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science for a changing world

Geology, network topology, and spatial scaling of trout distribution in headwater catchments

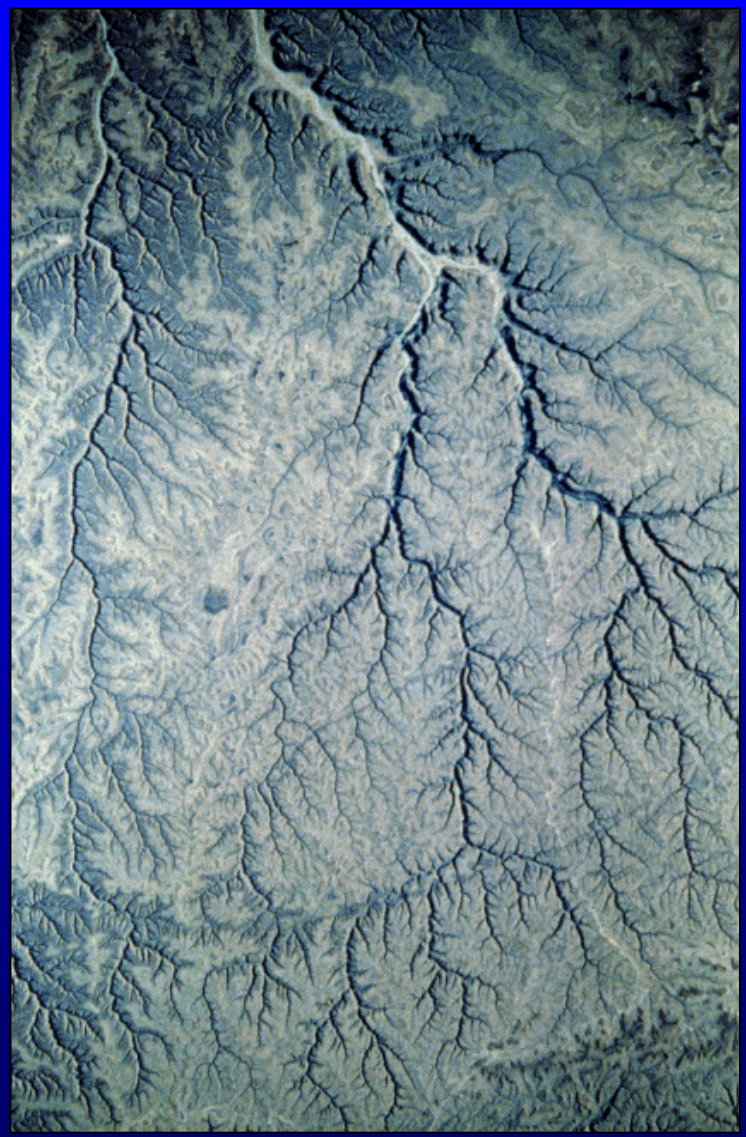
Christian E. Torgersen

USGS Forest and Rangeland Ecosystem Science Center, Cascadia Field Station

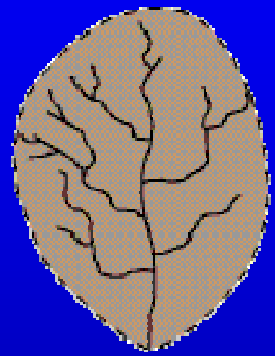
College of Forest Resources, University of Washington, Seattle

U.S. Department of the Interior
U.S. Geological Survey

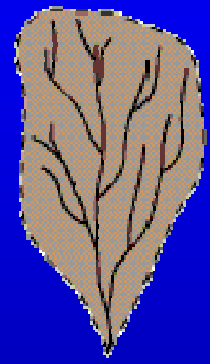
Networks in river systems



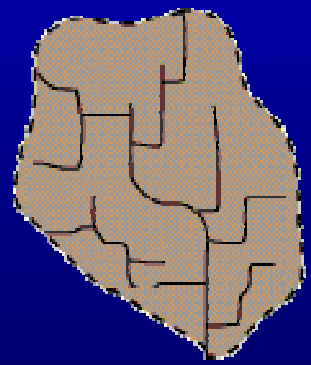
Drainage patterns



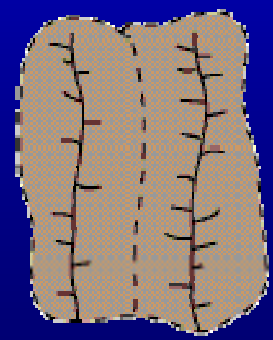
dendritic



parallel

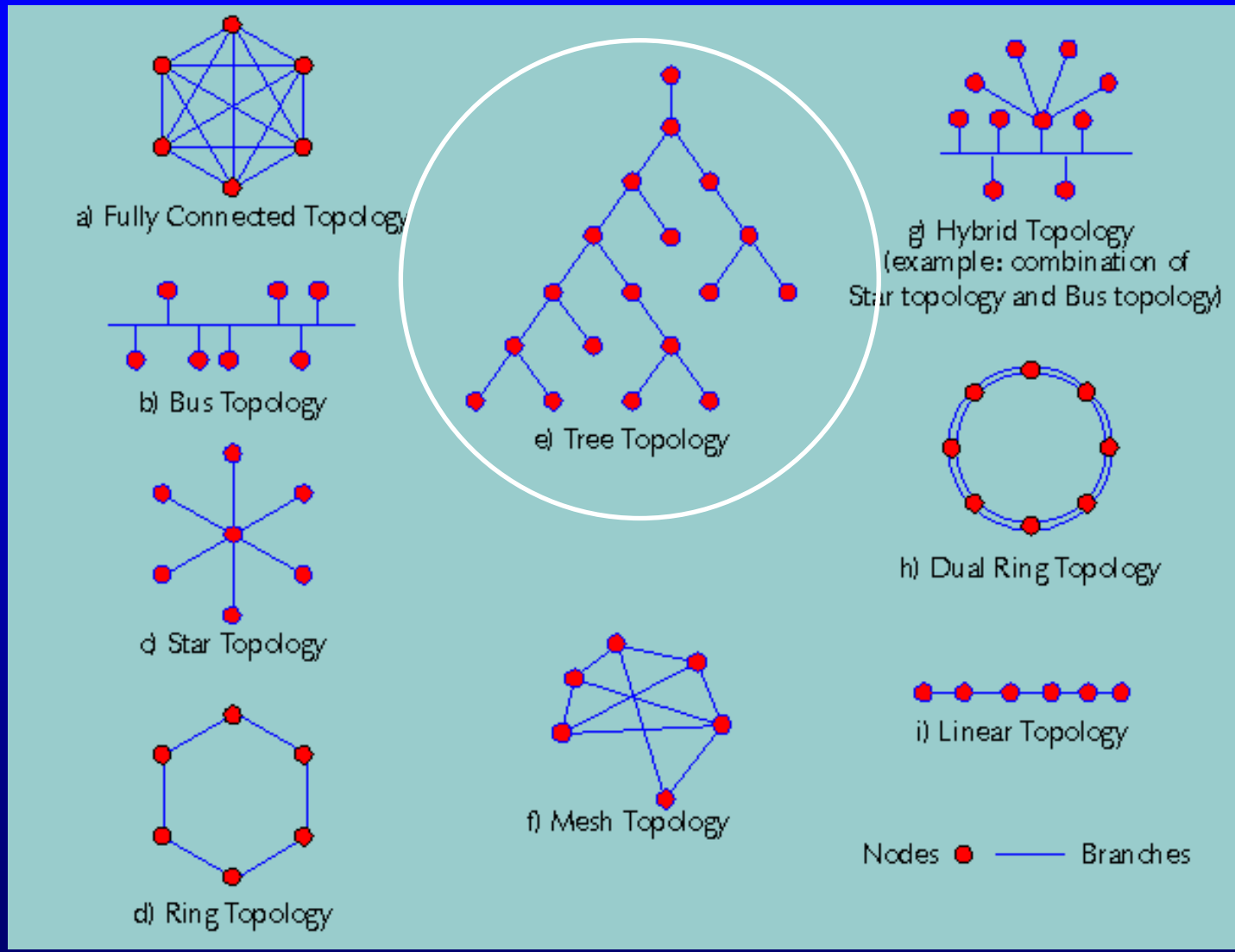


rectangular

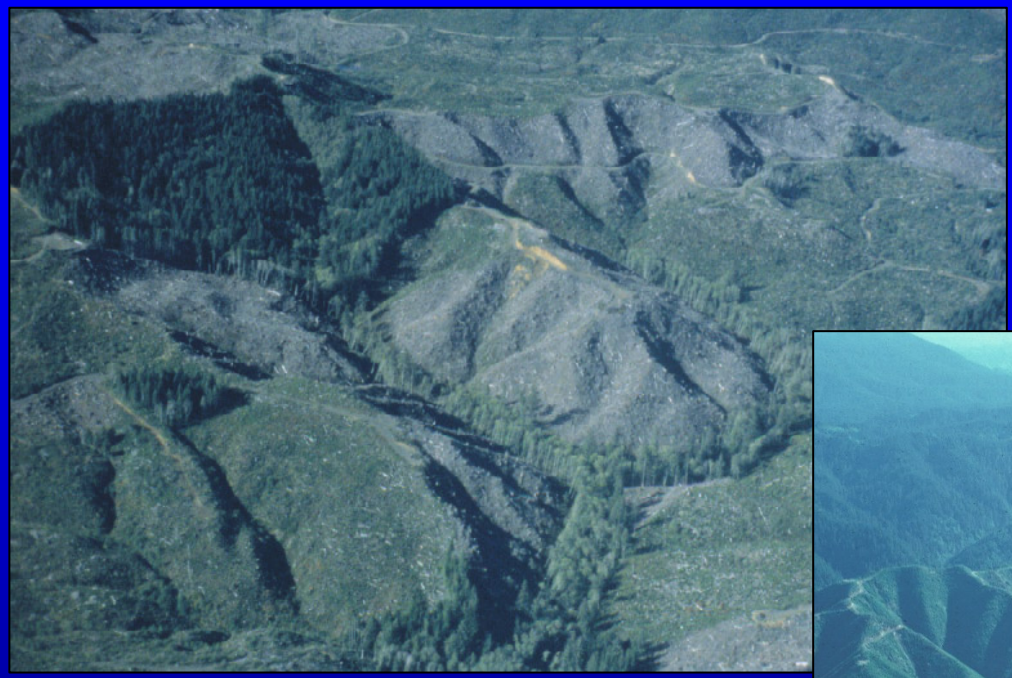


trellis

Network topology



Corridors and pathways



Riparian buffers

Landscape pattern

Topography


WASHINGTON
IDA
CALIFORNIA
NEVADA

Project Background

CFER Project: Influence of Landscape Pattern and Composition on Species in Forested Ecosystems of Western Oregon

Bob Gresswell, Doug Bateman, and David Hockman-Wert

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

CFER Cooperative Forest Ecosystem Research

OREGON DEPARTMENT OF FORESTRY

USGS science for a changing world

OREGON STATE UNIVERSITY

Oncorhynchus clarki clarki
Coastal Cutthroat Trout

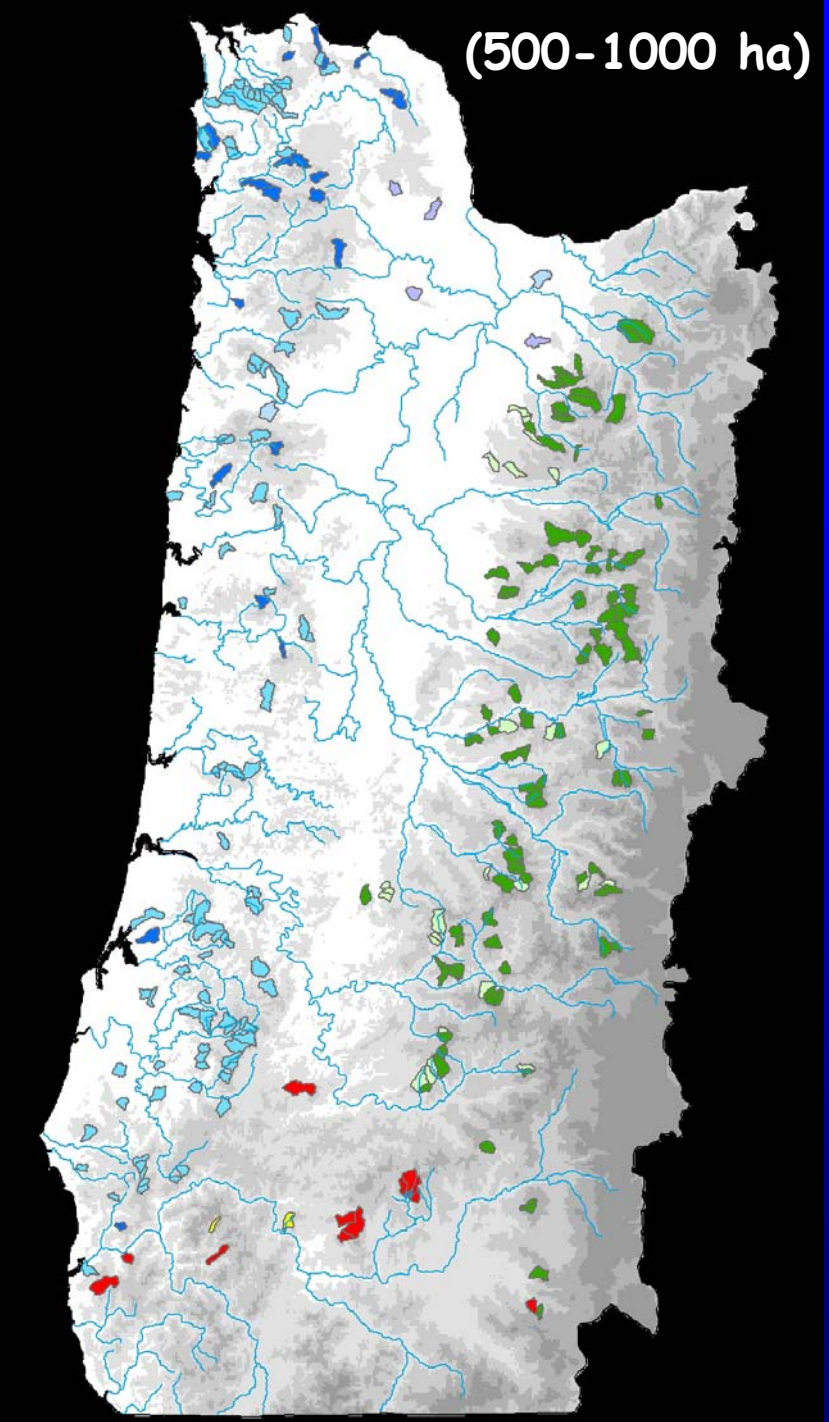






Objectives

- Make the analysis of spatial networks more accessible to ecologists and hydrologists.
- Provide geostatistical tools for calculating a network variogram.
- Demonstrate the utility of the method for understanding spatial structure in fish distribution.

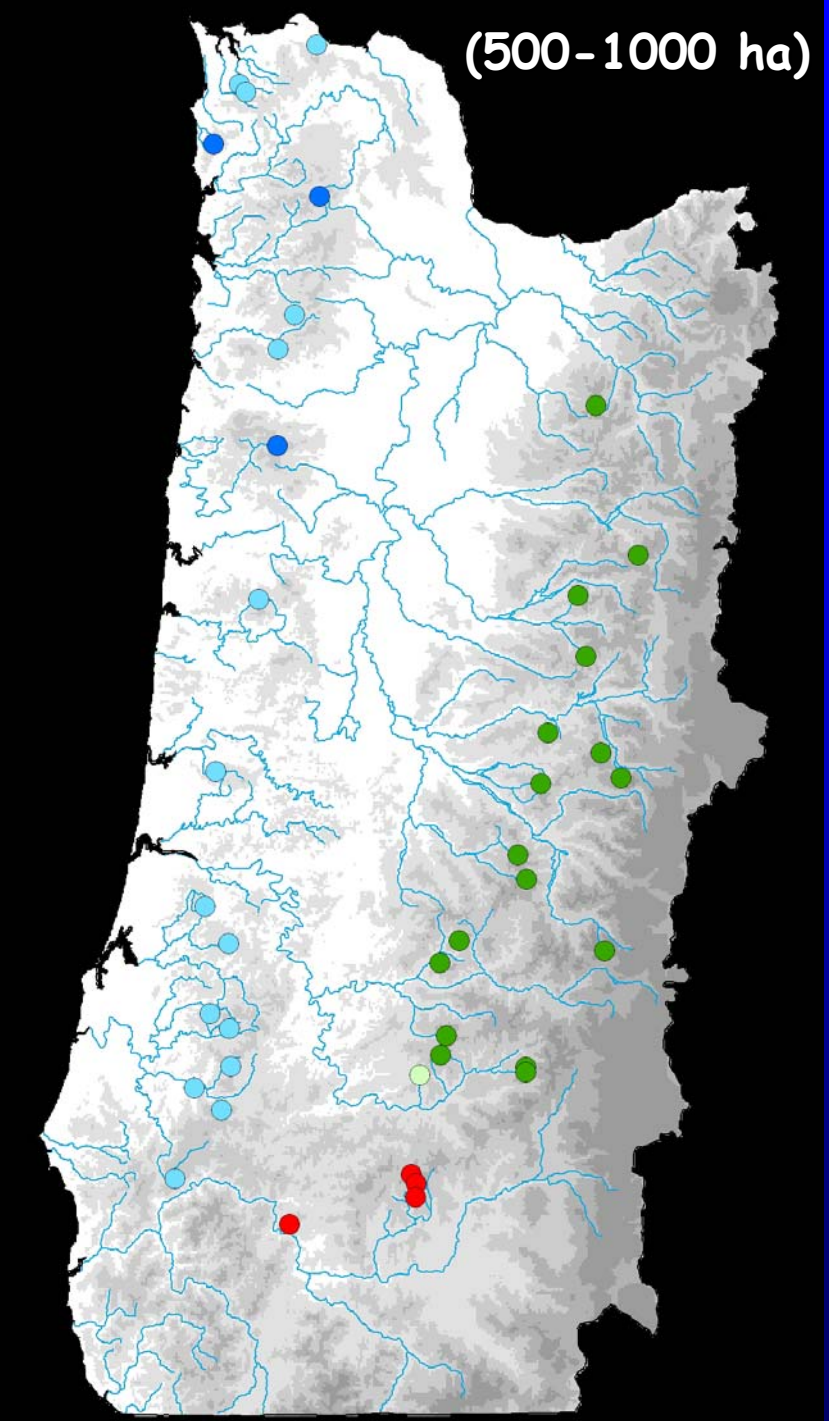


Site selection

Isolated headwater populations of coastal cutthroat trout (*N* = 269)

Ecoregion	Rock type: Hard	Rock type: Soft
Coast Range	●	●
Cascades	●	●
Klamath	●	●

(Gresswell et al. 2004. GIS/Spatial Analyses in Fishery and Aquatic Sciences)



Site selection

Randomly selected populations (n = 40)

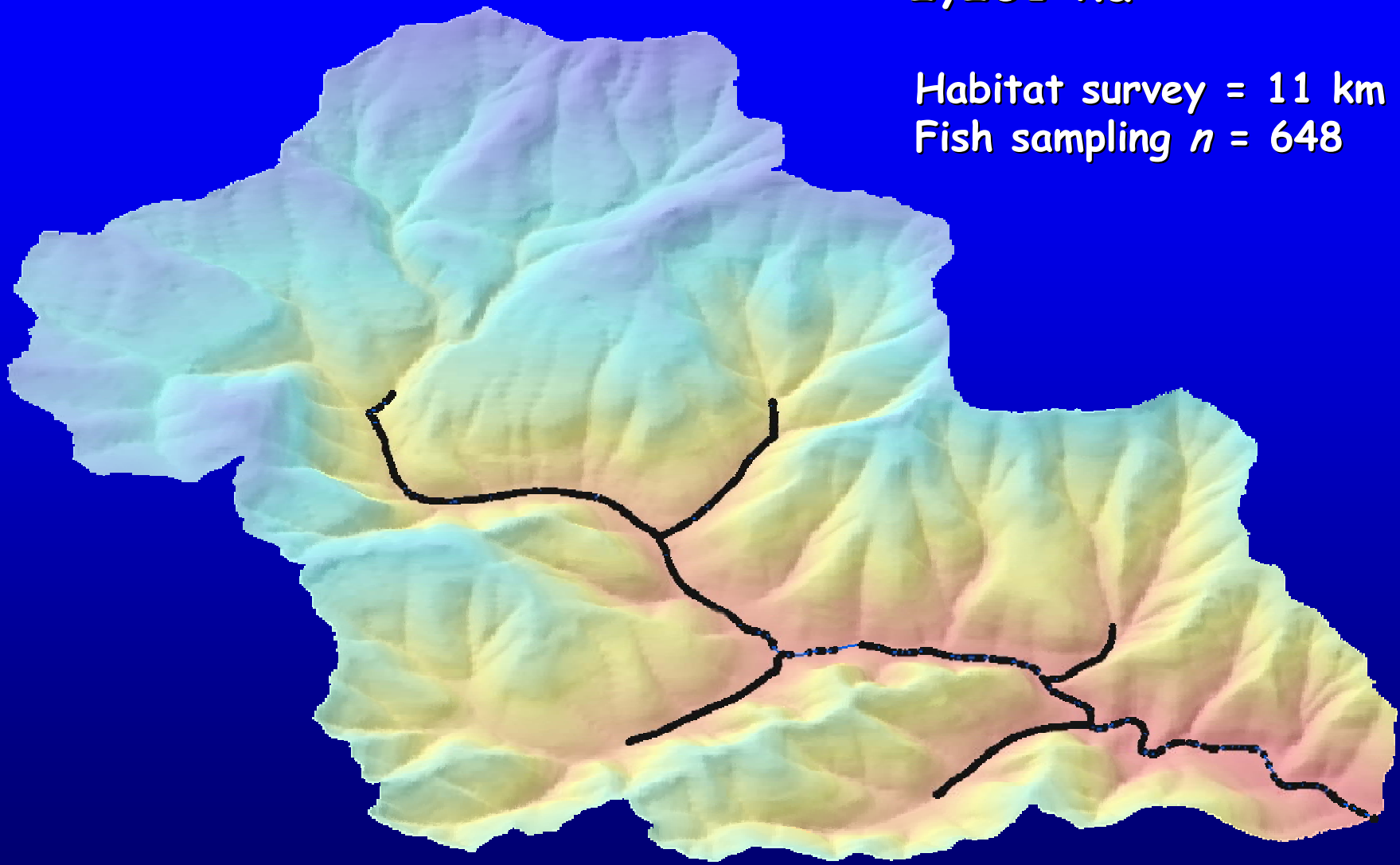
Ecoregion	Rock type: Hard	Rock type: Soft
Coast Range	●	●
Cascades	●	●
Klamath	●	●

(Gresswell et al. 2004. GIS/Spatial Analyses in Fishery and Aquatic Sciences)

Landscape pattern

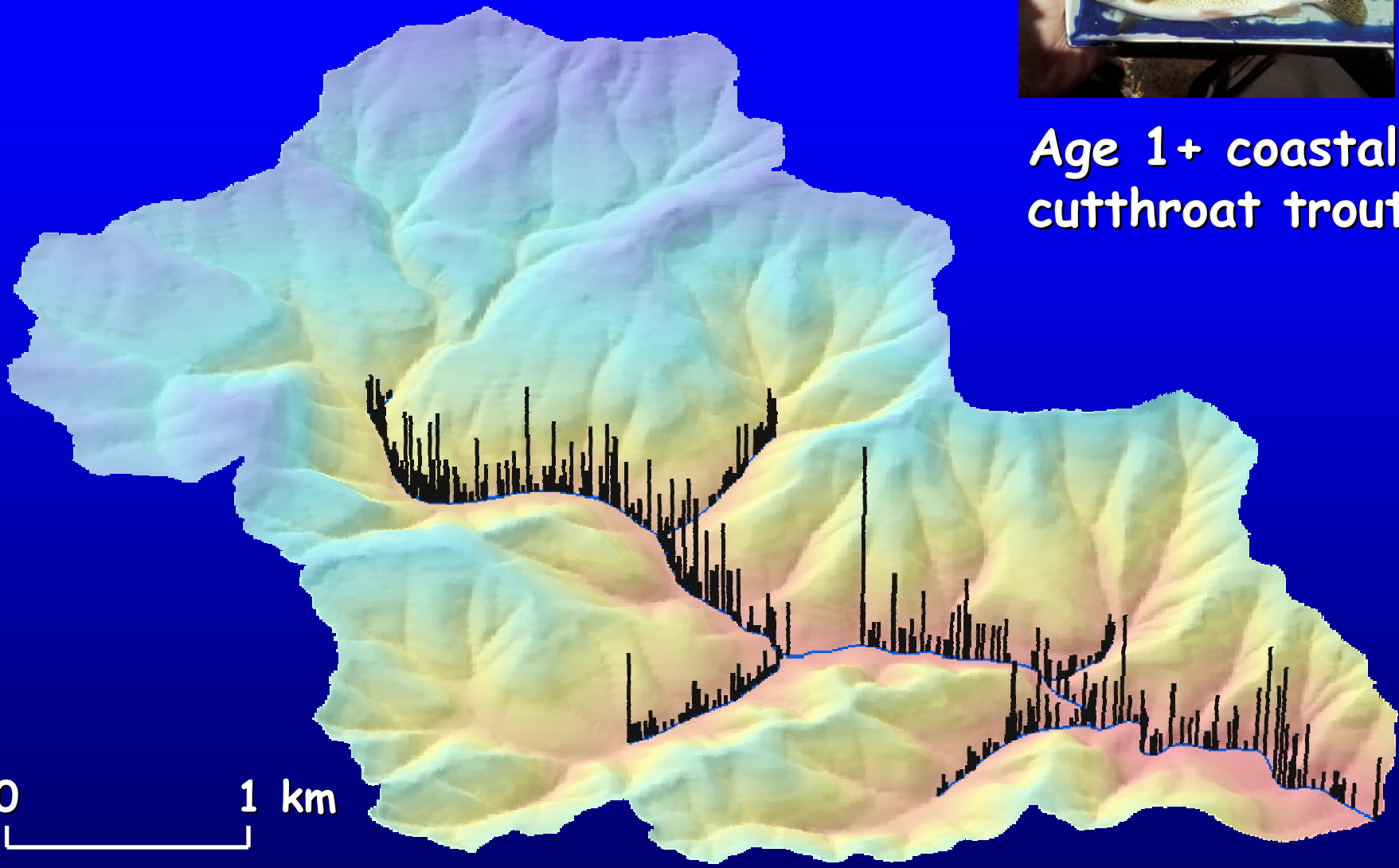
Third-order basin
2,201 ha

Habitat survey = 11 km
Fish sampling *n* = 648



Fish distribution

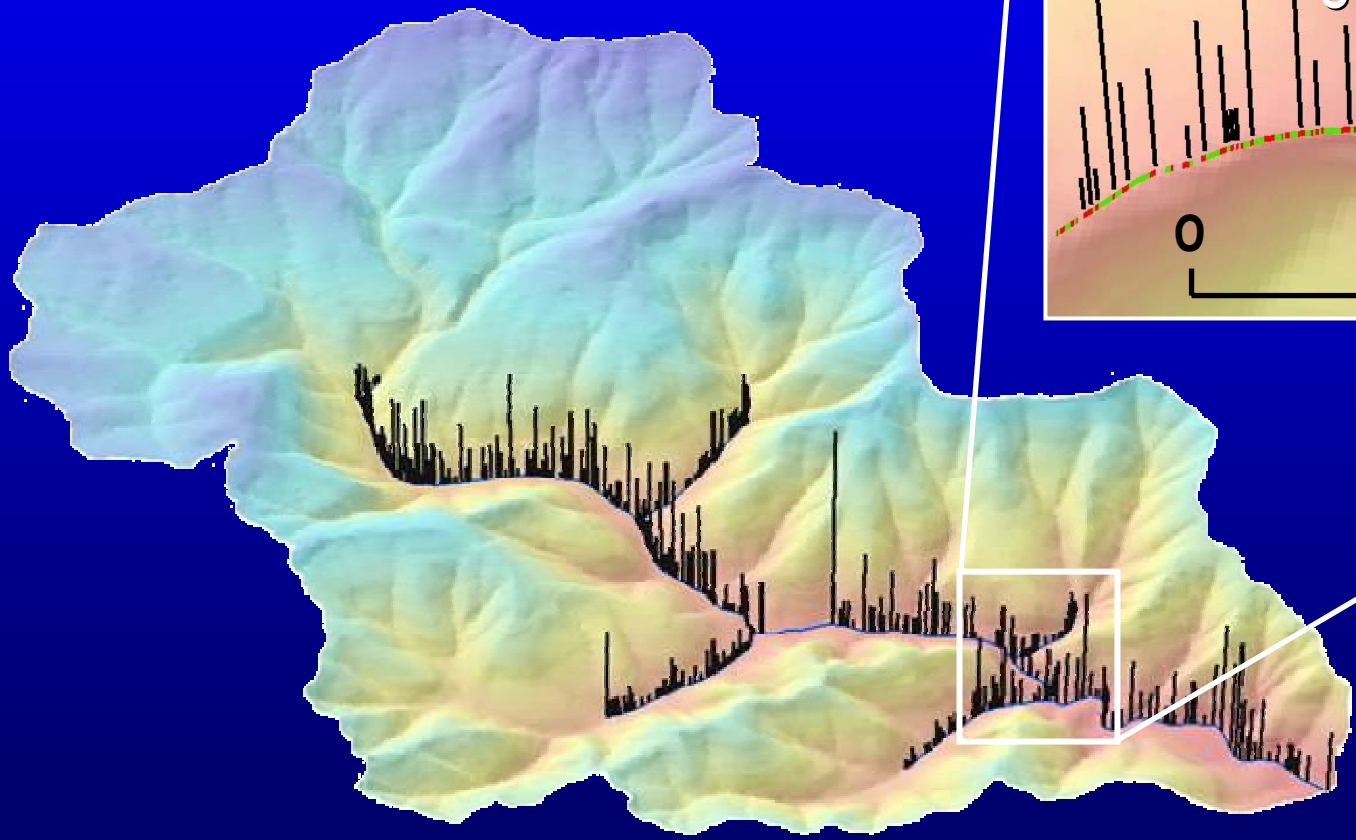
Age 1+ coastal cutthroat trout

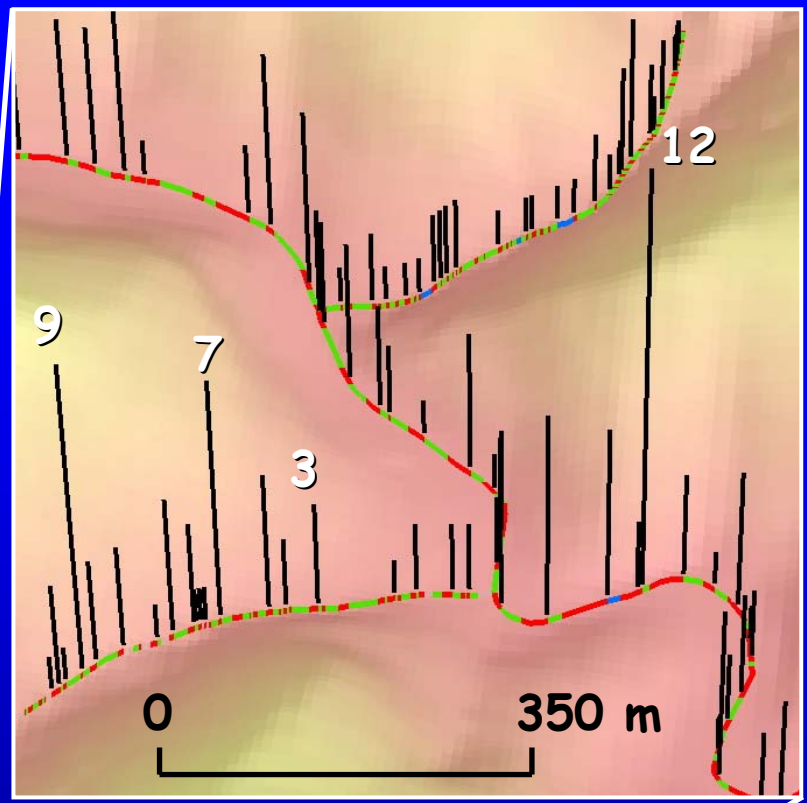


(Gresswell, Torgersen, and Bateman, In press, *Influence of landscape on stream habitats and biological assemblages*)

Fine- and coarse-scale patterns

Pool
Riffle/rapid
Cascade



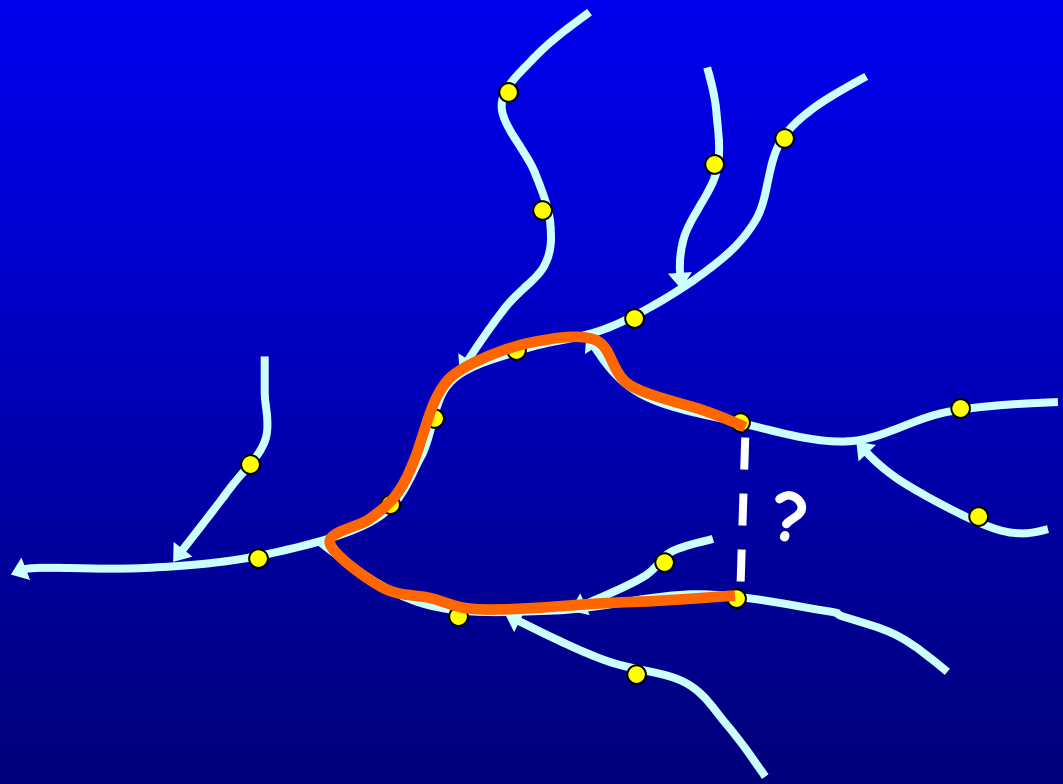


(Torgersen et al. 2004, *GIS in Fisheries and Aquatic Sciences*)

Quantifying spatial pattern

What is spatial dependence, autocorrelation?

- Euclidean vs. network distance
- Geographical Information System (GIS)



(Ganio, Torgersen, and Gresswell 2005, *Frontiers in Ecology and the Environment*)

Modeling spatial dependence with the semivariogram

$$\gamma(d) = \frac{1}{2W}\sum_{h=1}^{n}\sum_{i=1}^{n} w_{hi}(y_h - y_i)^2$$

for $h \neq i$, where h and i are points along a line

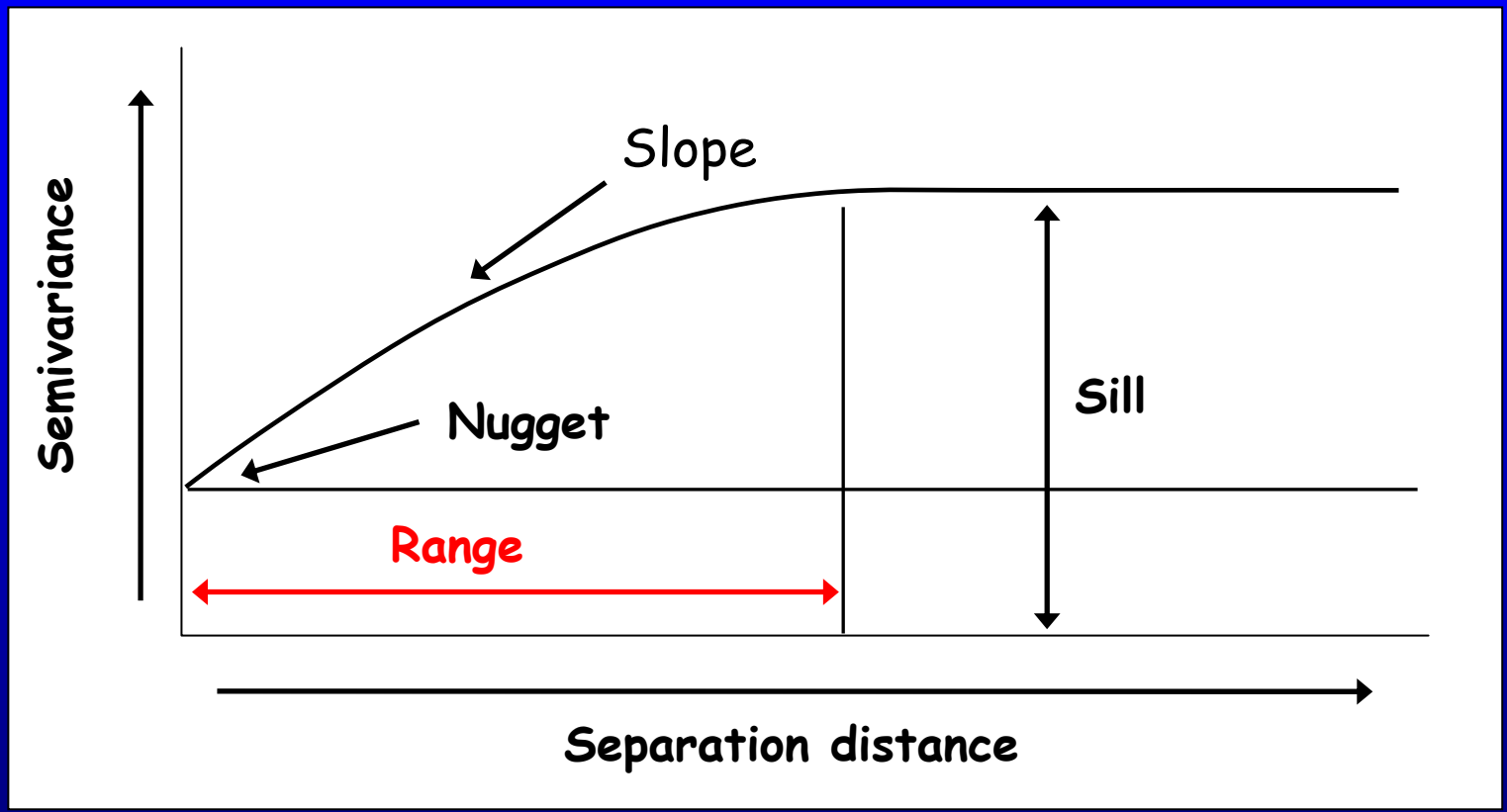
Legendre and Legendre (1983)

Yikes!

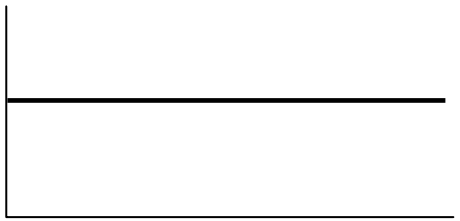
But it's only…

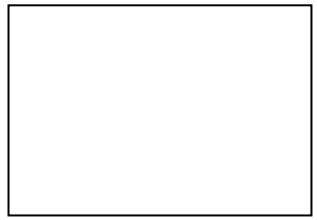
"half the average squared difference between pairs of points separated by a given distance"

Anatomy of the semivariogram

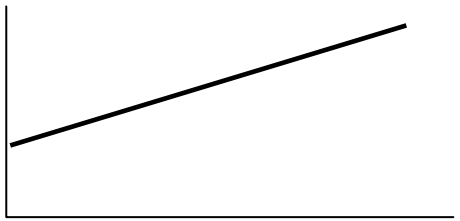


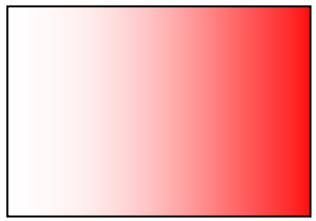
Variograms and spatial patterns



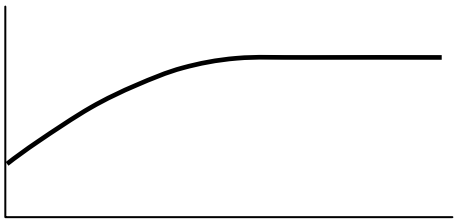


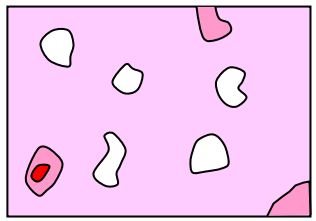
Random, homogeneous



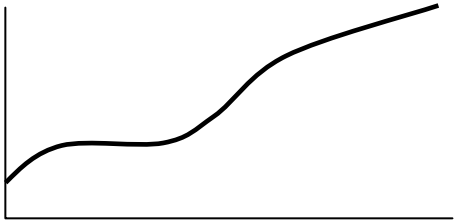


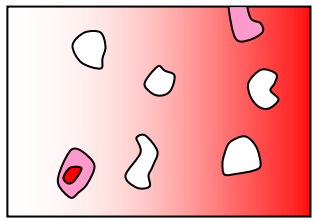
Large-scale, continuous gradient





Small-scale patchiness



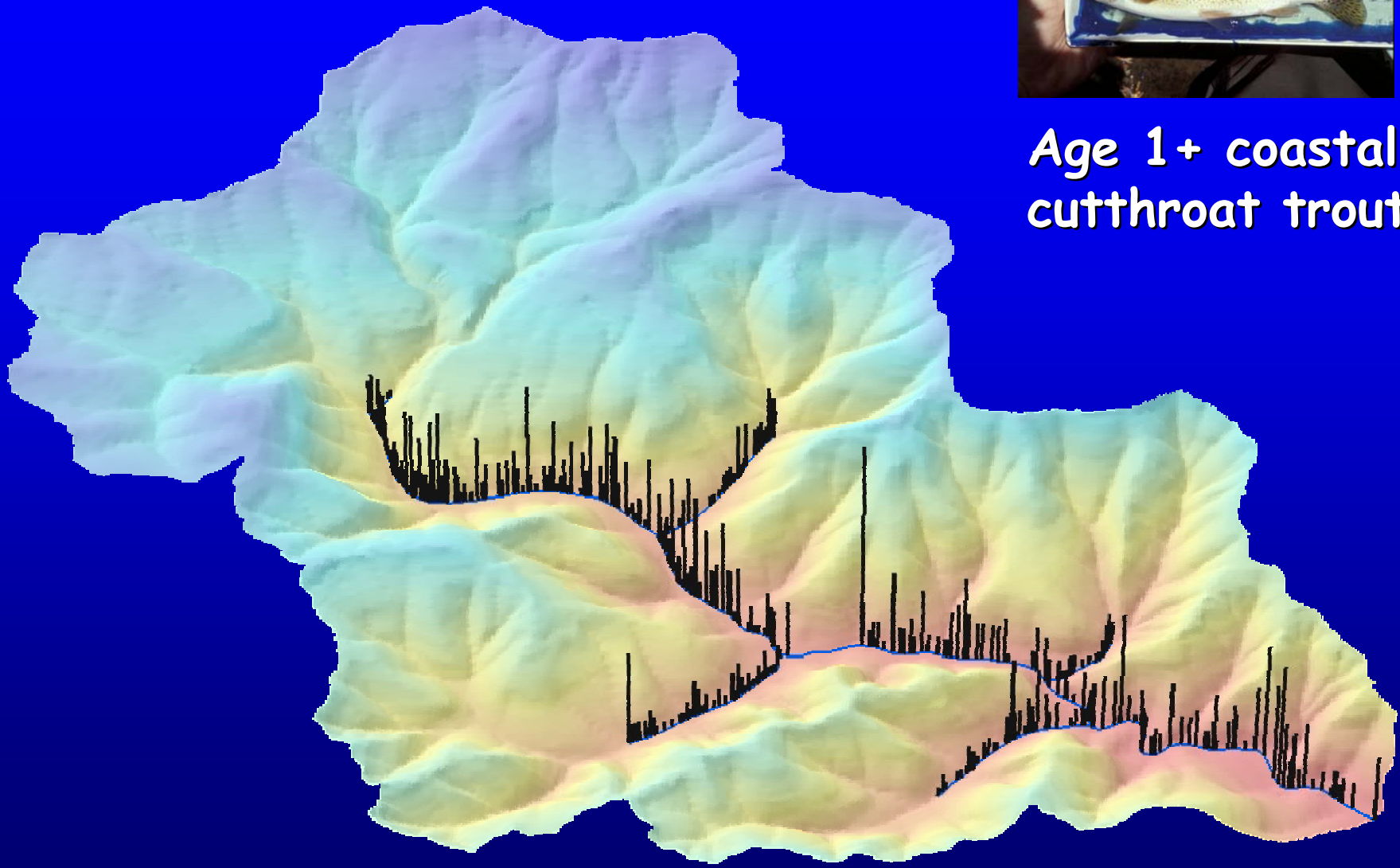


Nested heterogeneity

(Ettema and Wardle 2002)

Back to the *real* data…

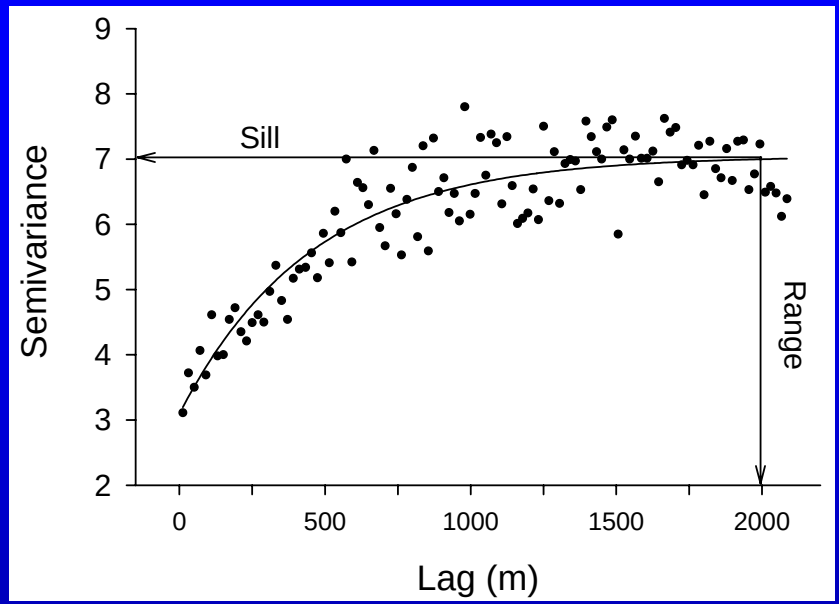
Age 1+ coastal cutthroat trout



Network variogram of fish counts…

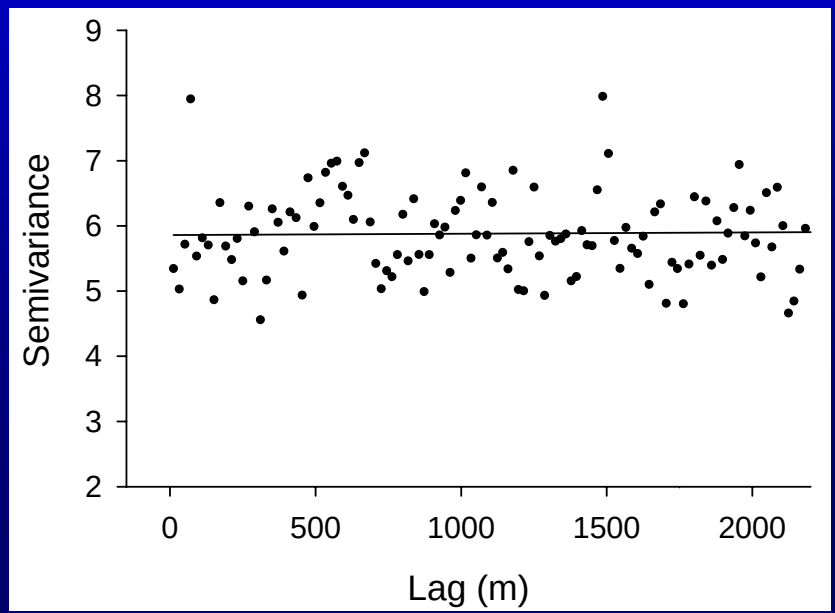
Semivariogram

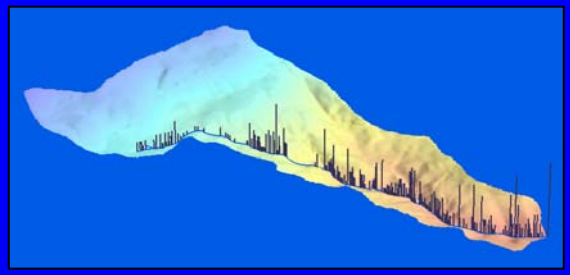
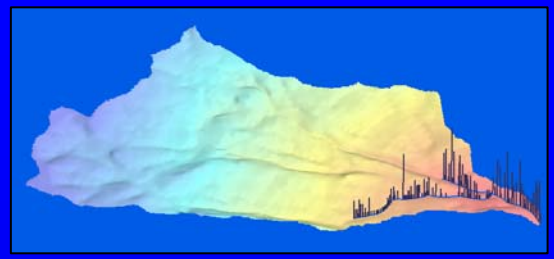
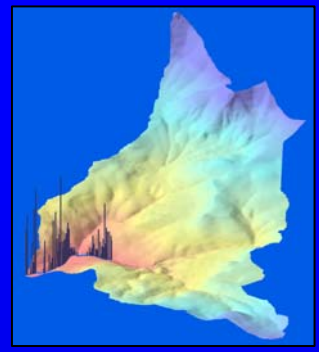
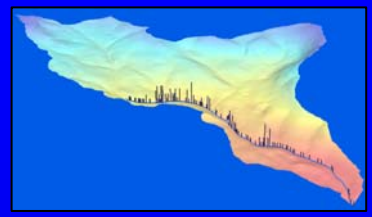
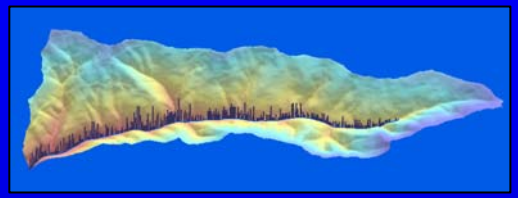
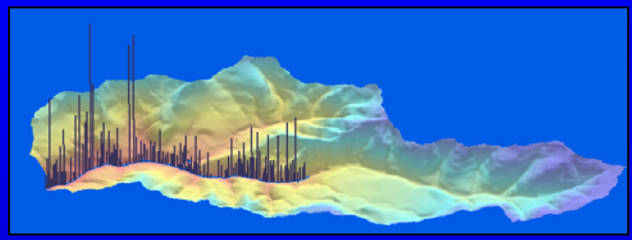
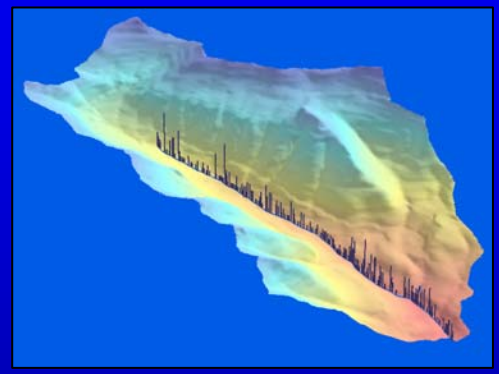
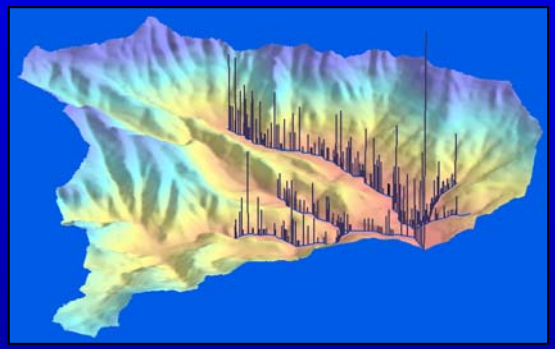
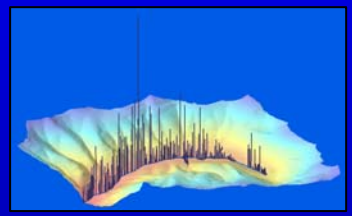
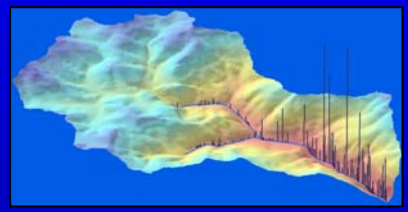
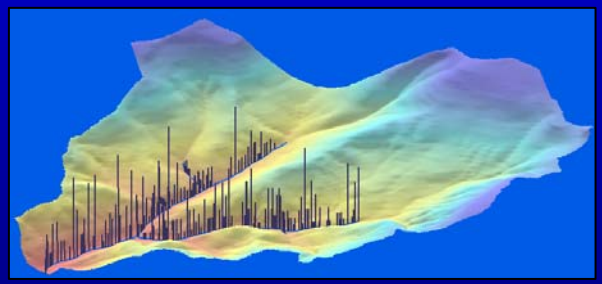
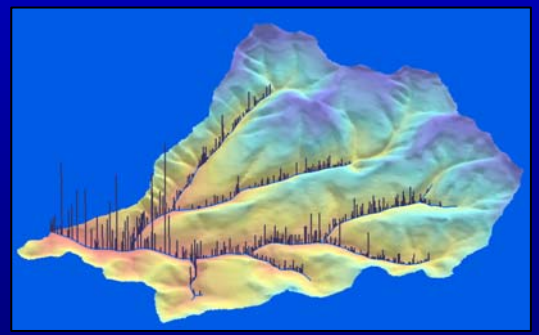
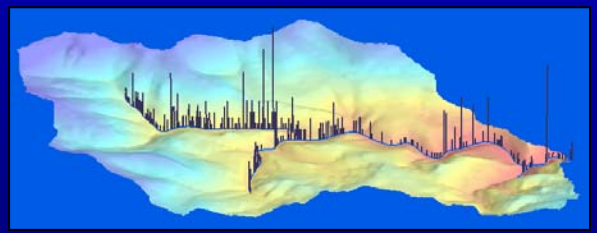
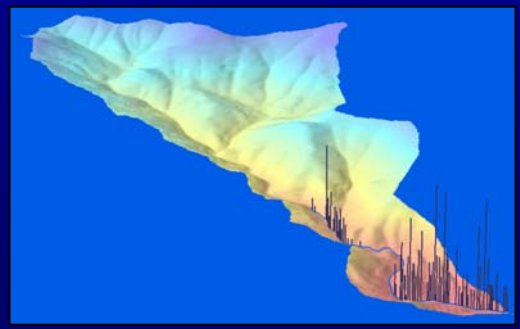
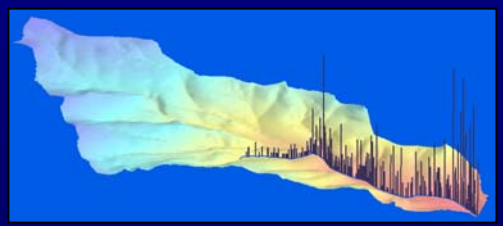
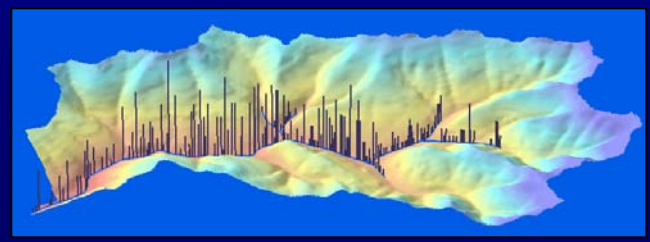
- Fitted spherical model



Randomization

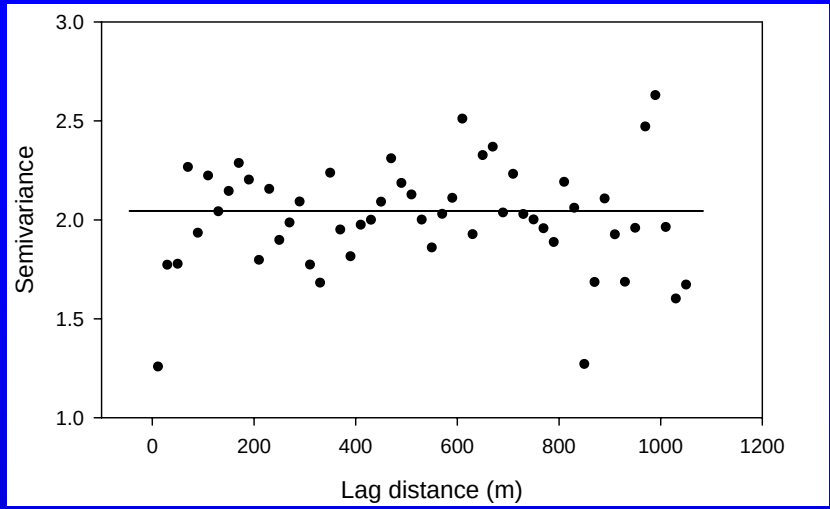
- Test of spatial dependence



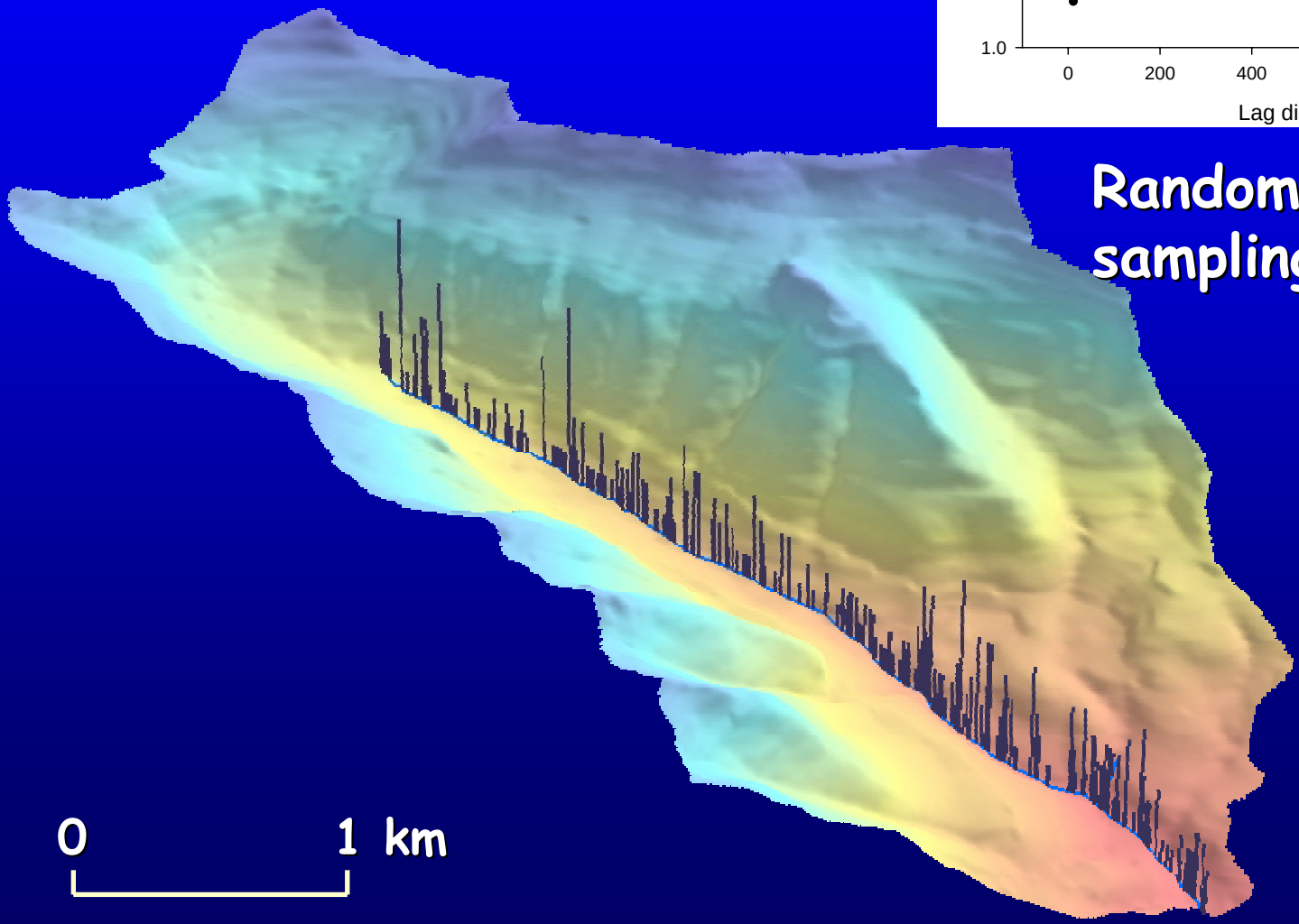

















Hardy Creek

Cascade Range

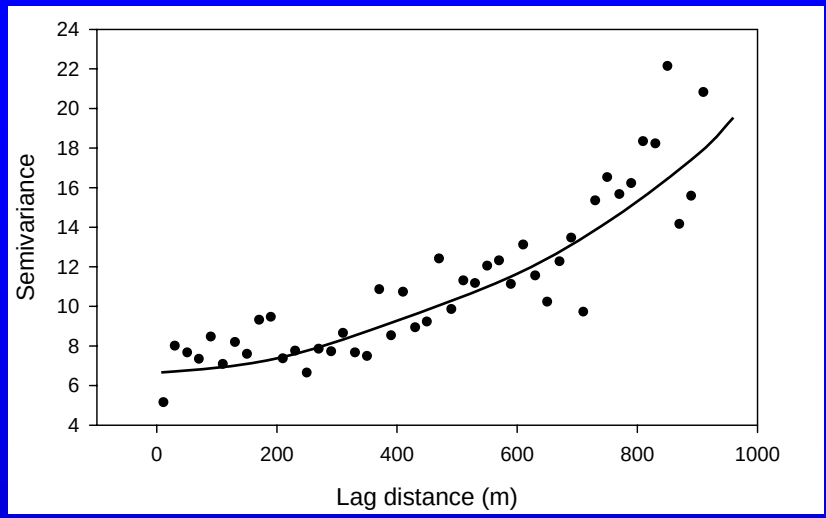


Random, incorrect sampling scale (?)

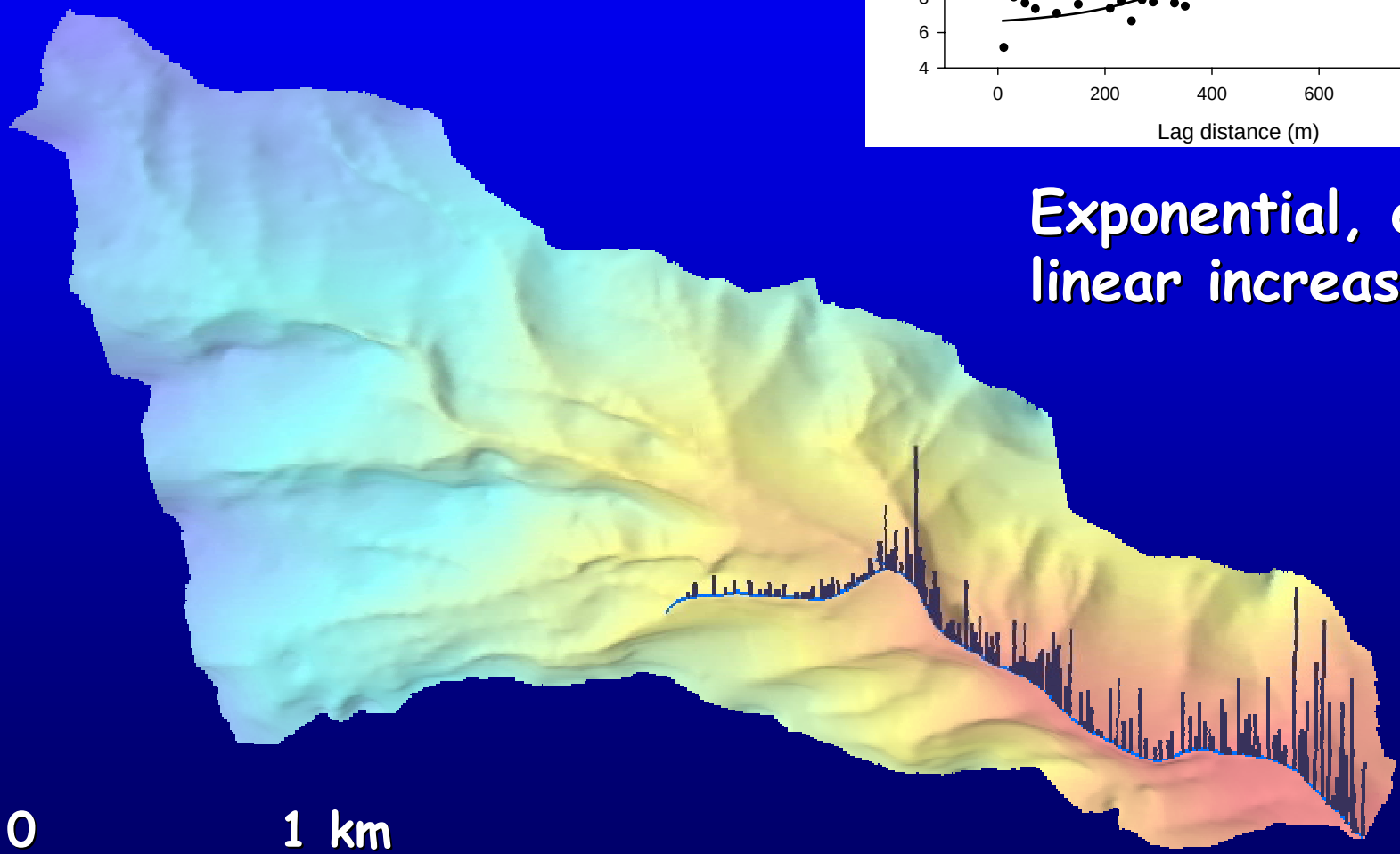


E. Fork Laying Creek

Cascade Range

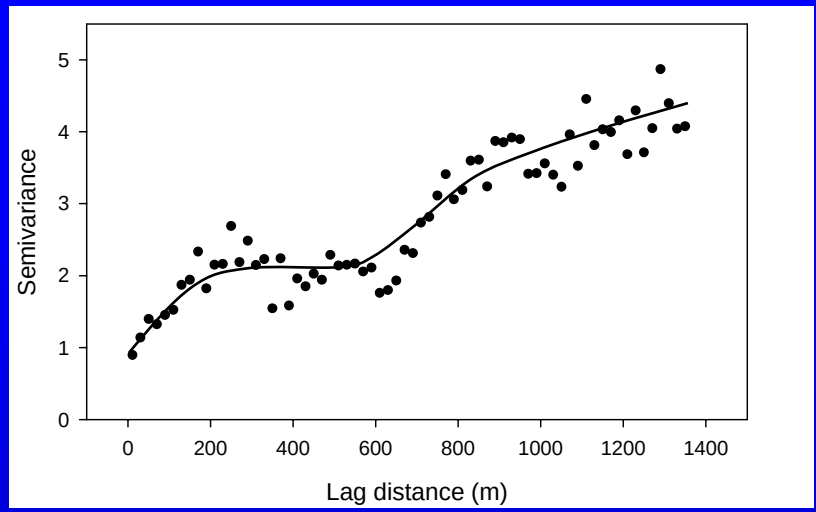


Exponential, or linear increase

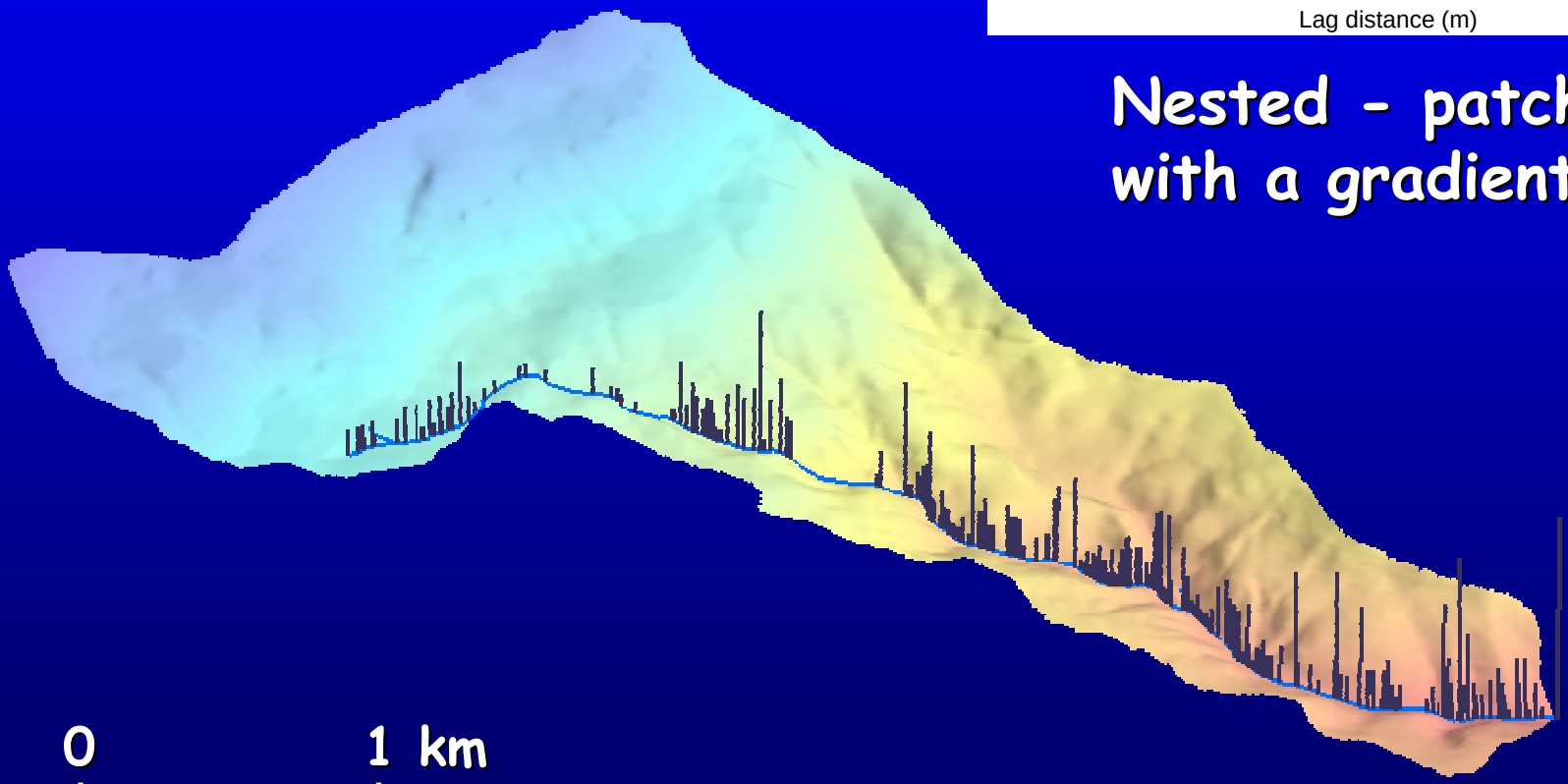


Miller Creek

Cascade Range



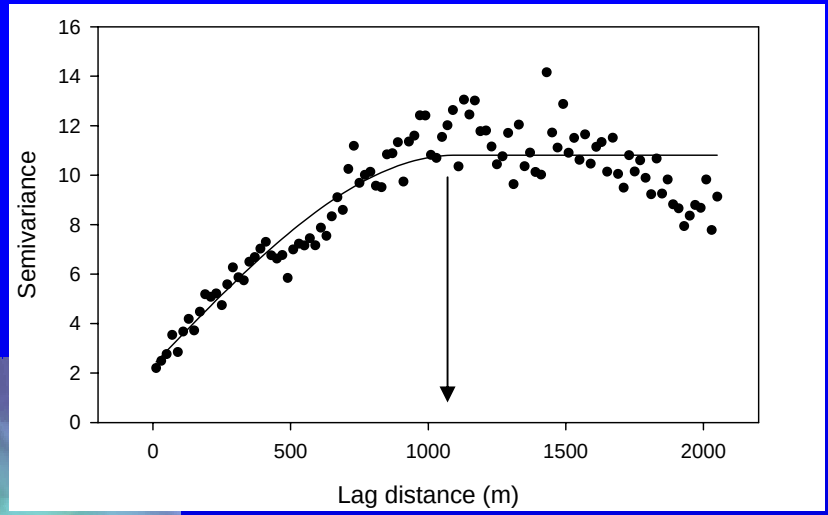
Nested - patchy with a gradient



0 1 km

Glenn Creek

Coast Range

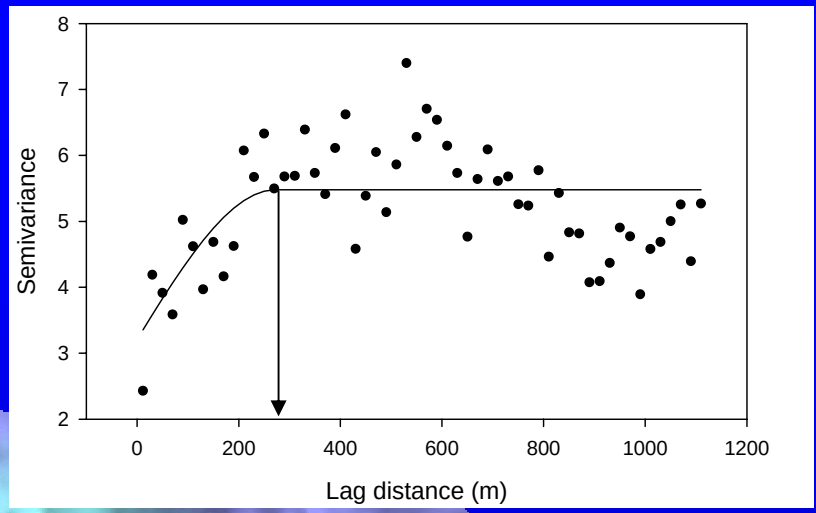


Range = 1099 m

0 1 km

N. Fork Ecola

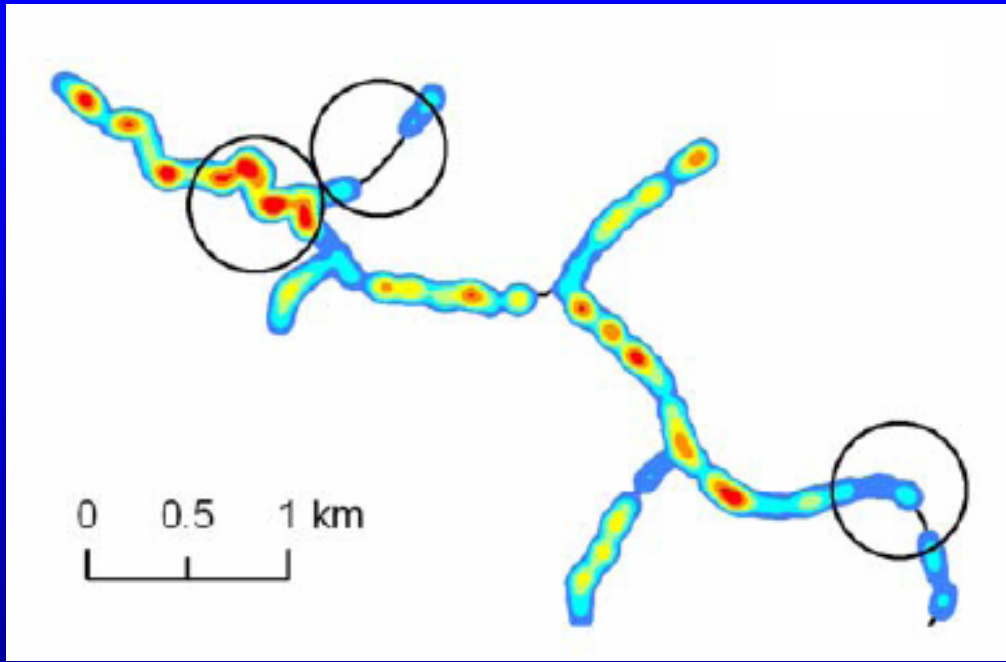
Coast Range



Range = 272 m

0 0.5 km

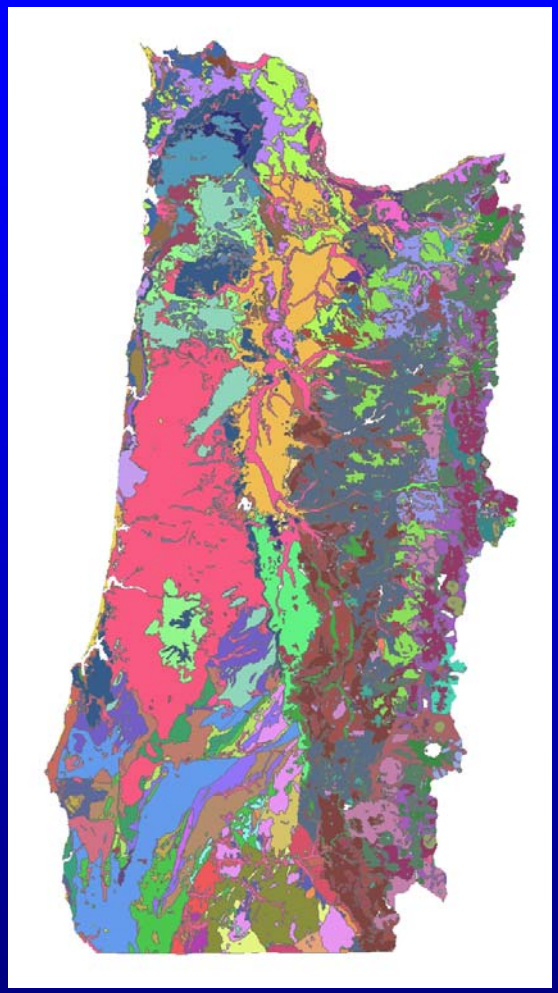
Spatial scale



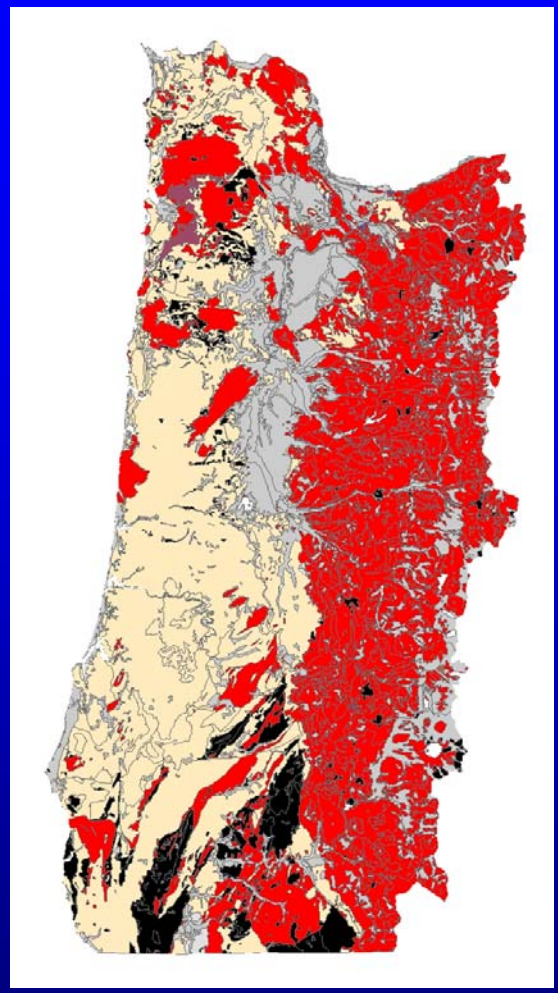
Relative abundance of coastal cutthroat trout

Population dynamics, patch size, sampling/ monitoring, habitat conservation.

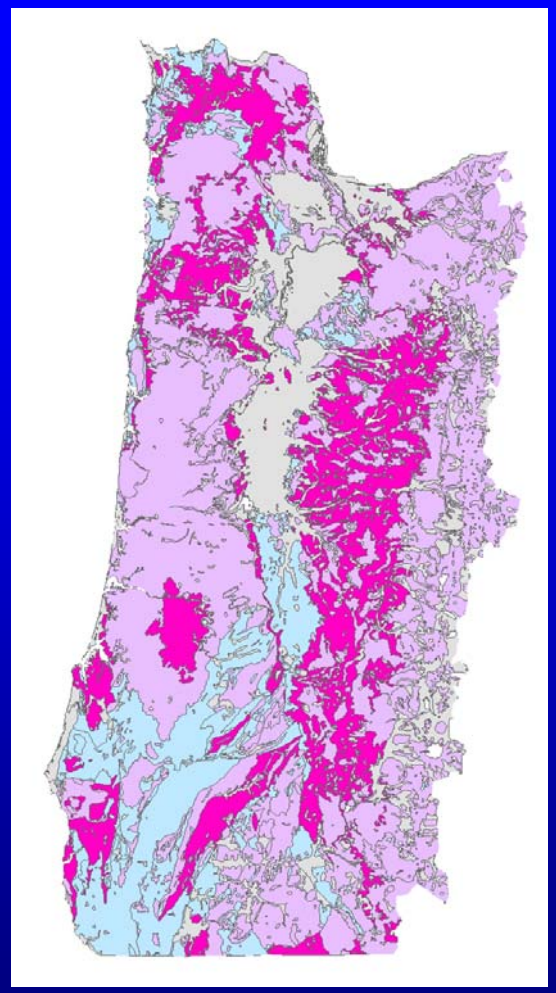
Bedrock geology vs. rock stability



1:500K-scale geologic map (Walker and MacLeod 1991)



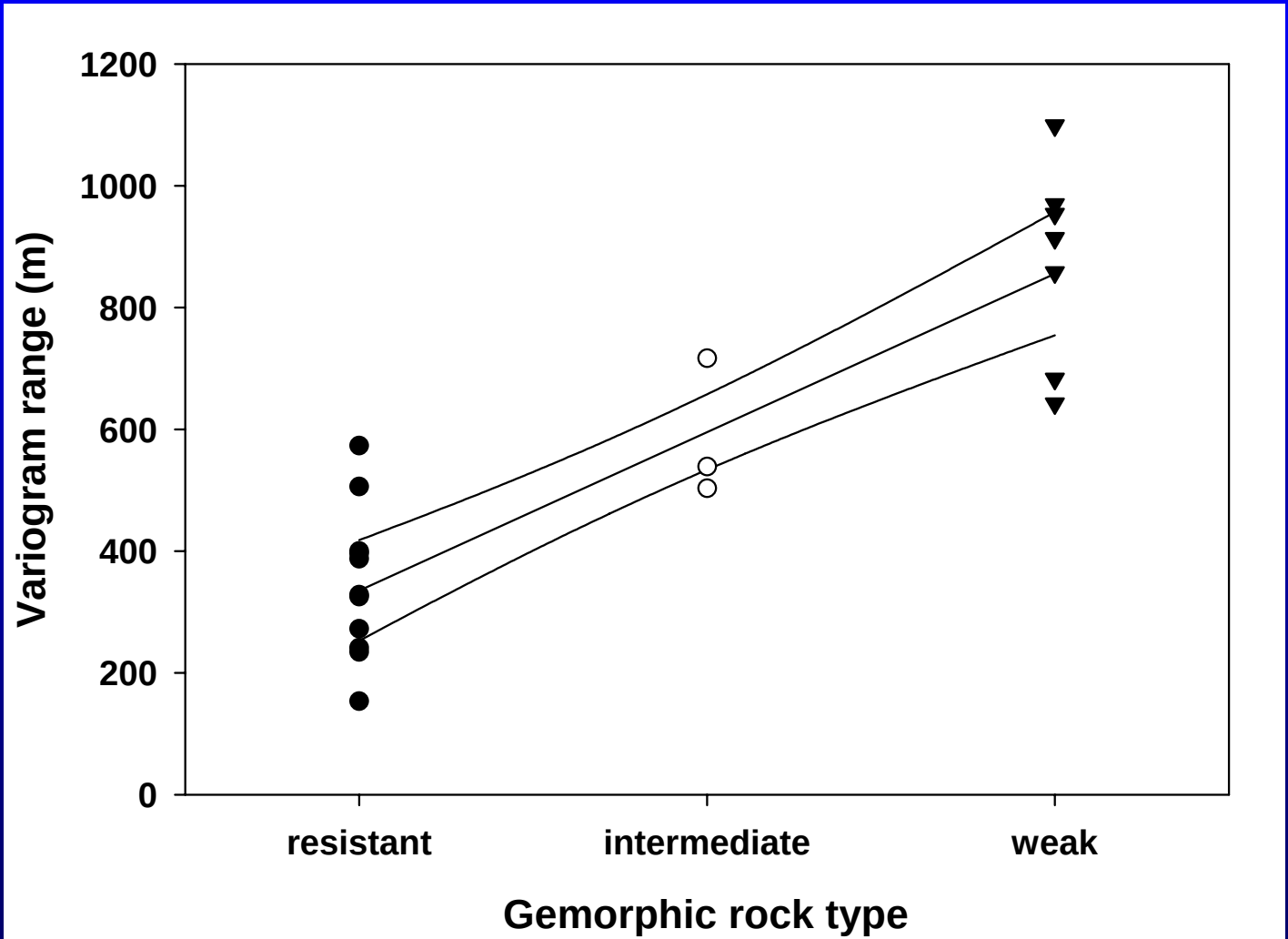
Sedimentary, basalt, intrusive



Weak, intermediate, resistant (Ricks and Swanson, unpublished data)

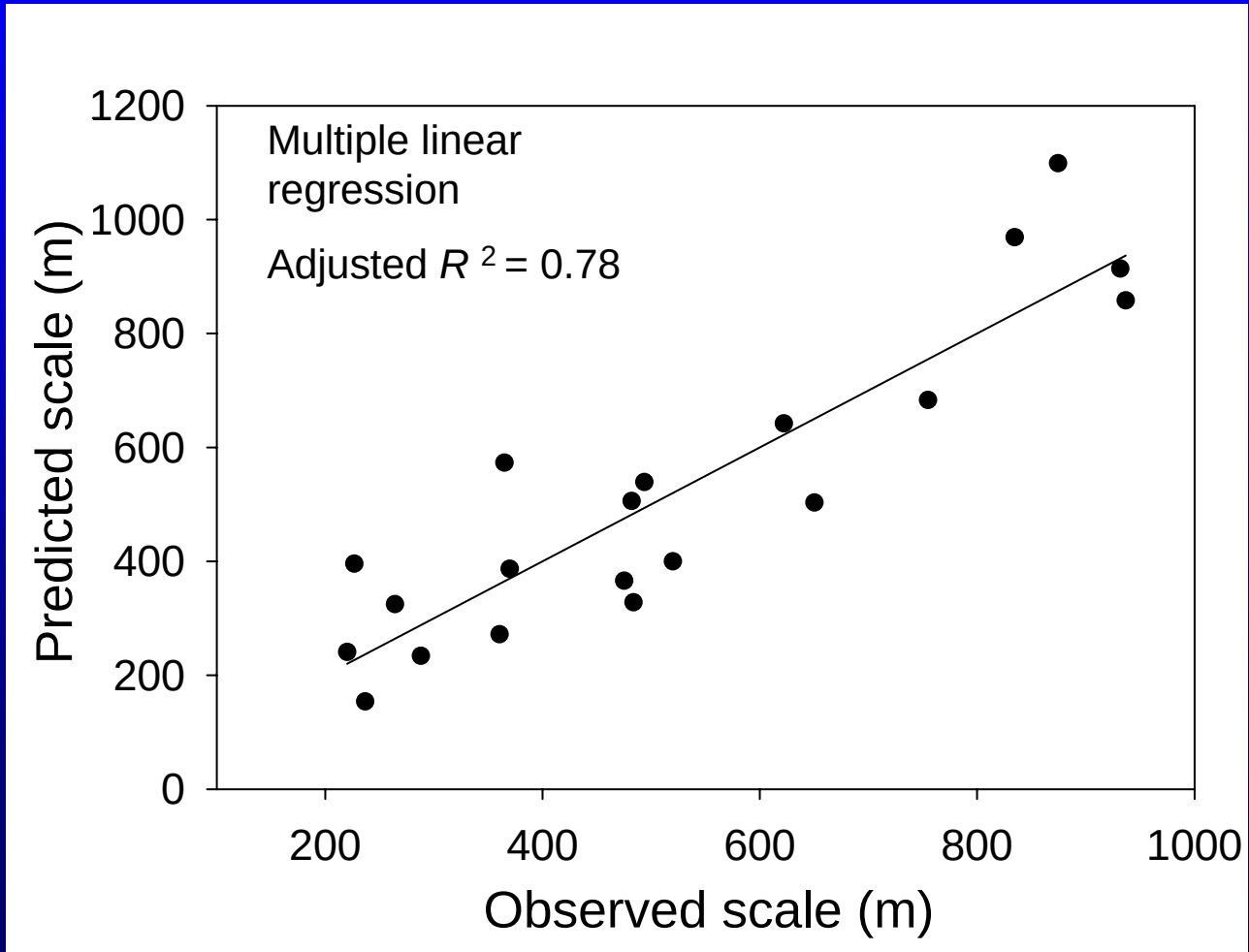
Spatial variability in fish distribution and landscape characteristics

Range is often inter-preted as the average patch size.



Predicting the spatial scale of variation in trout distribution

- Weak rock (+)
- Resistant rock (-)
- Mean distance between tributaries (+)



Conclusions

- Coastal cutthroat trout distribution exhibited strong spatial structuring at scales of 200-1000 m.
- Empirical variograms provided an effective means to compare spatial structure among watersheds.
- Scale of variation (patch size) in trout distribution corresponded with landscape characteristics.

Broader implications

- Geostatistical analysis can be applied in stream networks but requires specific statistical considerations.
- Existing geospatial and statistical software can be used (with minor modifications) to describe spatial pattern in networks.
- Explicit incorporation of network spatial structure has much to offer ecology and hydrology.

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