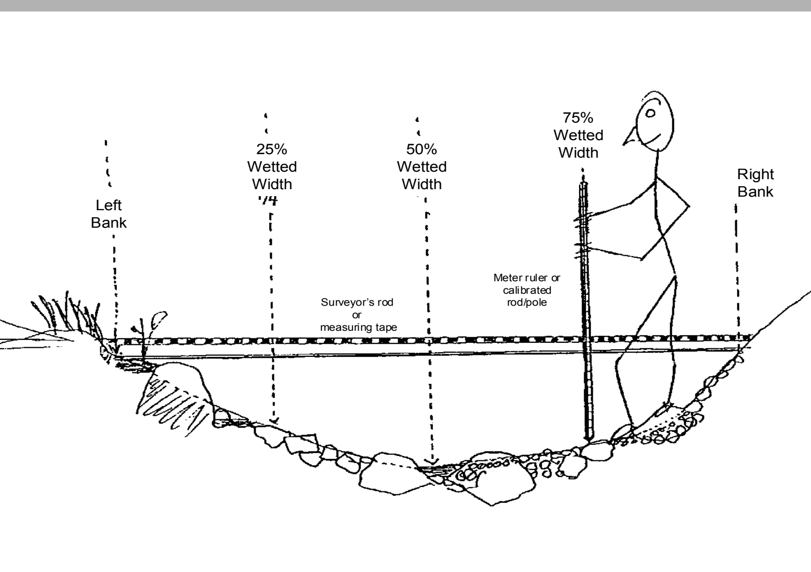
END of Talk -- Extra Slides

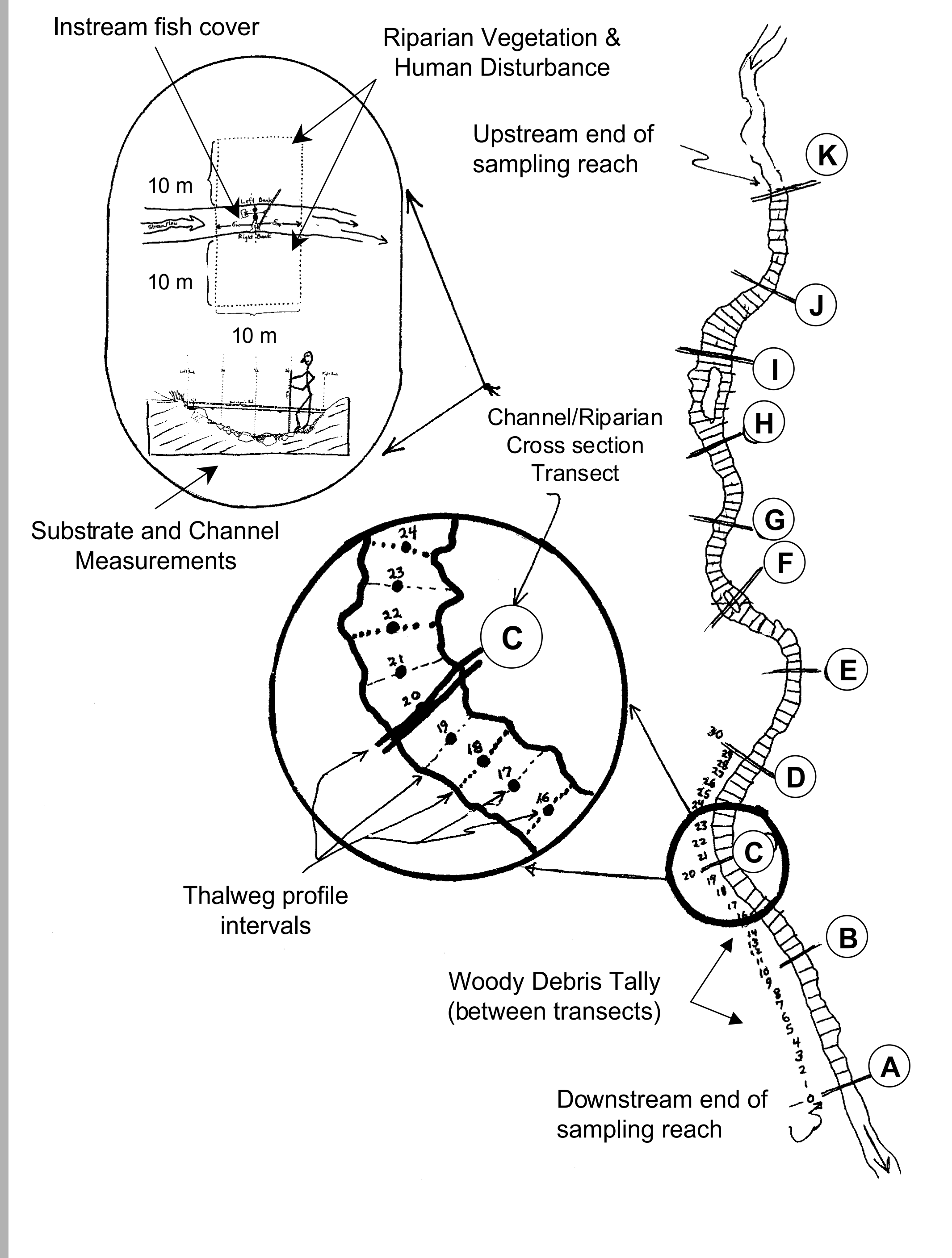
Controls on Bed Particle Size



Plot Design: Wadeable Stream Physical Habitat

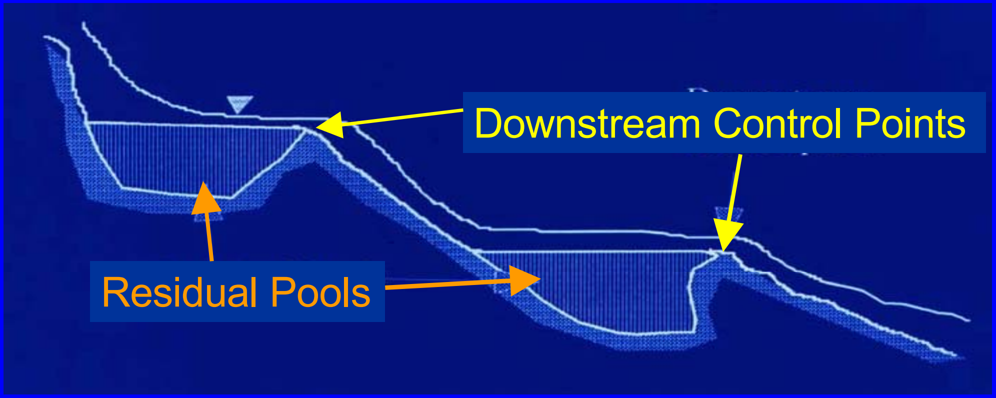






Woody debris and channel bed irregularities reduce effective shear stress ($\rho g R^*_{bf} S$) available to move bed substrate

Quantifying Pools Using Residual Pool Concept



- Residual Pools delineated on thalweg depth profile --- over reach length 40 X Ch-Width.
- Mean Residual Depth spread over reach length

$R^*_{bf} \simeq R_{bf} - R_p - R_w$ ----------- Where:

$R_{bf} \simeq$ 0.5 x Bankfull Depth

$R_p \simeq$ Mean Residual Depth = 0.5 x Mean Thalweg Resid.Depth)

$R_w \simeq$ Mean Wood Depth = (Wood Volume)/(Channel Area)

Correlation of Bed Substrate with Basin + Riparian Disturbance

(Pearson r)

	n	RBS	Dgm	D*cbf
Whole Region	104	-.53****	-.47****	-.03
Sedimentary	74	-.53****	-.48****	.00
Volcanic	30	-.39*	-.24	+.14

*	= p<0.1
****	= p<0.0001