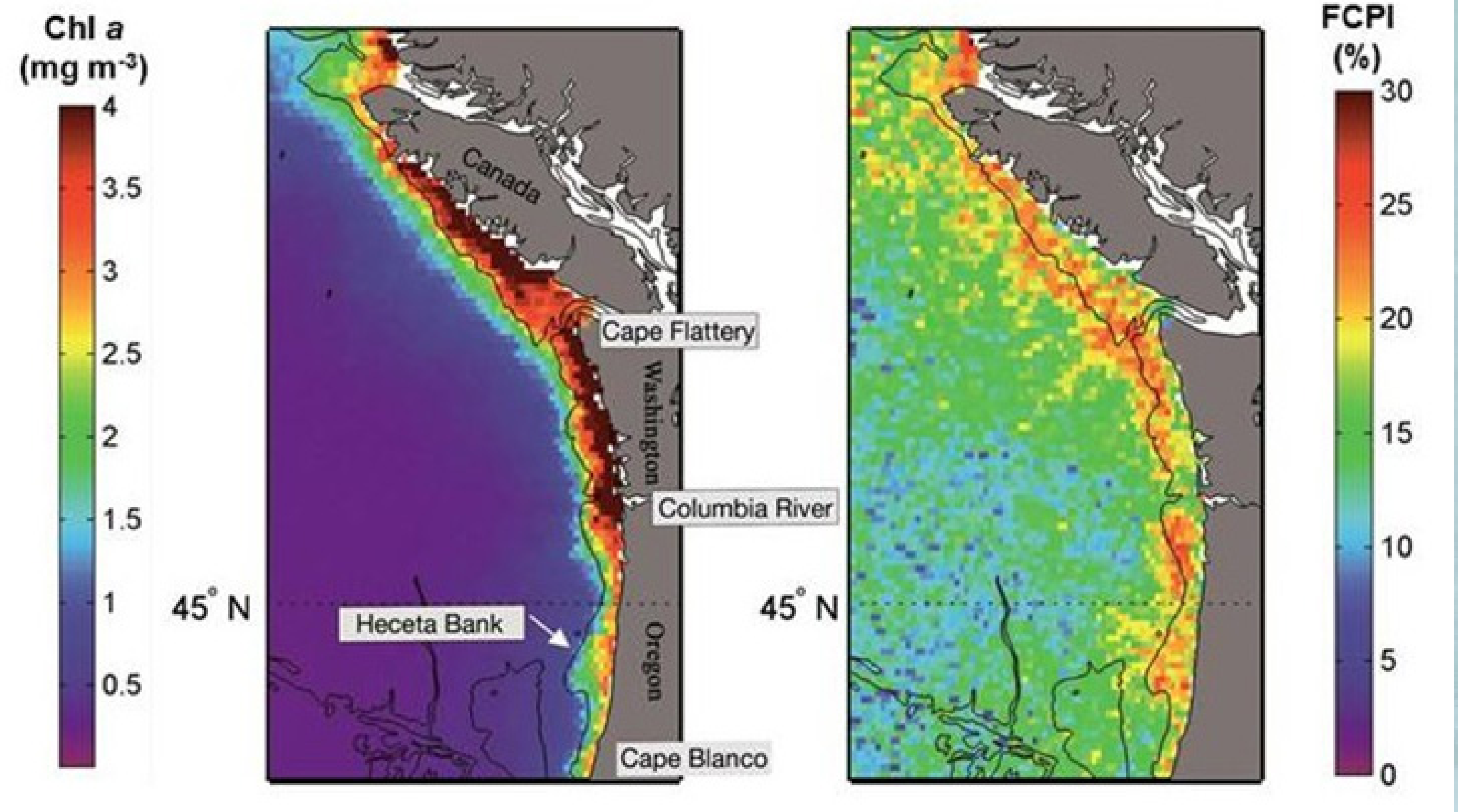
How Are Streams Different from Landscapes? Evolving Approaches for Data Analysis in Stream Networks

Rebecca Flitcroft

USDA Forest Service, PNW Research Station, Corvallis, Oregon, USA

Landscape concepts



Suryan et al. 2012 Marine Ecology Progress Series

Spatial Autocorrelation
Spatial Statistics

- Spatial autocorrelation:
  - Moran's I
  - Geary's C
  - Getis's G
  - Standard deviational ellipse
- Spatial interpolation
  - Inverse distance weighting
  - Kriging
- Spatial regression
  - Geographically weighted regression
  - Markov Chain Monte Carlo methods

Advantages of a Landscape Approach

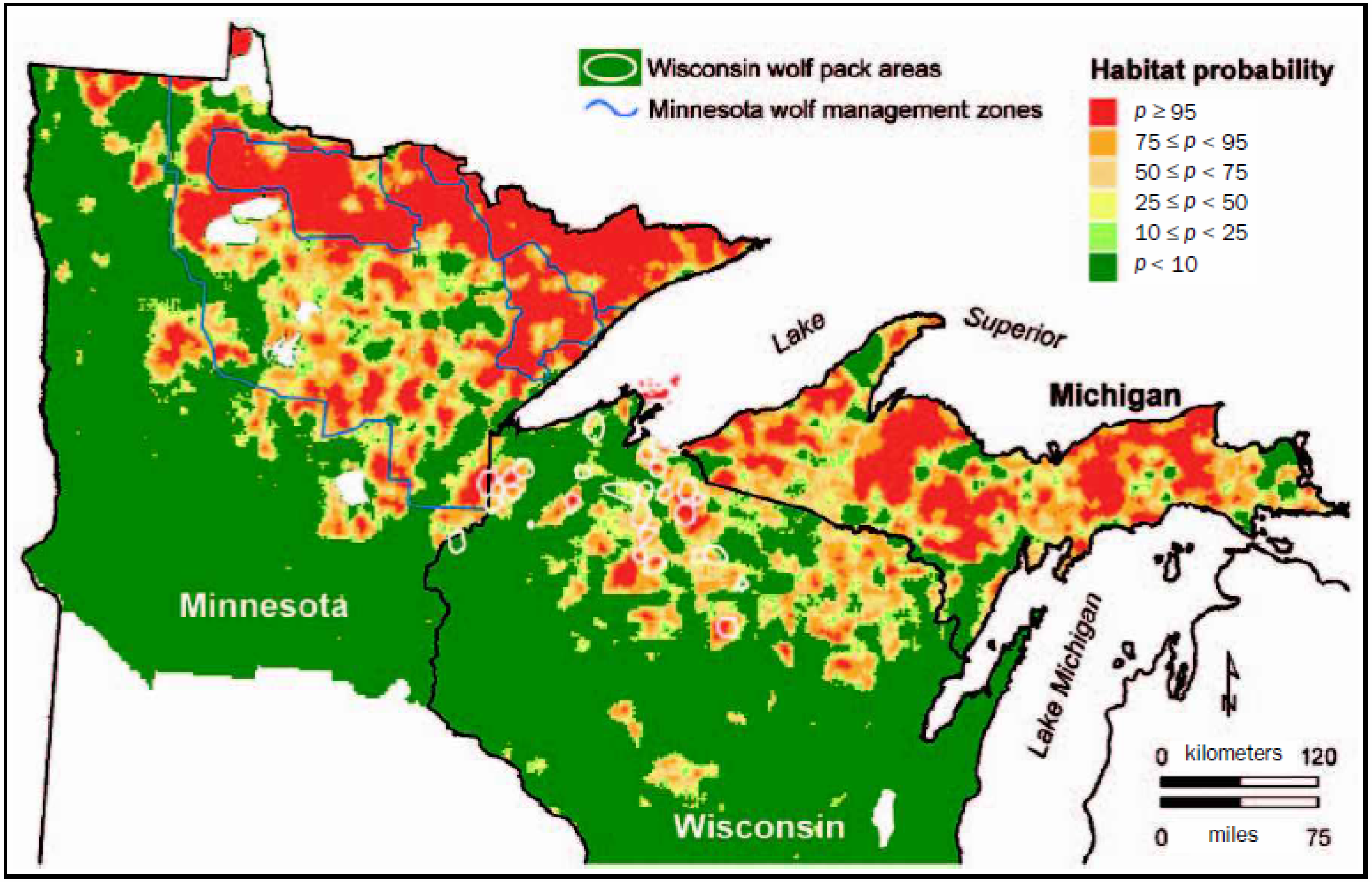


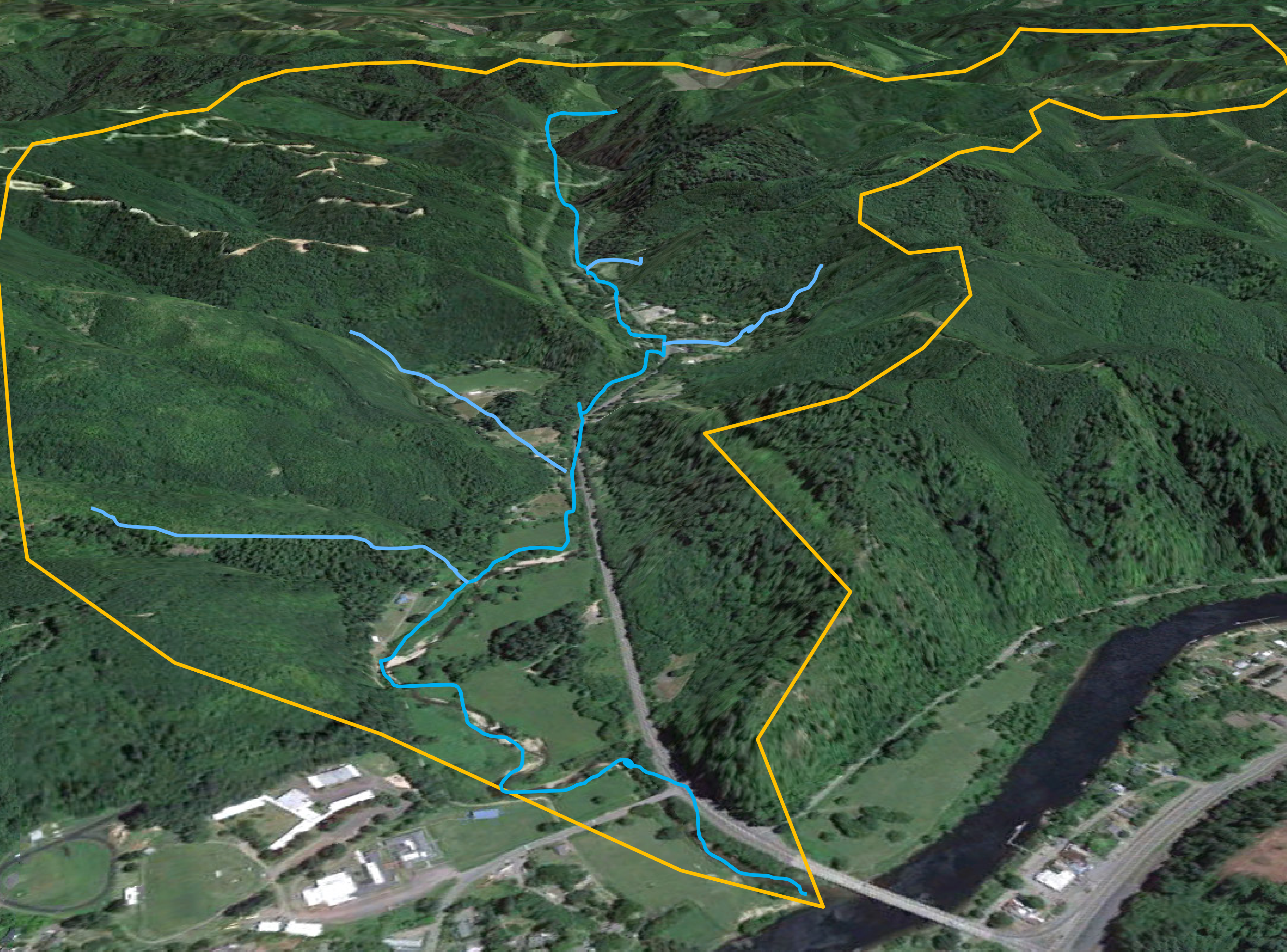
Figure 2. Probability of favorable wolf habitat for Minnesota, northern Wisconsin, and upper Michigan, based on a logistic model using road density as the predictor variable. Modified from Mladenoff and colleagues (1995).

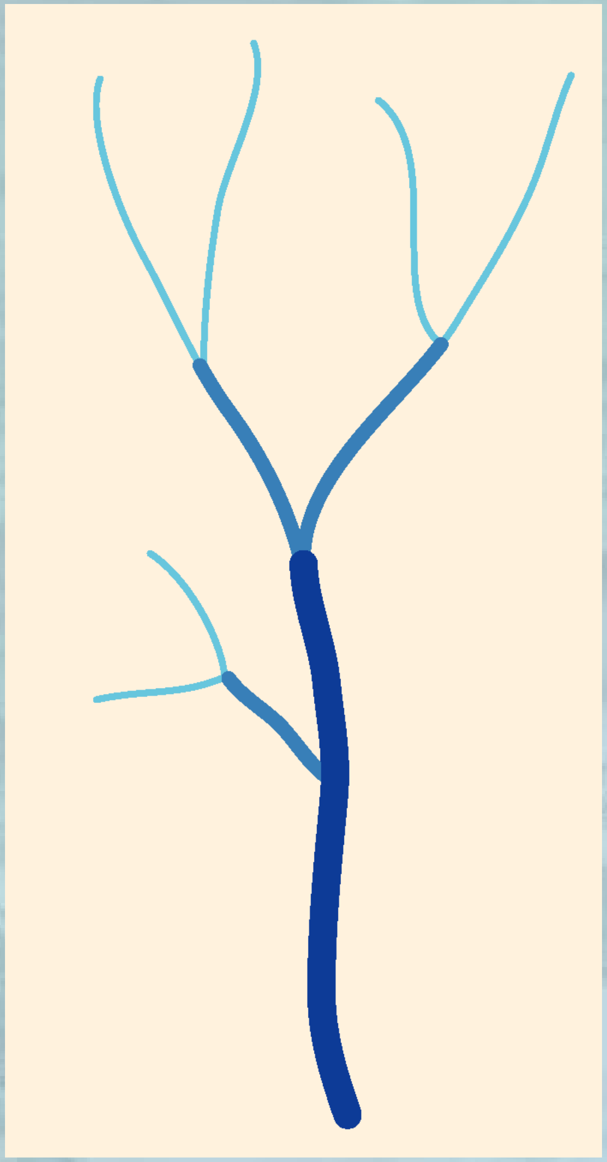
Miller et al. 2004 BioScience

Spatial Statistical Software

- SAS
- ArcGIS
- Stata
- Systat
- PASSaGE
- SaTScan
- R
- PySAL
- Quantum GIS
- GRASS
- Legacy
- STARS
- GeoDaSpace
- GeoDaNet
- SANET
- Minerva

Photo from NASA; Ganio et al. 2005



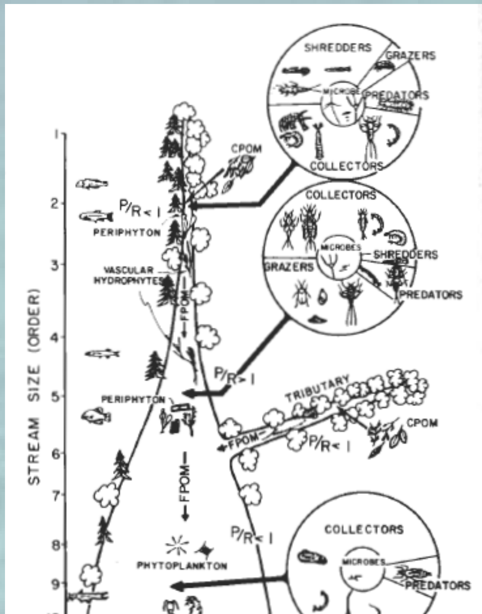


Dendritic

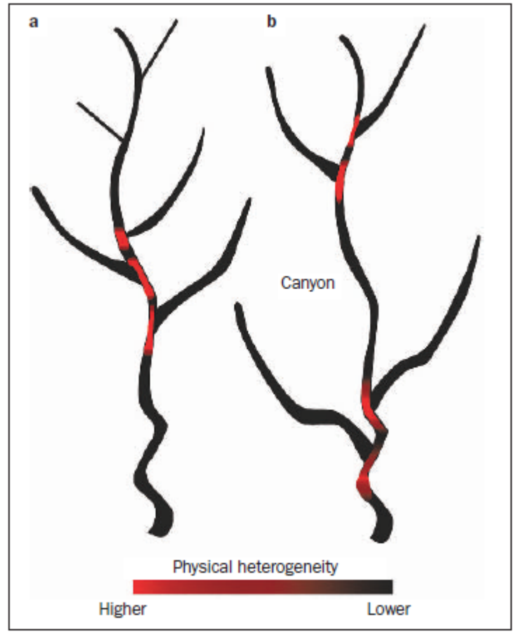
Features of a Stream Network

- Interconnected
- Directionality of flow for biotic and abiotic elements
- All elements of the network are related to one another

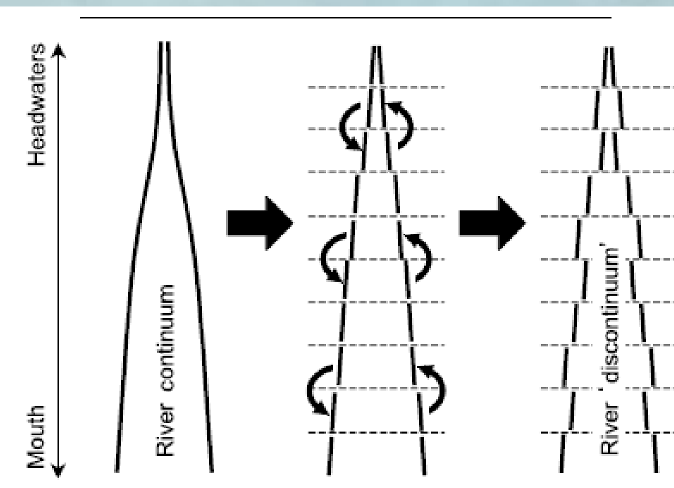
Aquatic Connectivity



Vannote et al. 1980

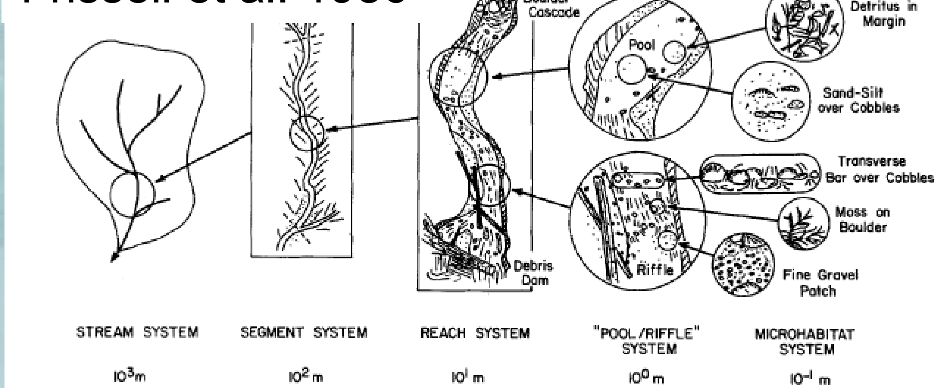


Benda et al. 2004

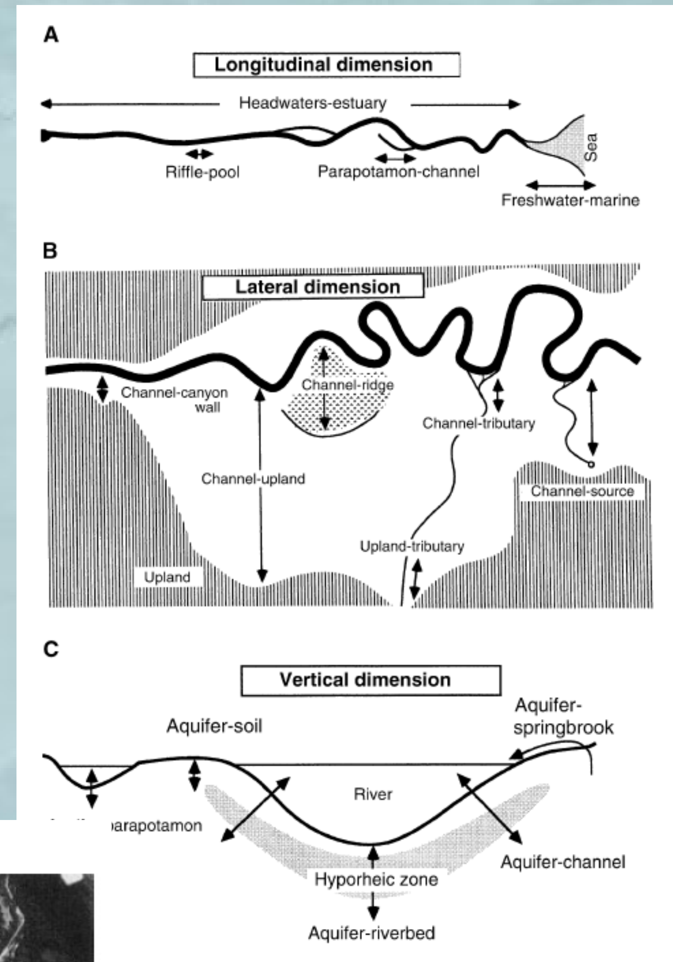


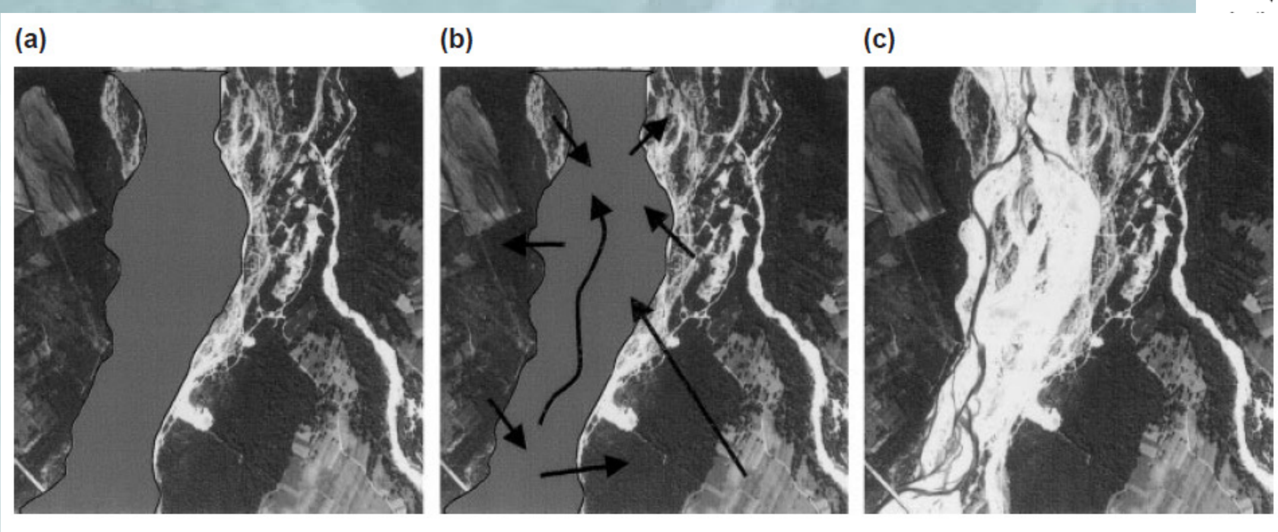
Poole 2002

Frissell et al. 1986



Ecological Concepts: Landscapes to Riverscapes

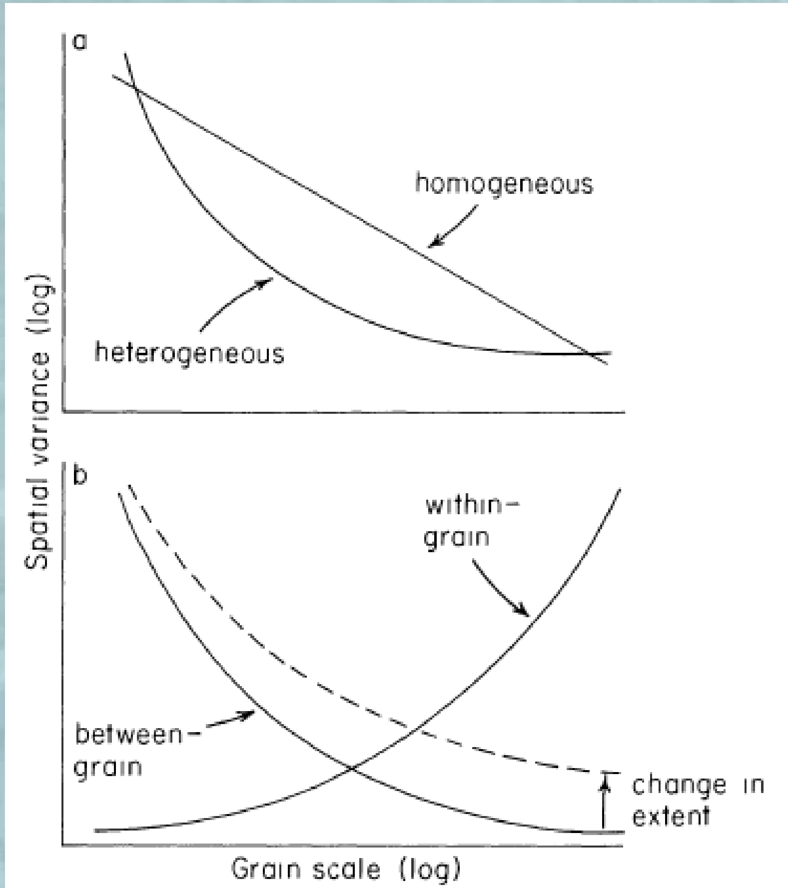




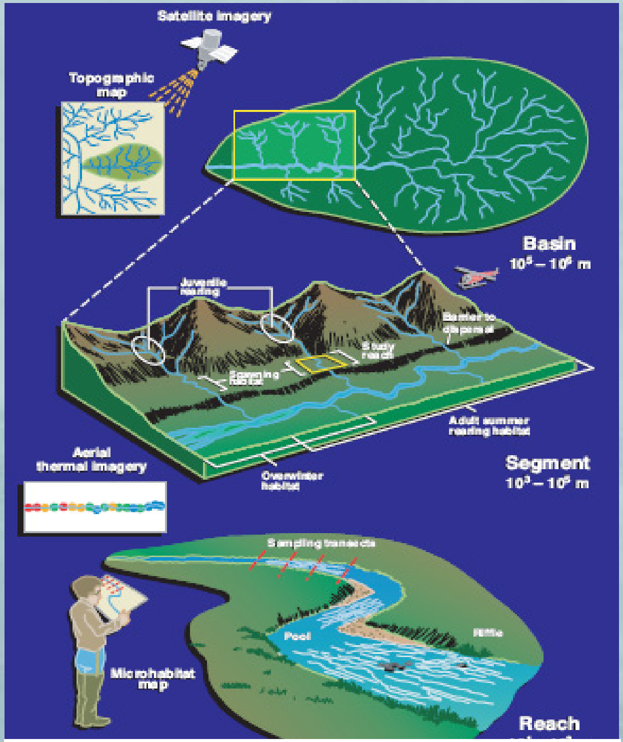
Wiens 2002

Similar Challenges in Analysis of Rivers and Landscapes

1. Scale-dependence



Wiens 1989 Functional Ecology

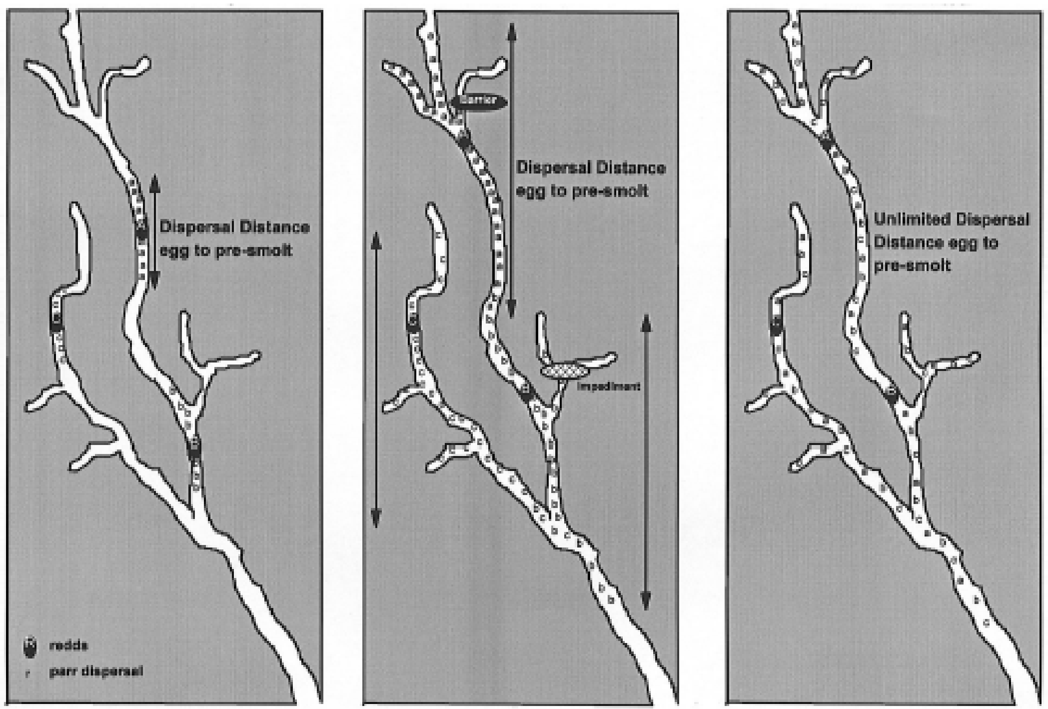


Fausch et al. 2002

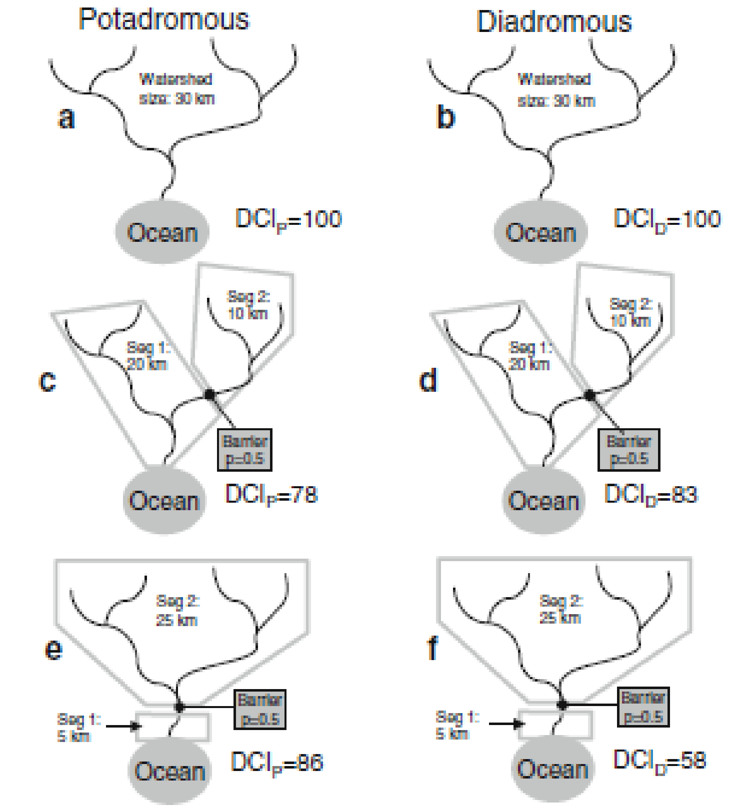
Similar Challenges in Analysis of Rivers and Landscapes

2. Mobility and Life History

Limited Dispersal | Constrained | Unlimited



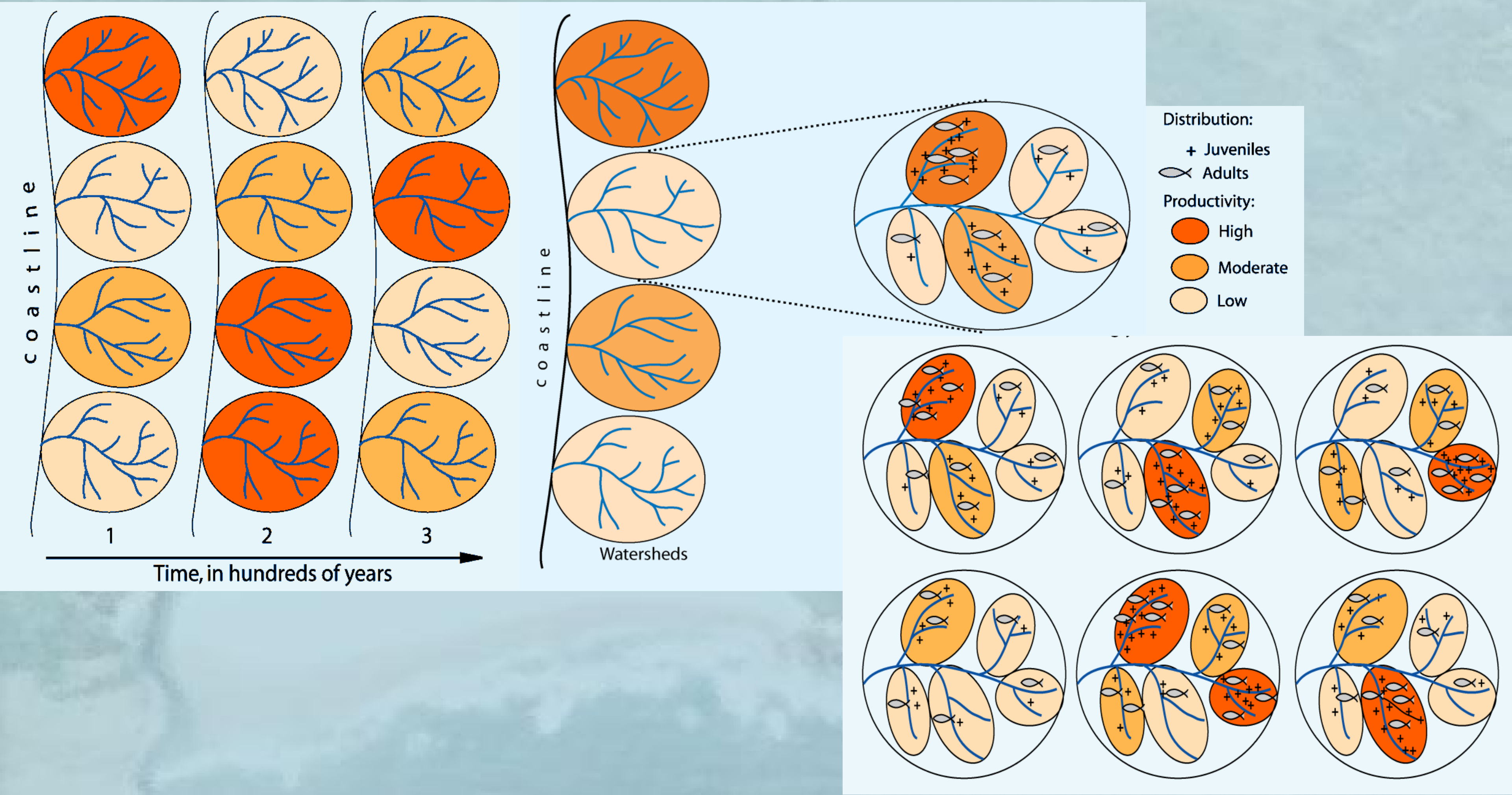
Kocik and Ferreri 1998



Cote et al. 2009 Dendritic Connectivity Index

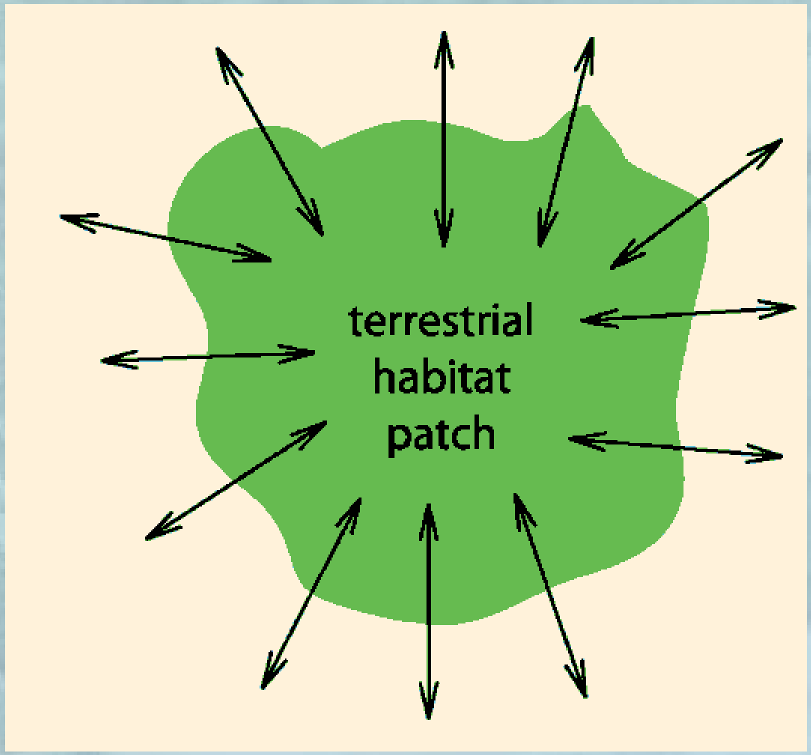
Similar Challenges in Analysis of Rivers and Landscapes

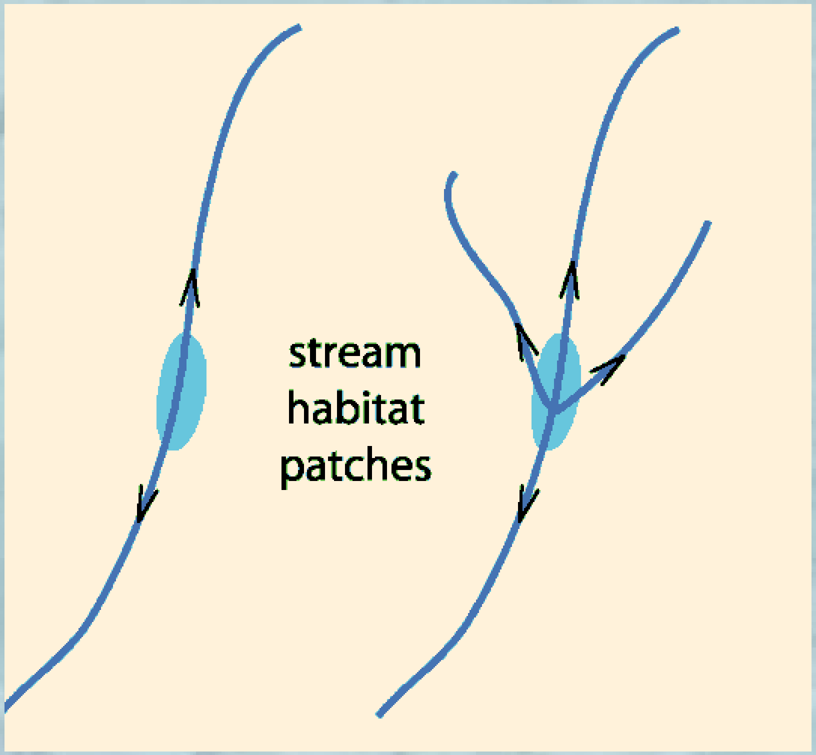
3. Habitat changes over time



How River Structure Confounds Spatial Statistical Methods

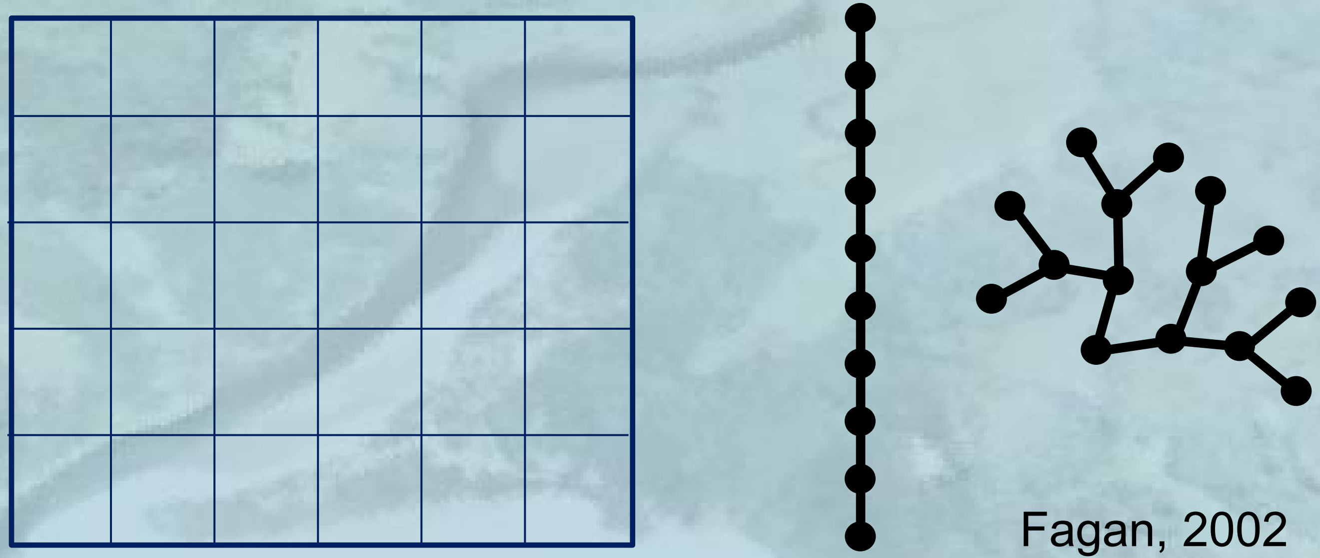
1. Directional, constrained, correlation





How River Structure Confounds Spatial Statistical Methods

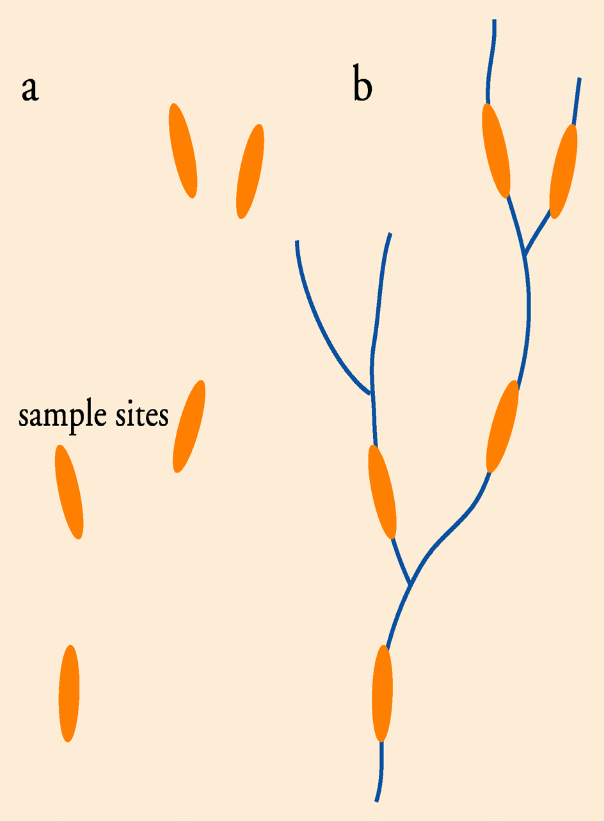
2. Network Configuration

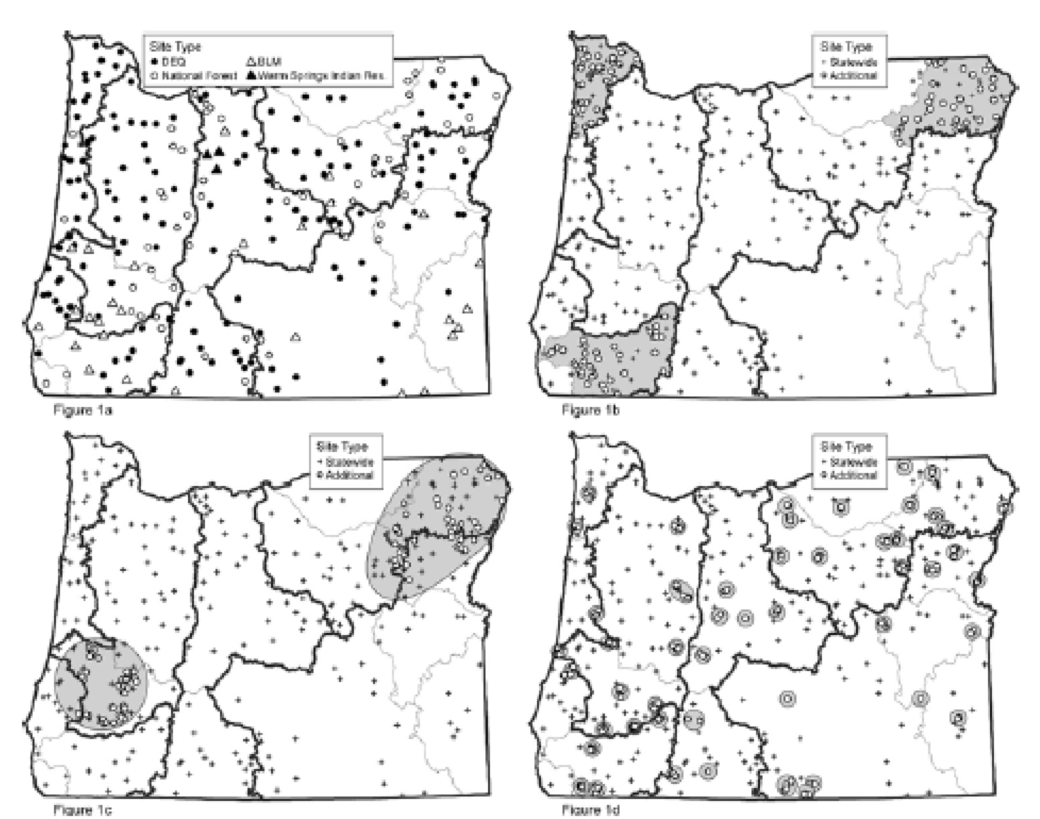


Fagan, 2002

Avoiding Correlation Altogether
Not so fast….

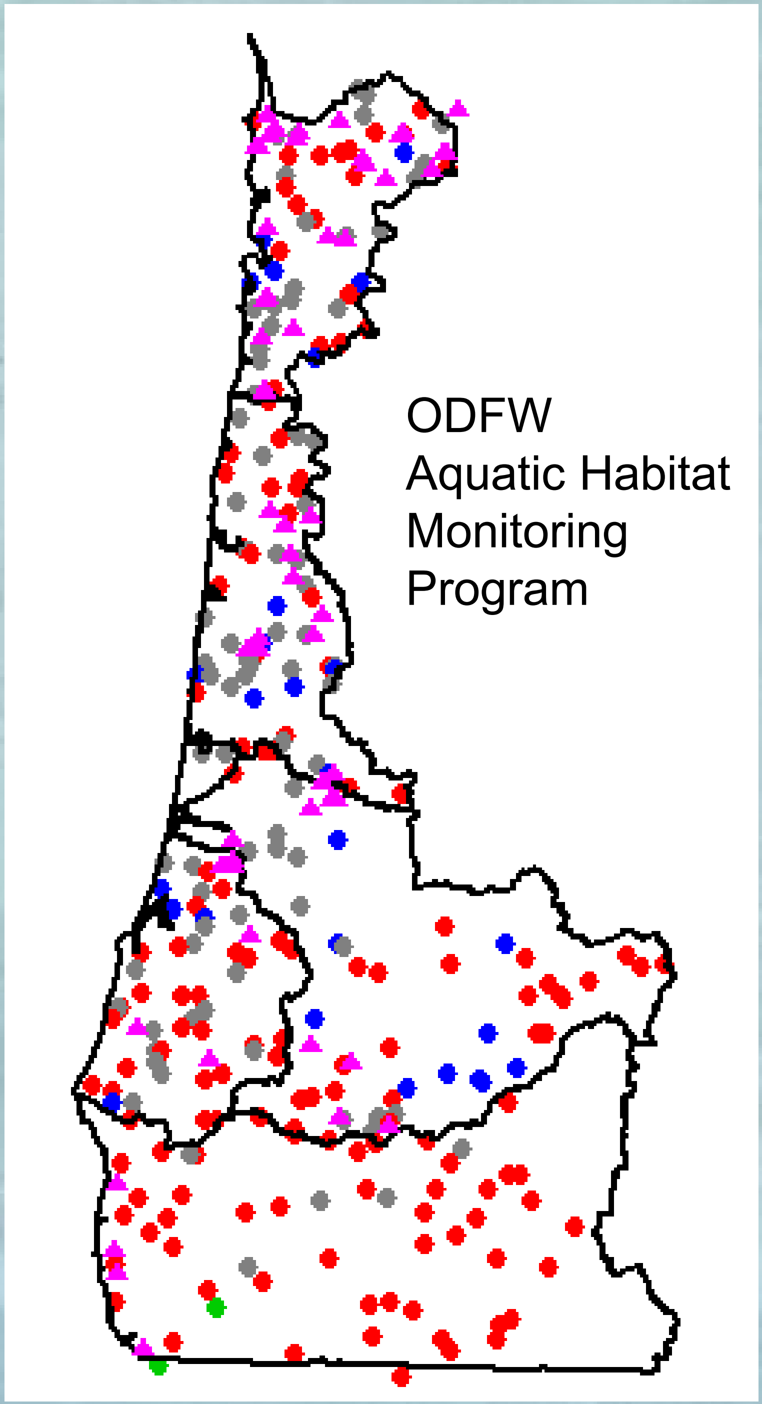
GRTS - EPA





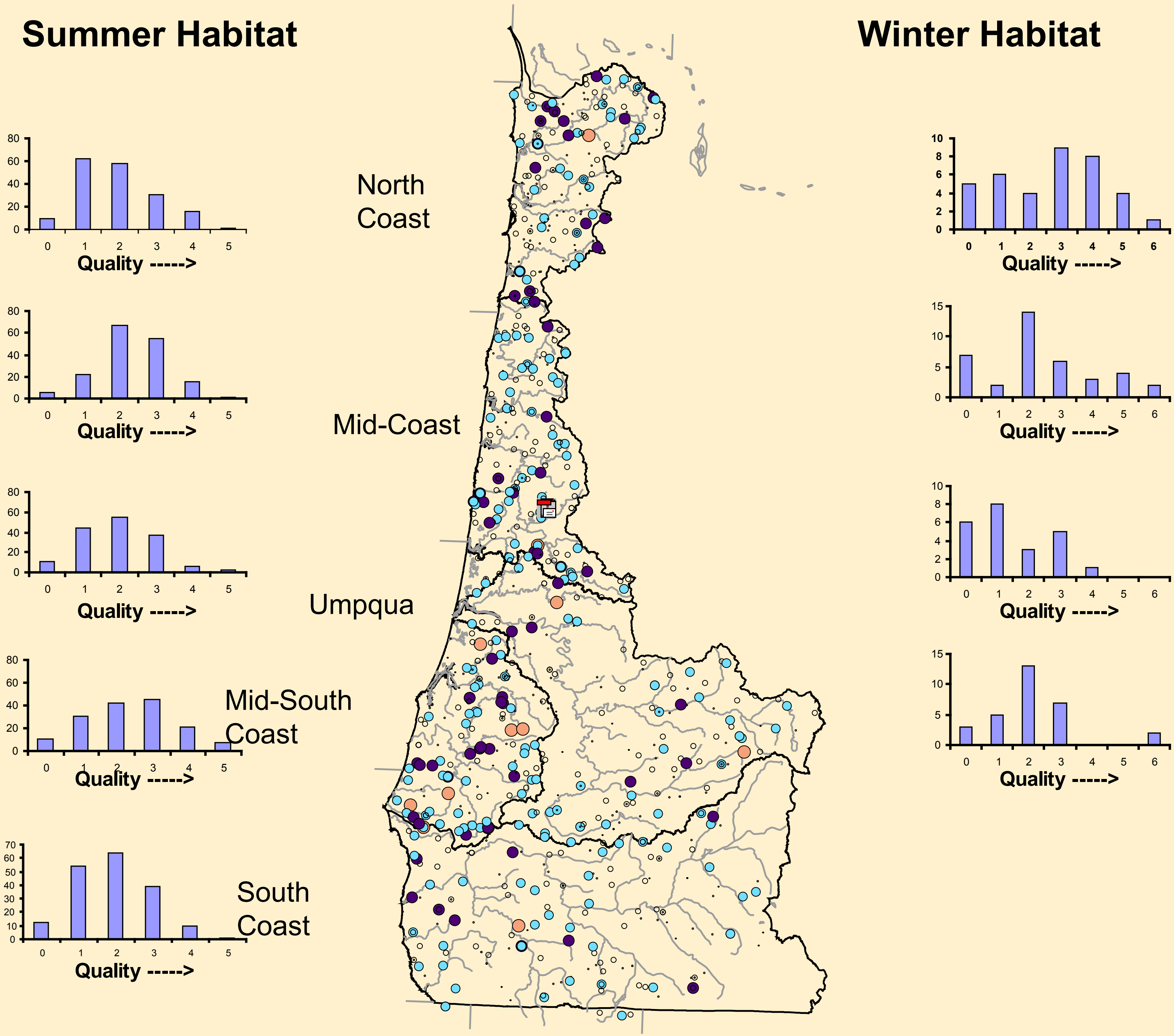
Larsen et al. 2009 J. of Ag, Bio, Envr Stats

Spatially Balanced Designs Allow for Trend Detection and Monitoring

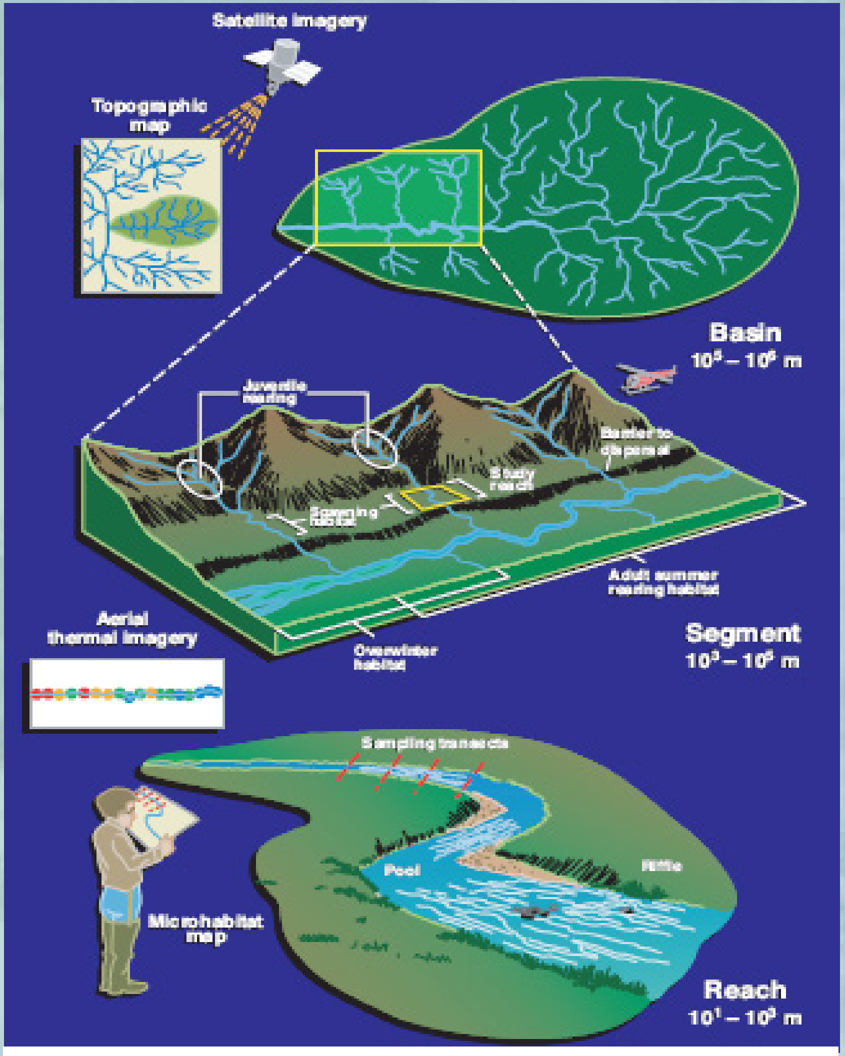


Summer Habitat

Winter Habitat

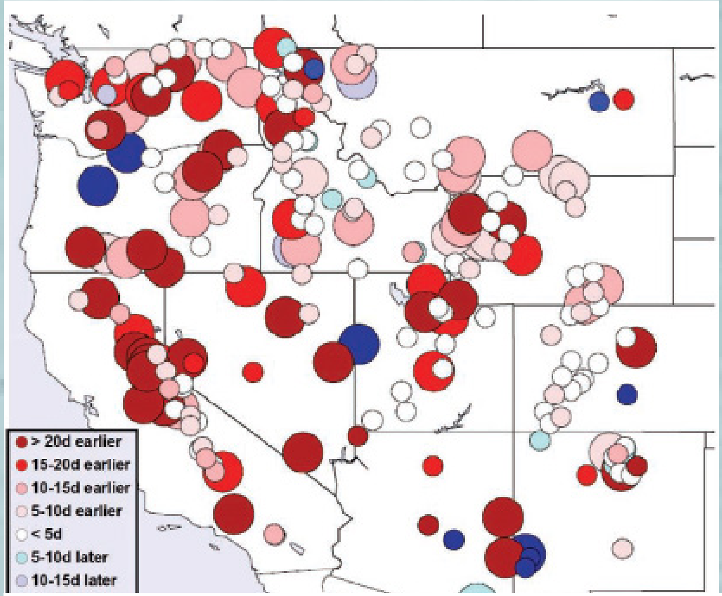


What About the Riverscape Story?



Fausch et al. 2002 BioScience

Quantifying spatio-temporal complexity



Rieman and Isaak 2010 from Stewart et al. 2005

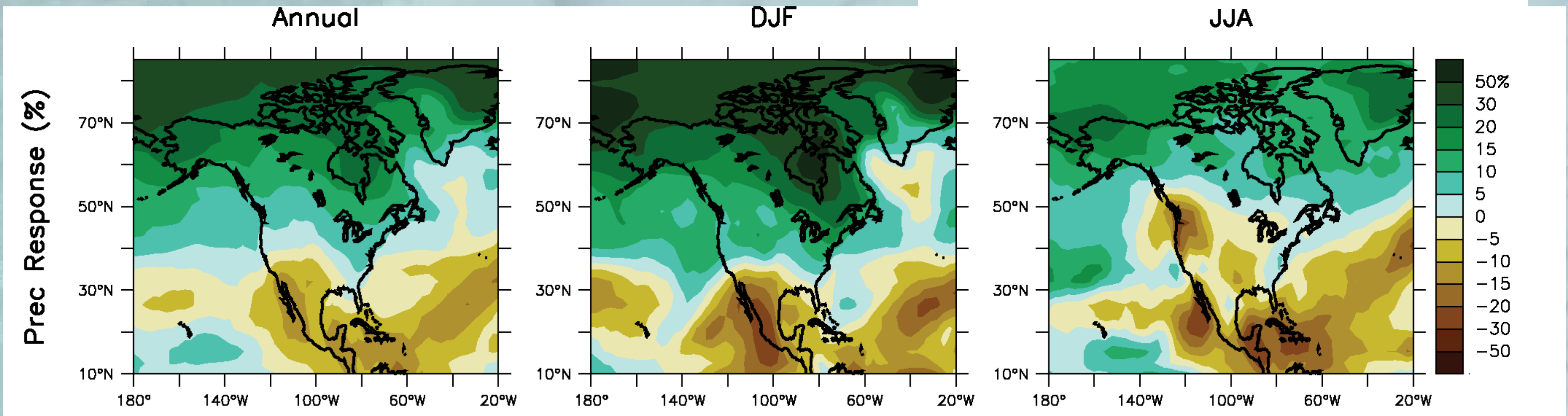
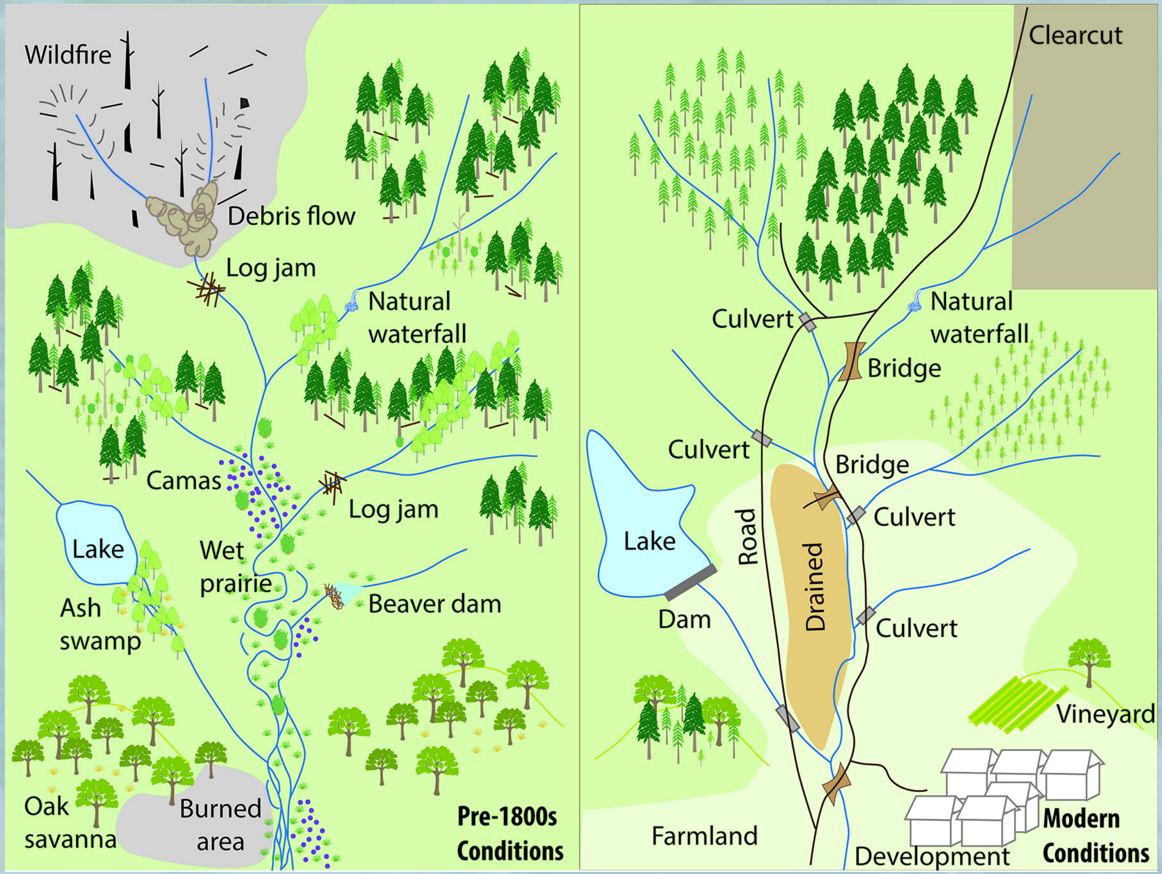


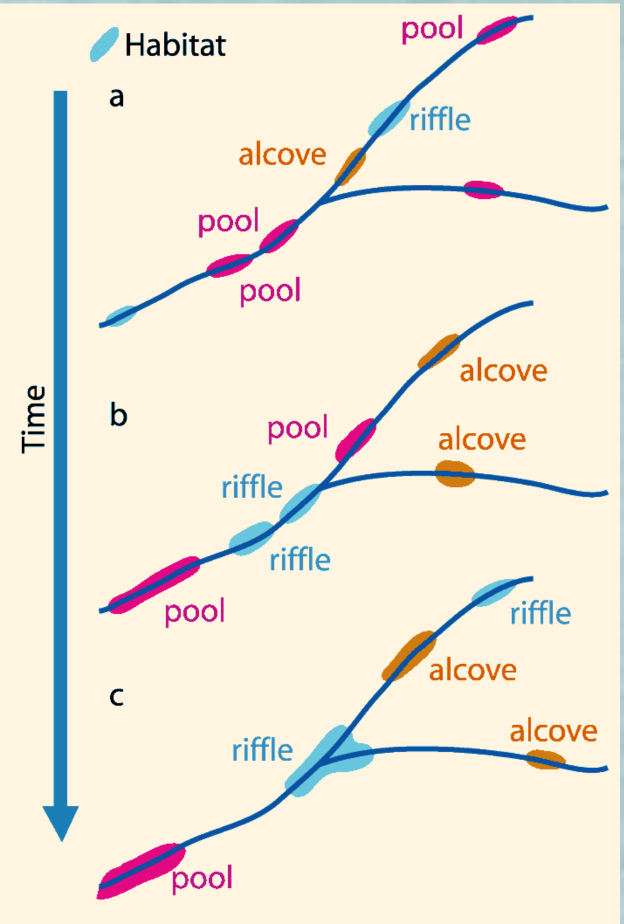
Figure 11.12. Temperature and precipitation changes over North America from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation.

IPCC Fourth Assessment Report 2007

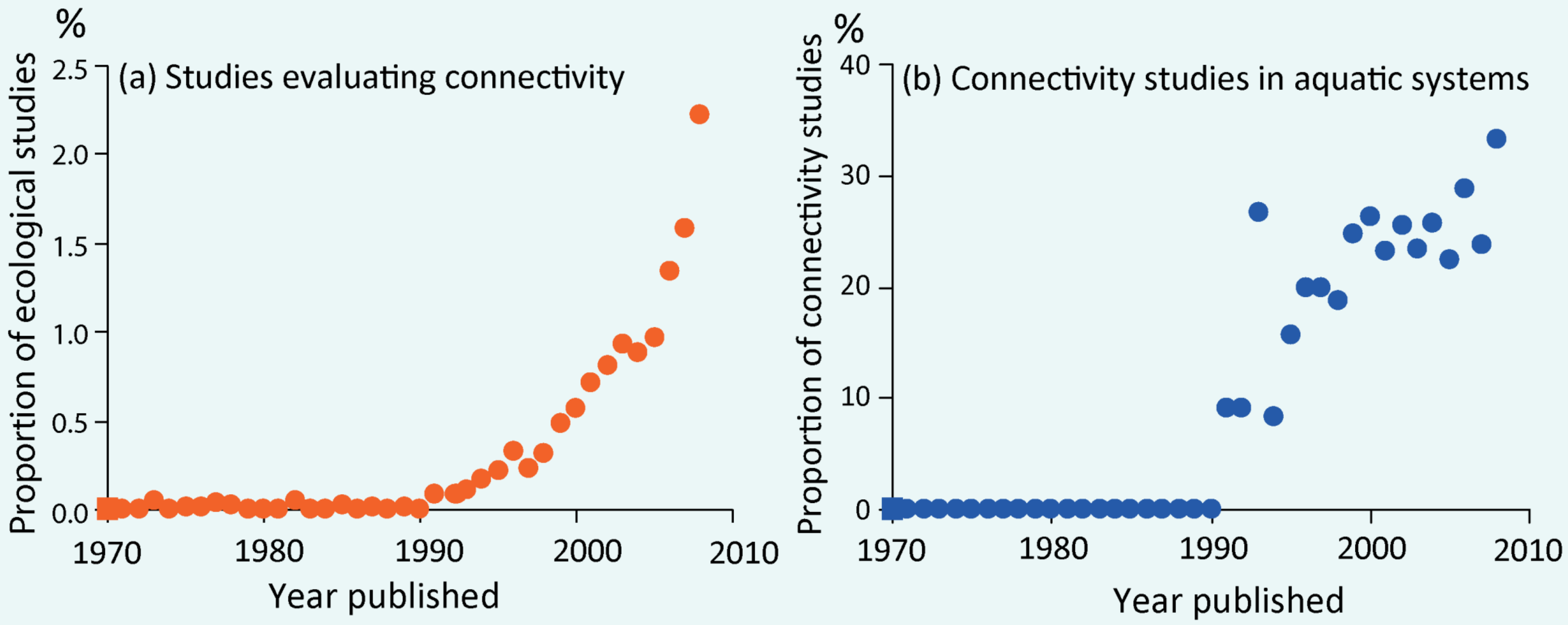
Studies of riverine fishes

- Dynamic connections
- Anthropogenic influences



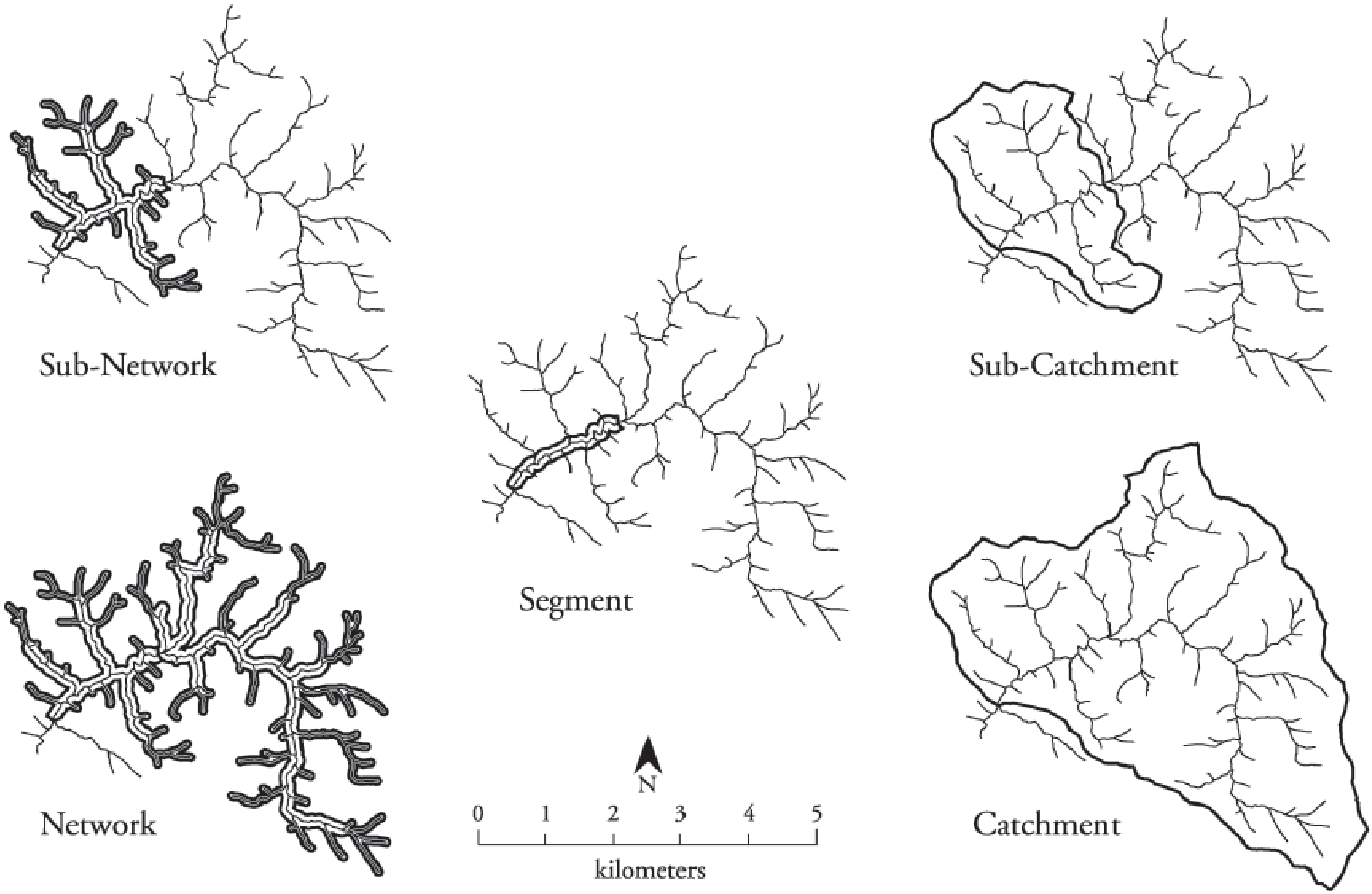


Emerging Analytical Approaches that are Network Specific



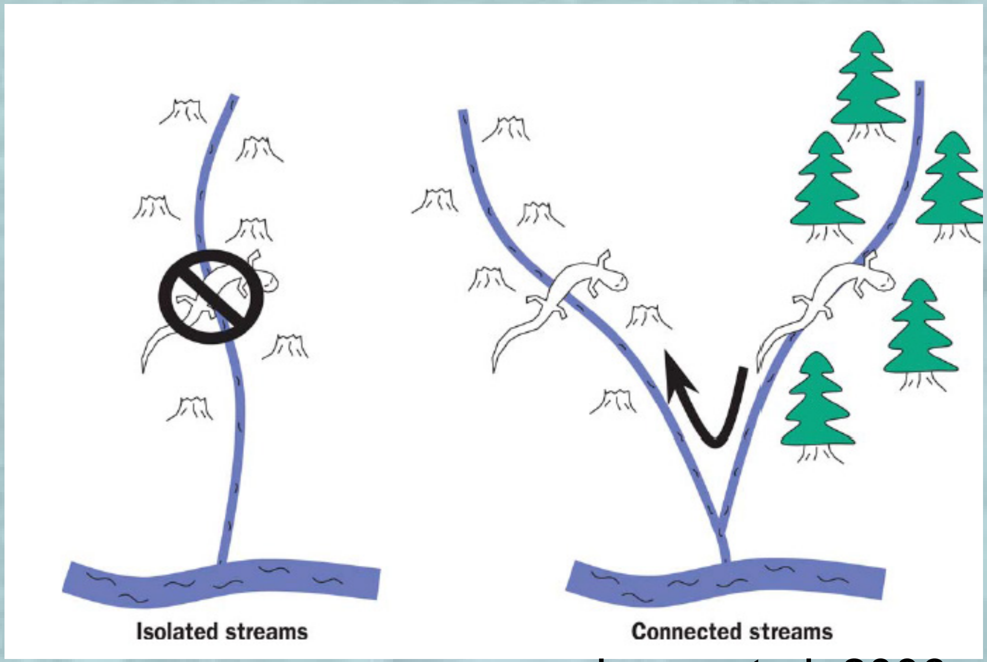
Fullerton et al. 2010, Freshwater Biology 55:2215-2237

Spatial Extent in River Networks

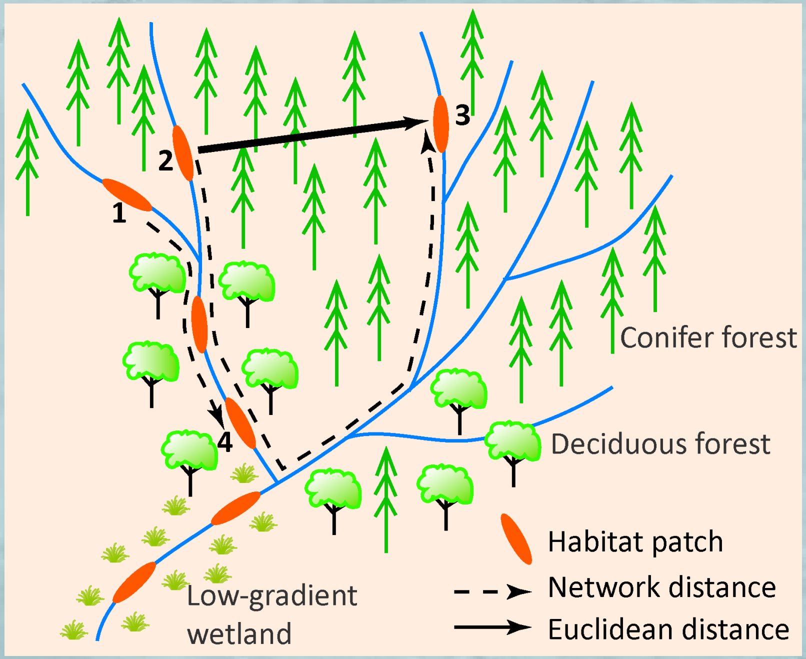


Burnett et al. 2006 American Fisheries Society Symposium 48

What does "Distance" mean for aquatic species?



Lowe et al. 2006

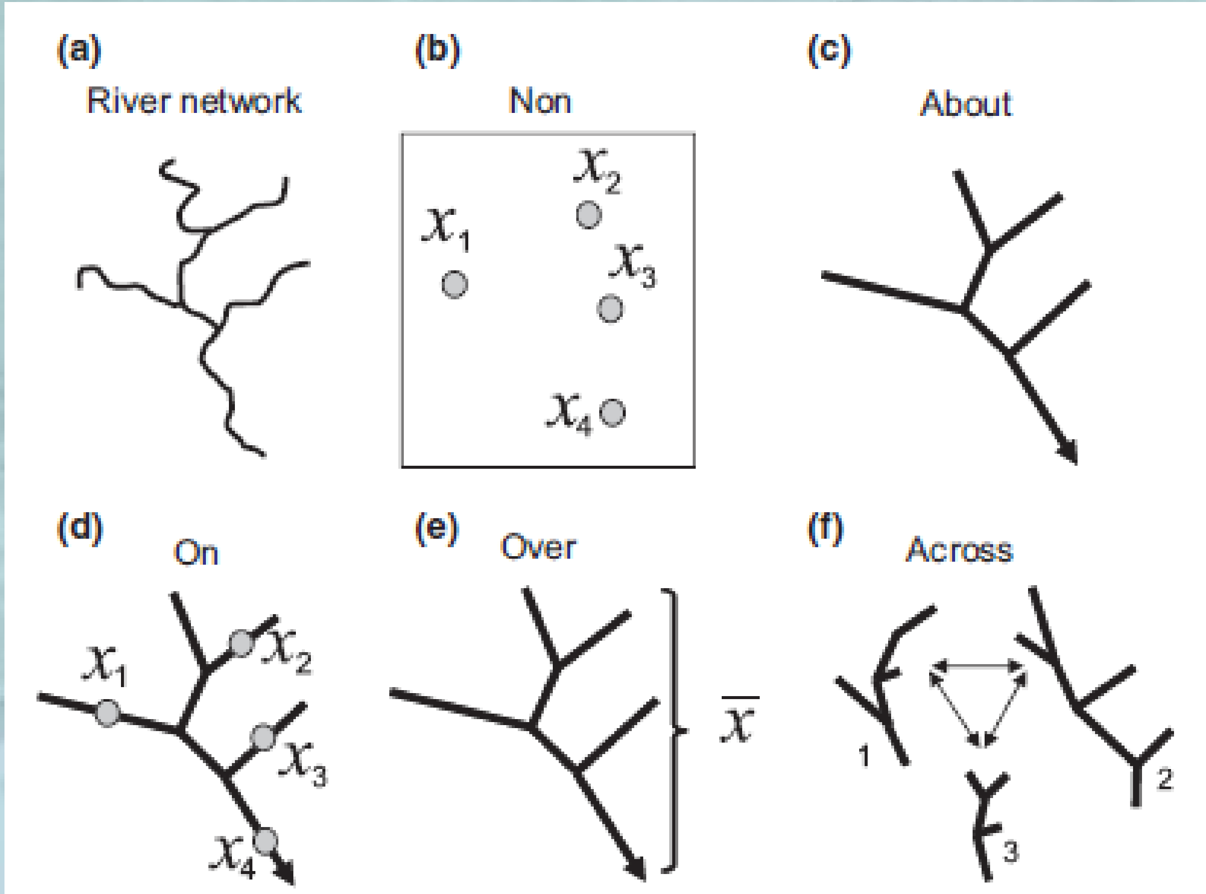


Flitcroft et al. 2012

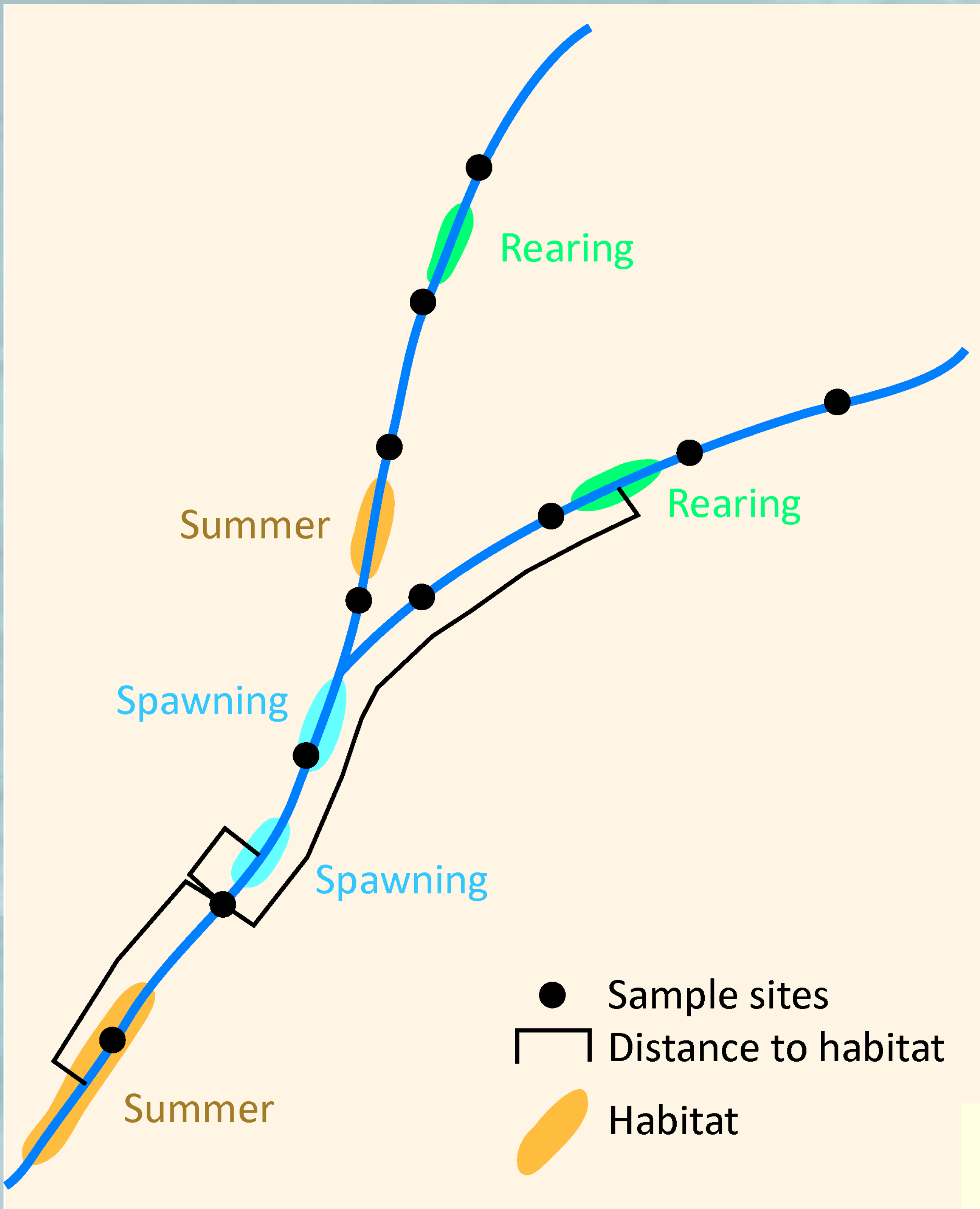
Statistical Innovations

- Network metrics
  - Can be used with common statistics
- Graph Theory
  - Hierarchy
  - Weighted
- Statistics that use network structure
  - Variograms
  - Flow Directed correlation

Statistical Innovations
Network Metrics



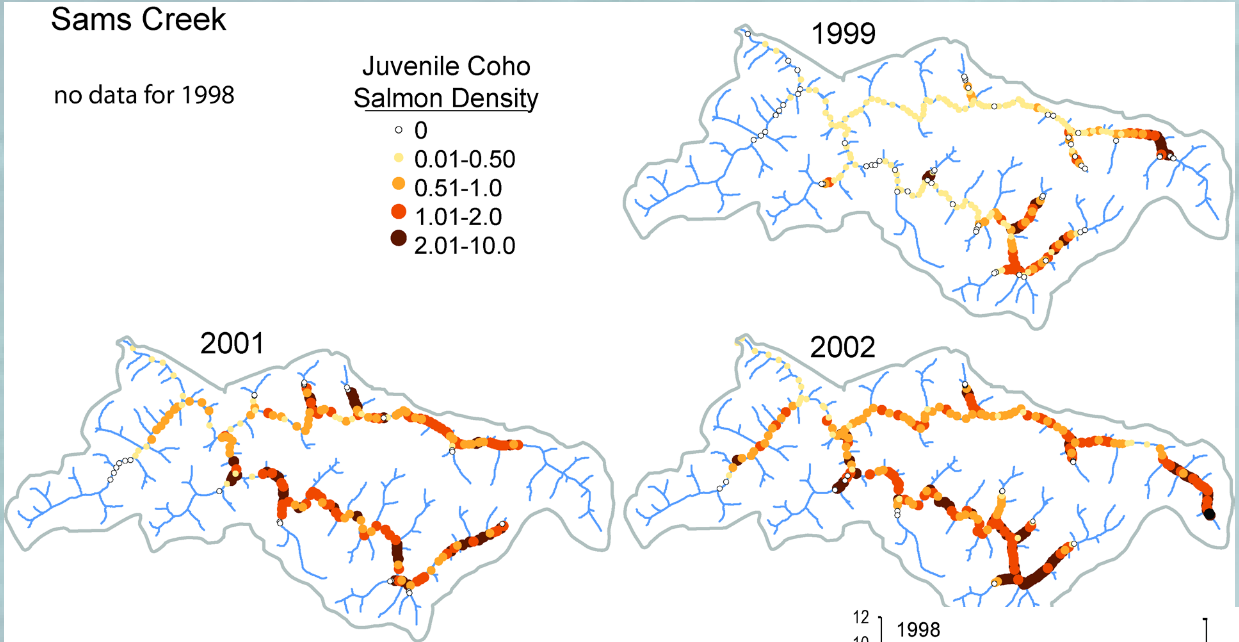
Peterson et al. 2013 Ecology Letters



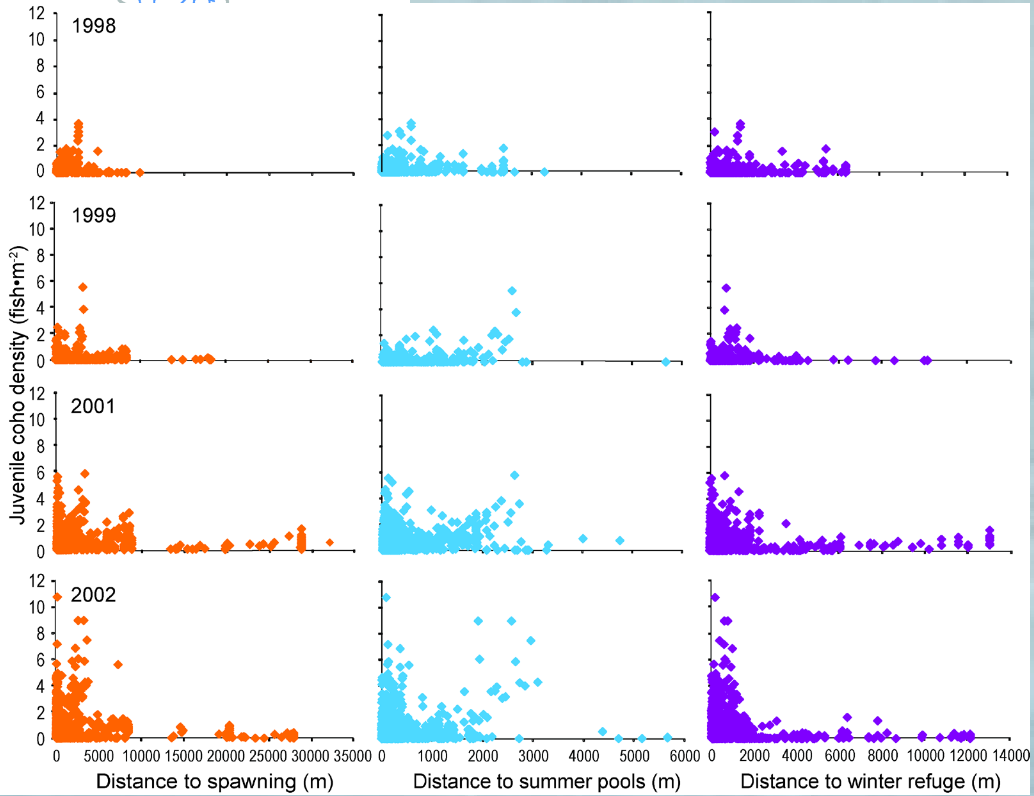
Proximity along the network

Flitcroft et al. 2012 Aquatic Conservation

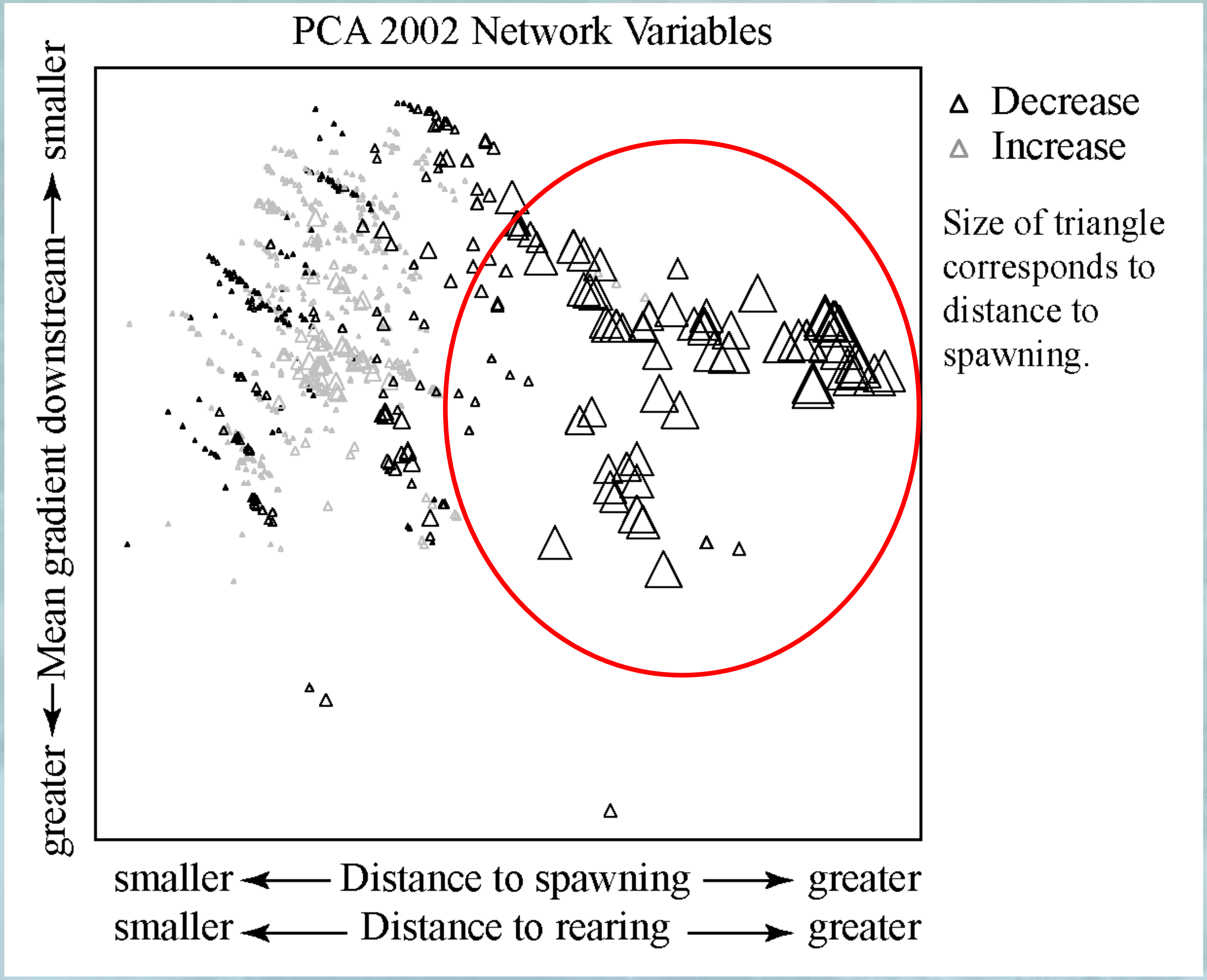
Juvenile Coho Salmon Density

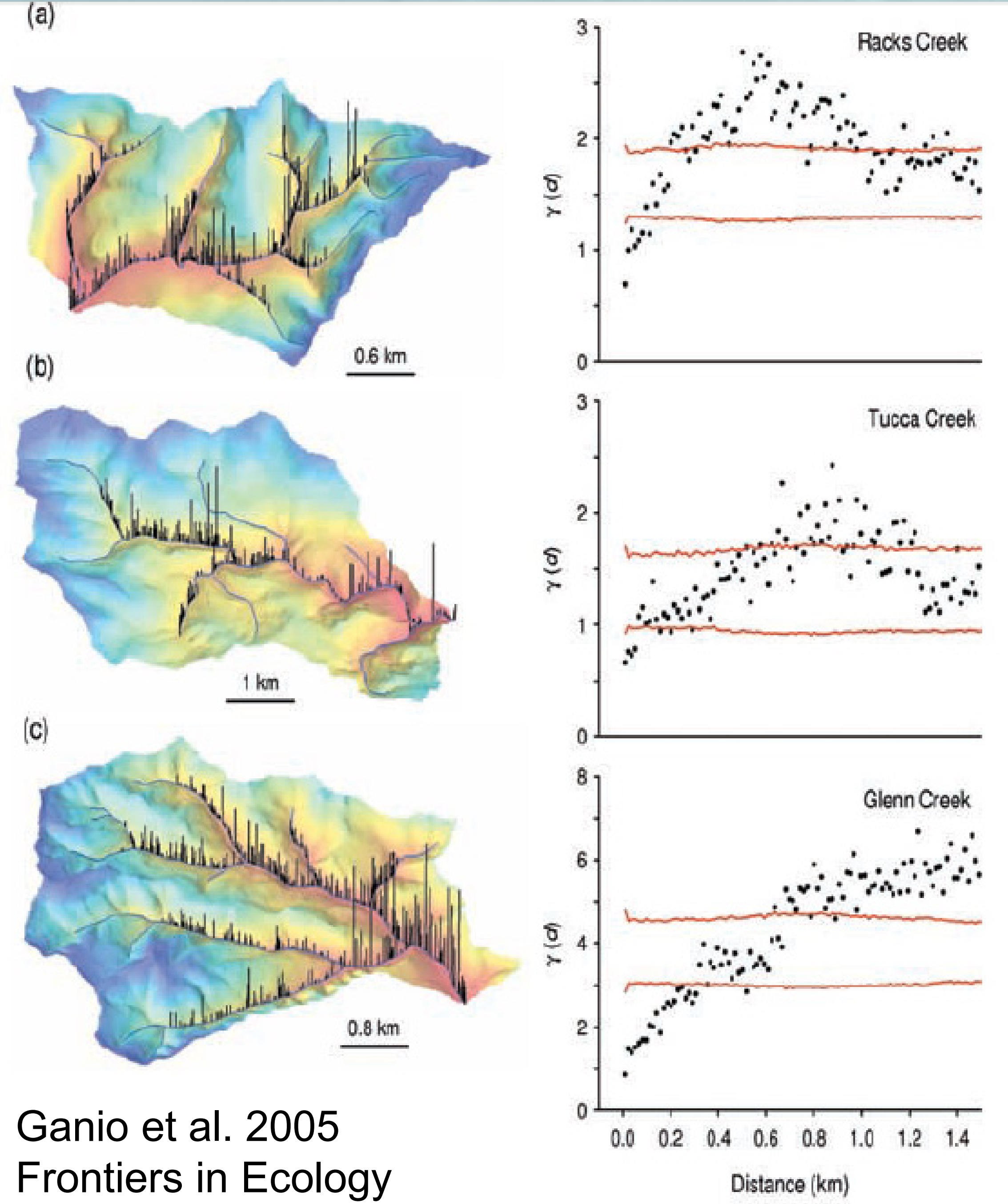


Flitcroft et al. 2012 Aquatic Conservation



PCA Network Variables



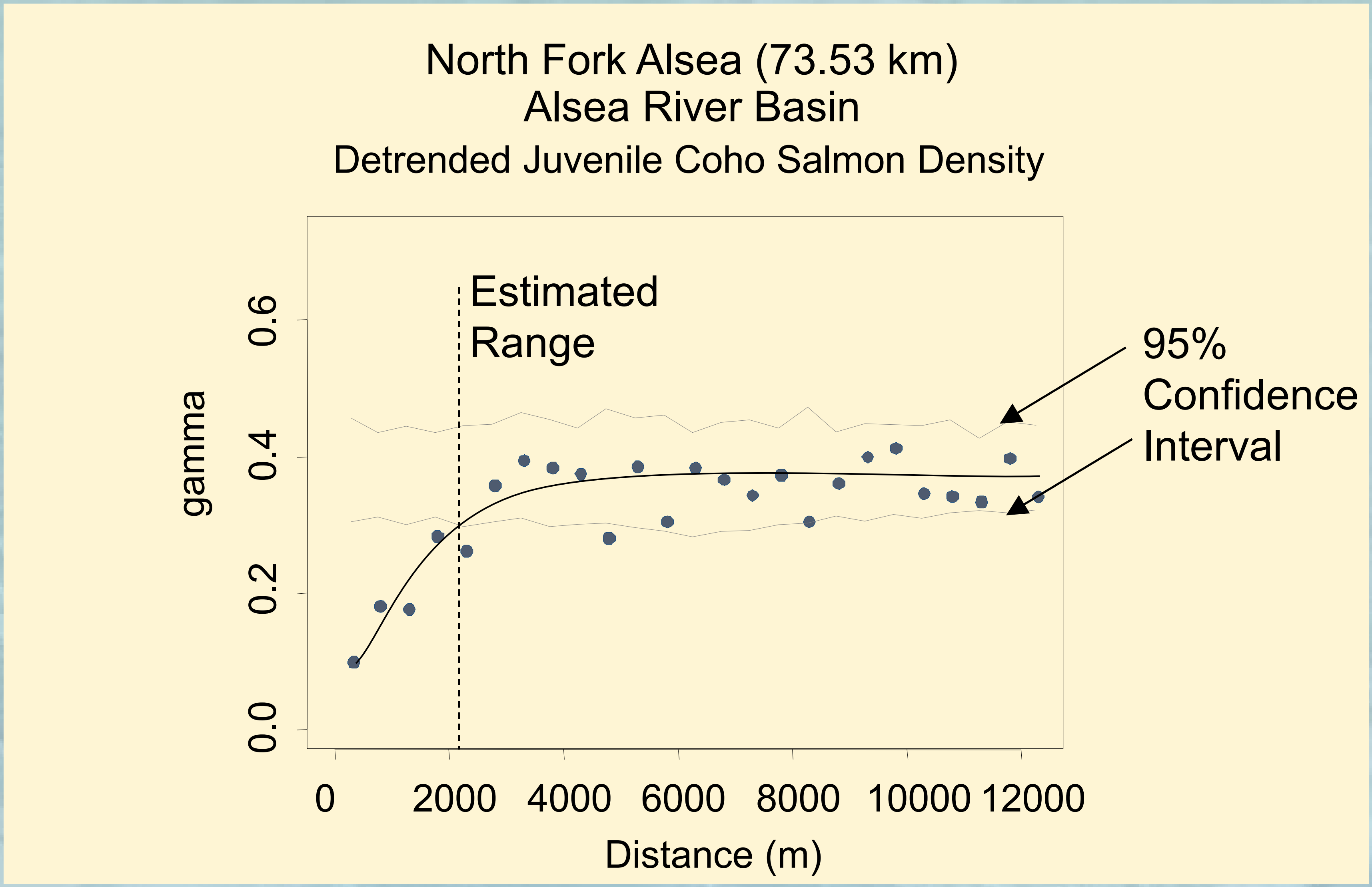


Ganio et al. 2005
Frontiers in Ecology

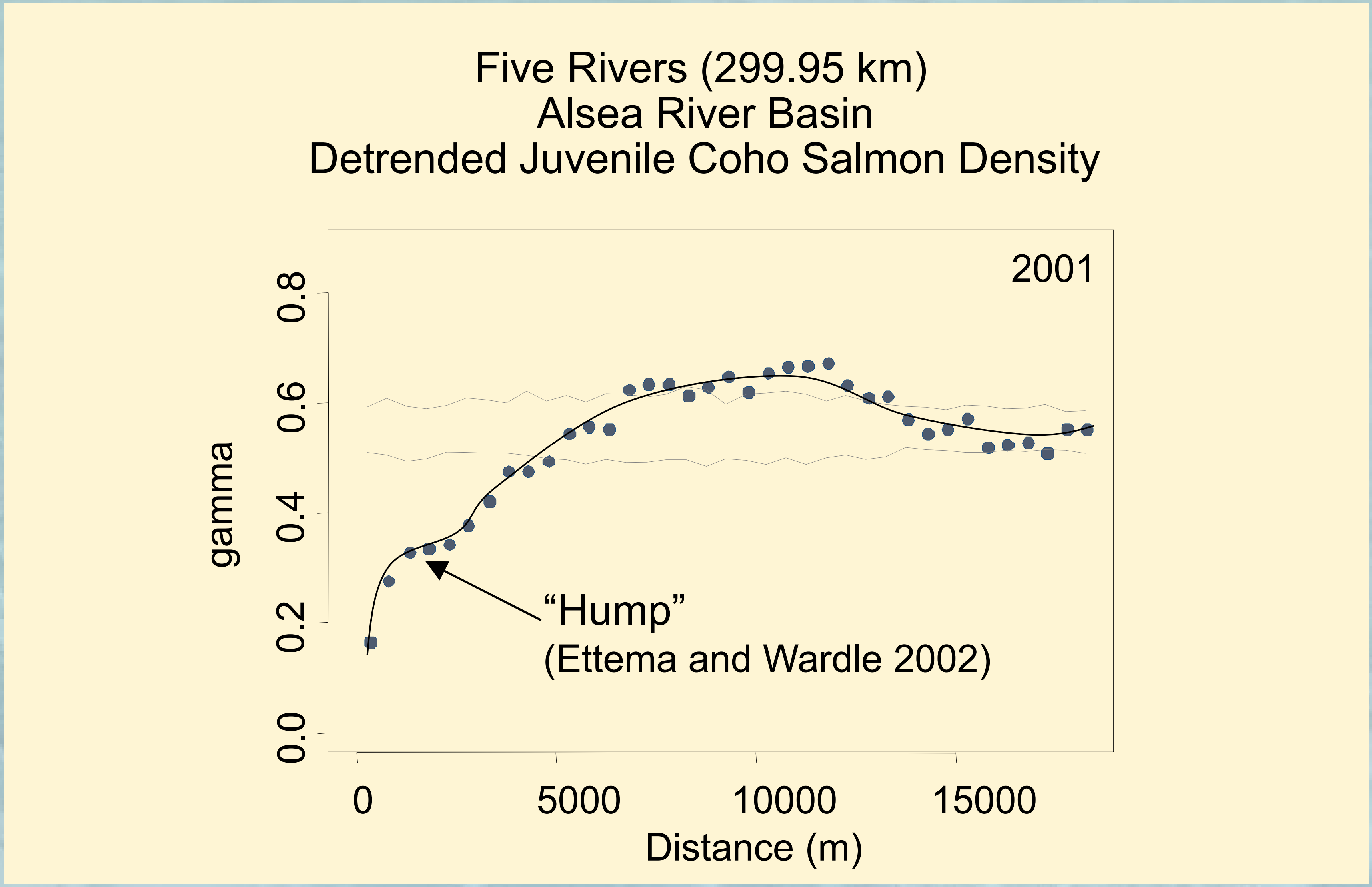
Statistical Innovations

Network Structure

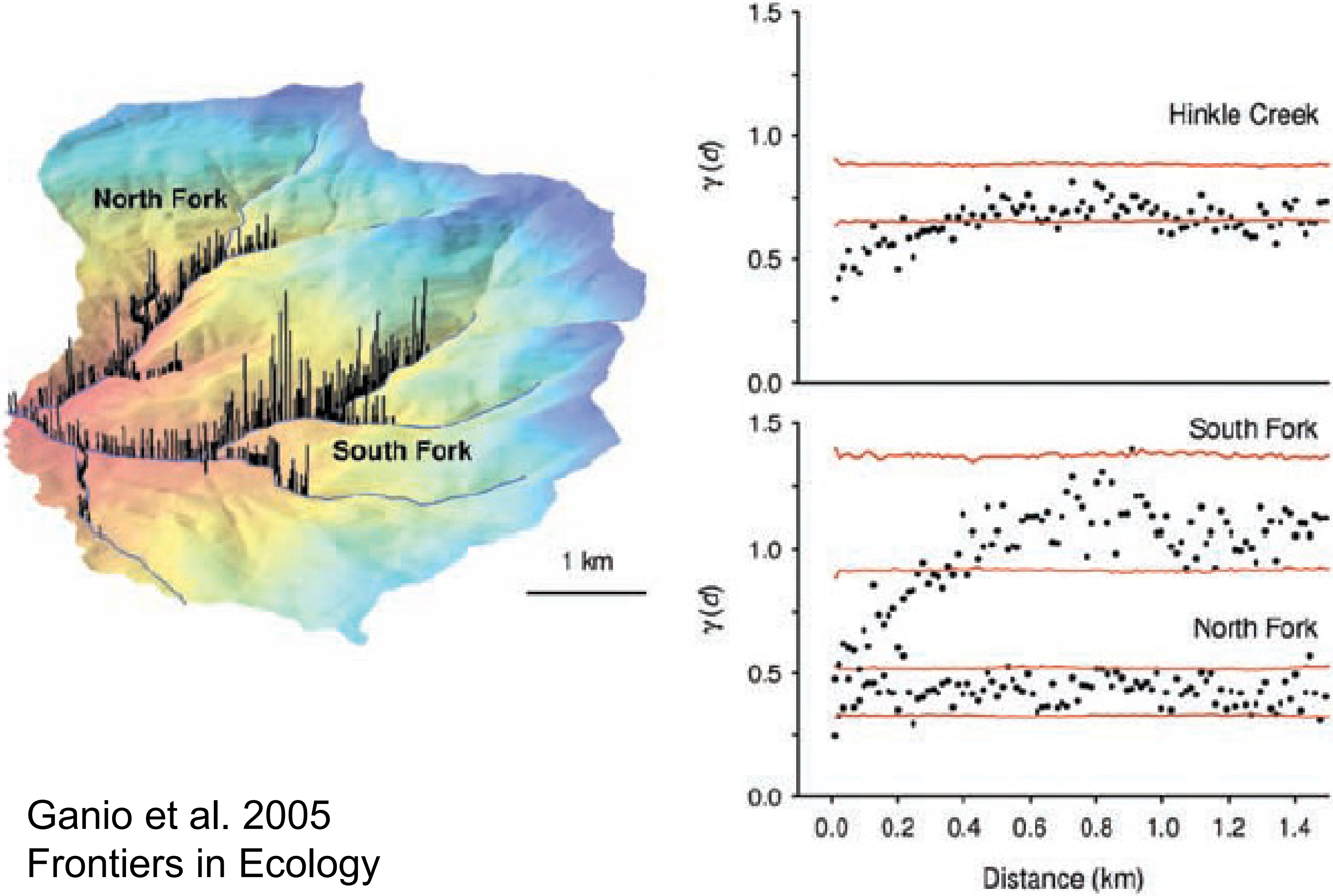
Variogram Patterns



Nested Spatial Structure?

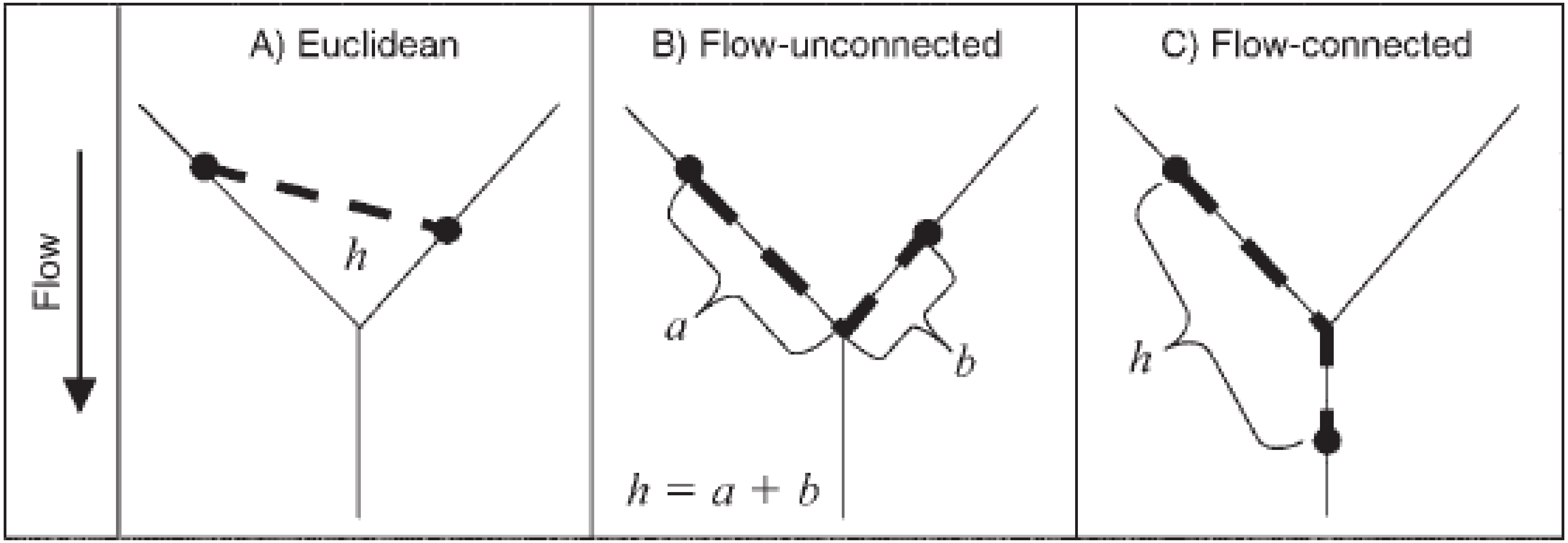


Extent Matters



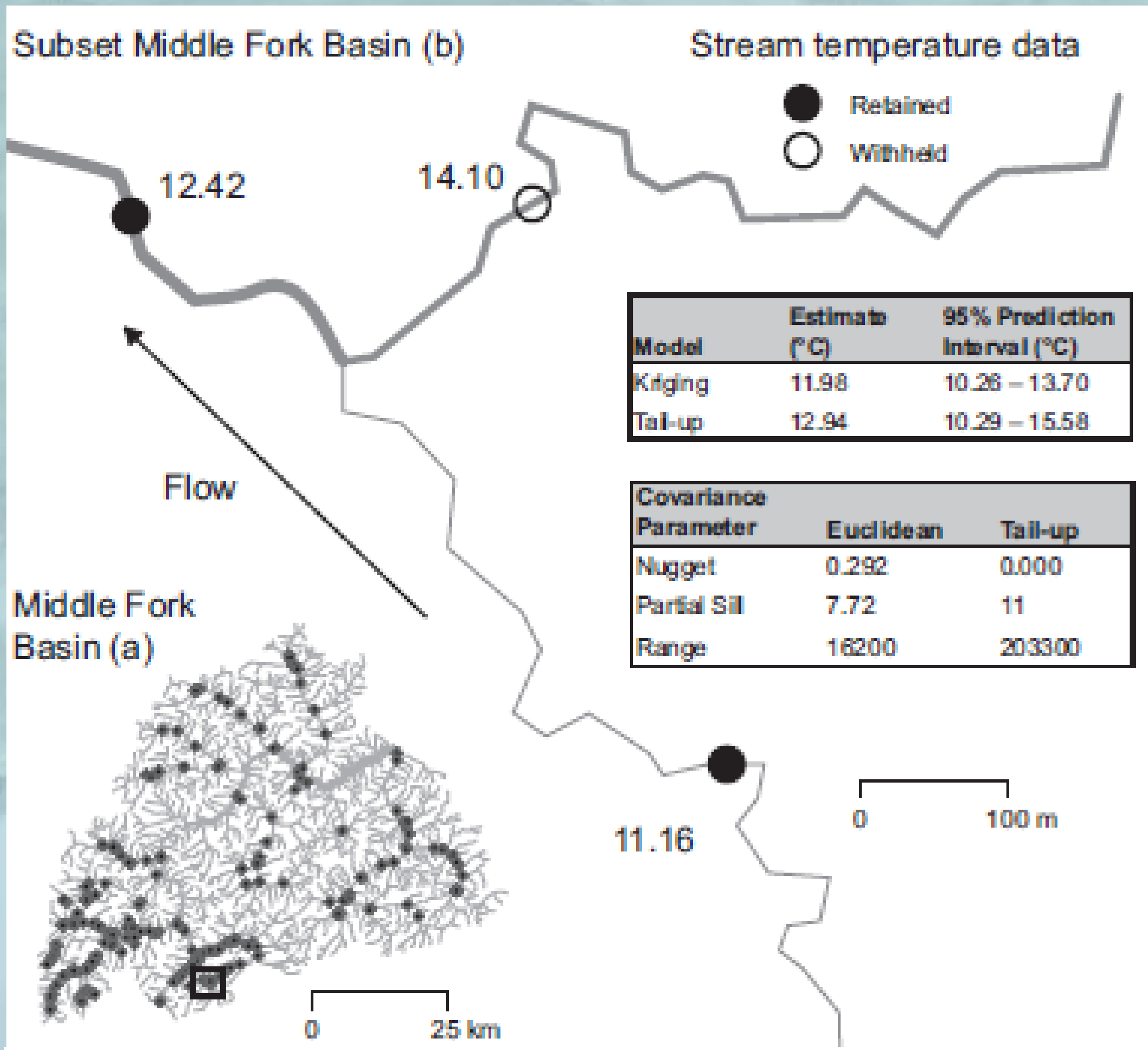
Ganio et al. 2005
Frontiers in Ecology

Flow Routing



Peterson and Ver Hoef 2010 – connectivity metrics

Network Based Prediction



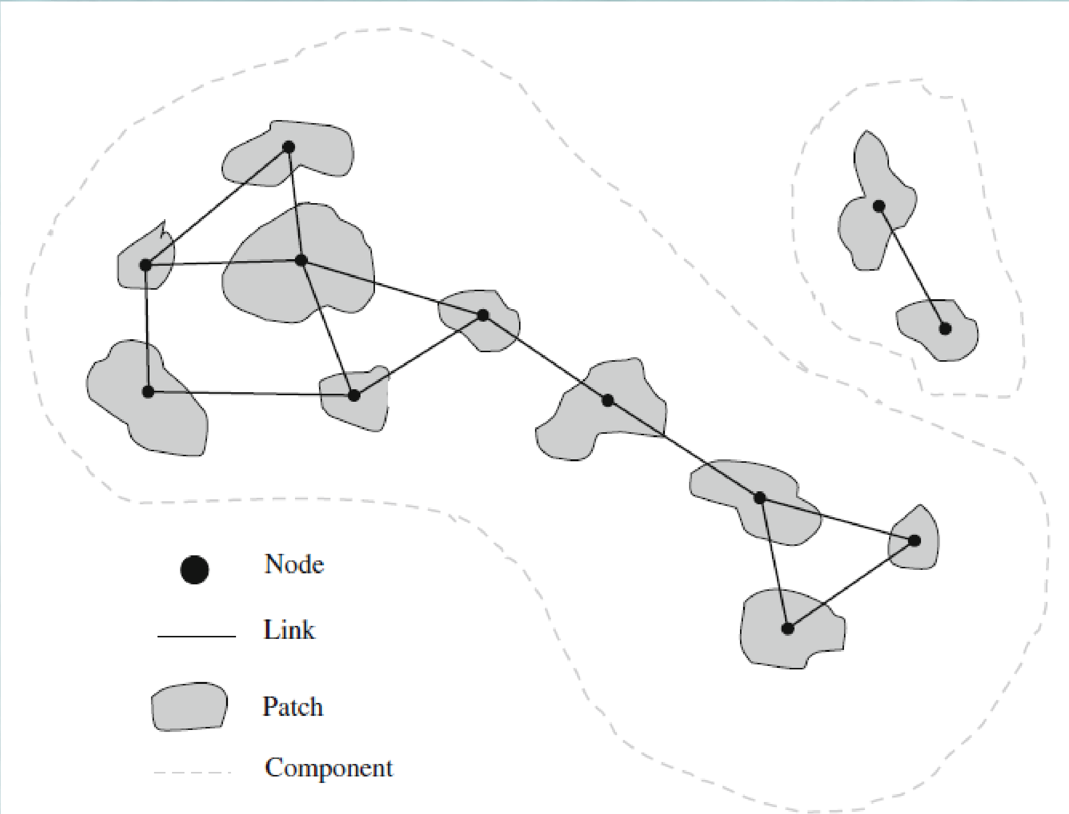
Model	Estimate (°C)	95% Prediction Interval (°C)
Kriging	11.98	10.26 – 13.70
Tail-up	12.94	10.29 – 15.58

Covariance Parameter	Euclidean	Tail-up
Nugget	0.292	0.000
Partial Sill	7.72	11
Range	16200	203300

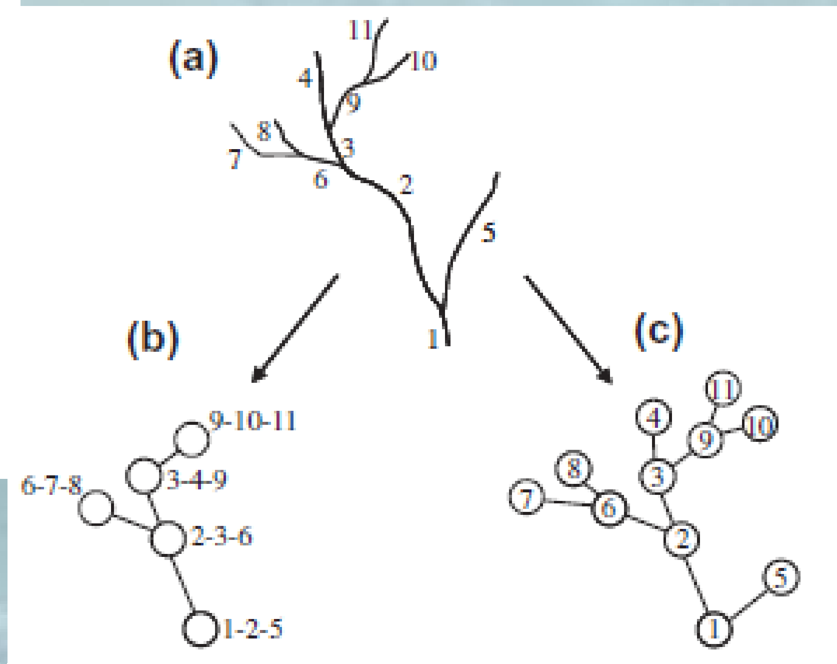
Peterson et al. 2013 Ecology Letters

Statistical Innovations

Graph Theory



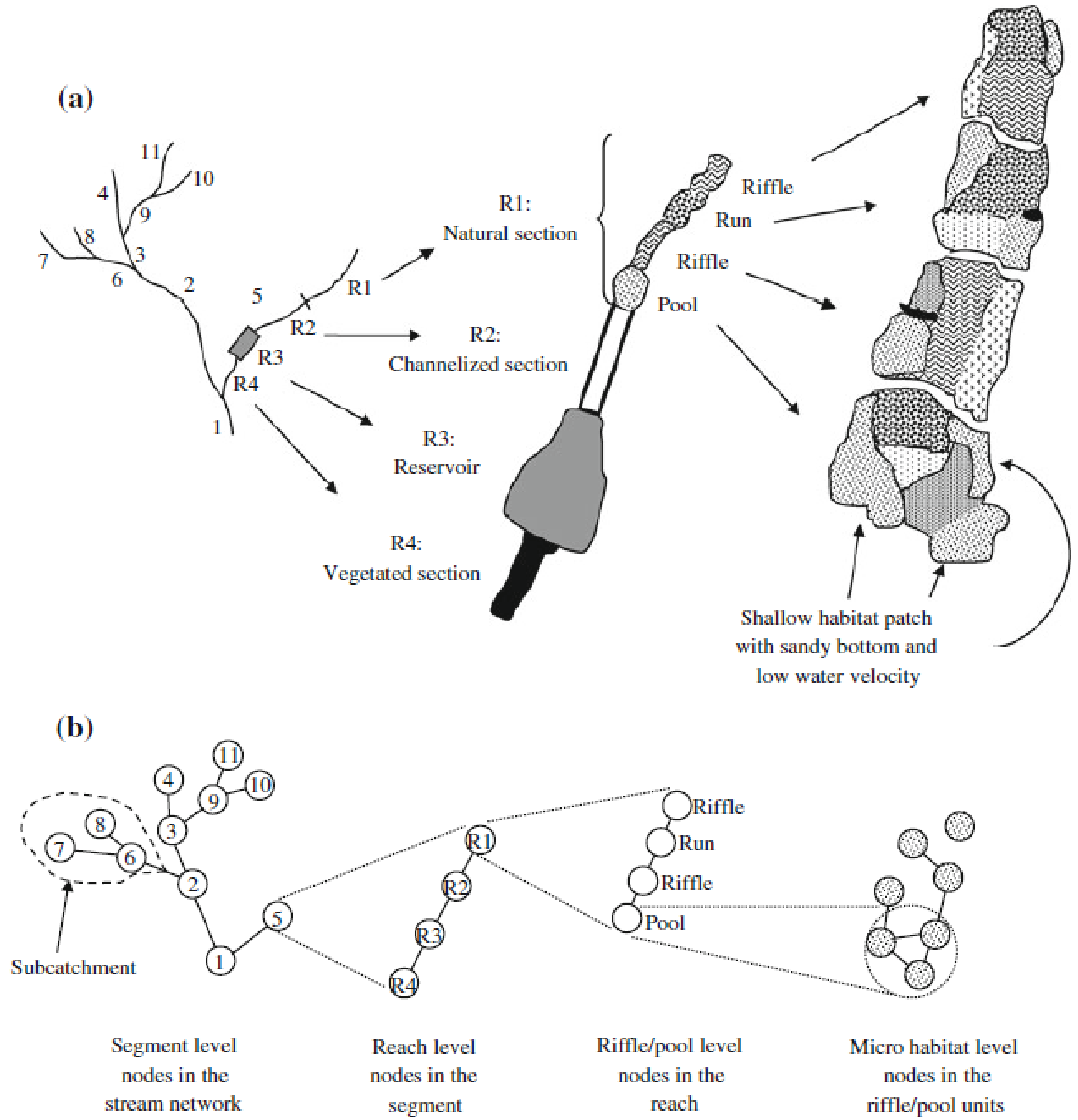
Eros et al. 2011 Landscape Ecology



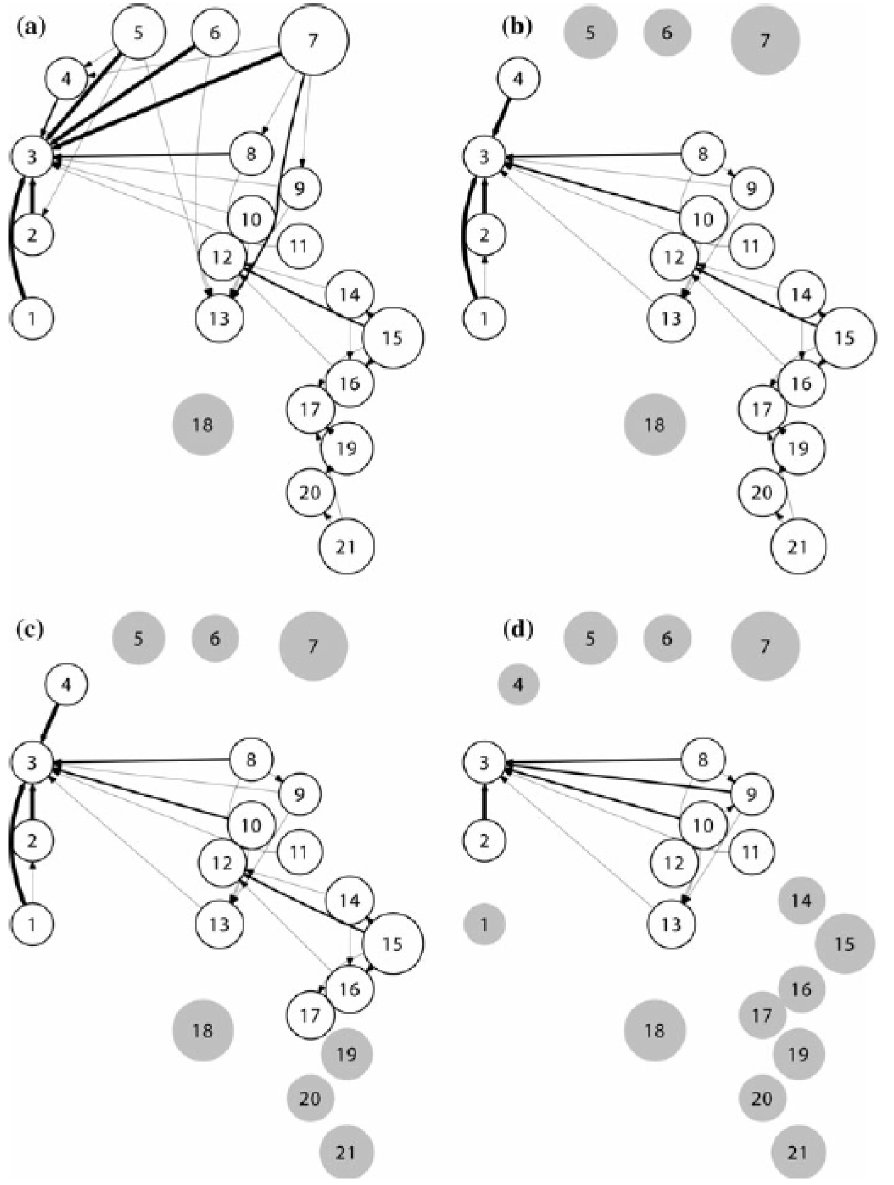
Eros et al. 2011 Biological Conservation

Graph Theory

Stream Hierarchy



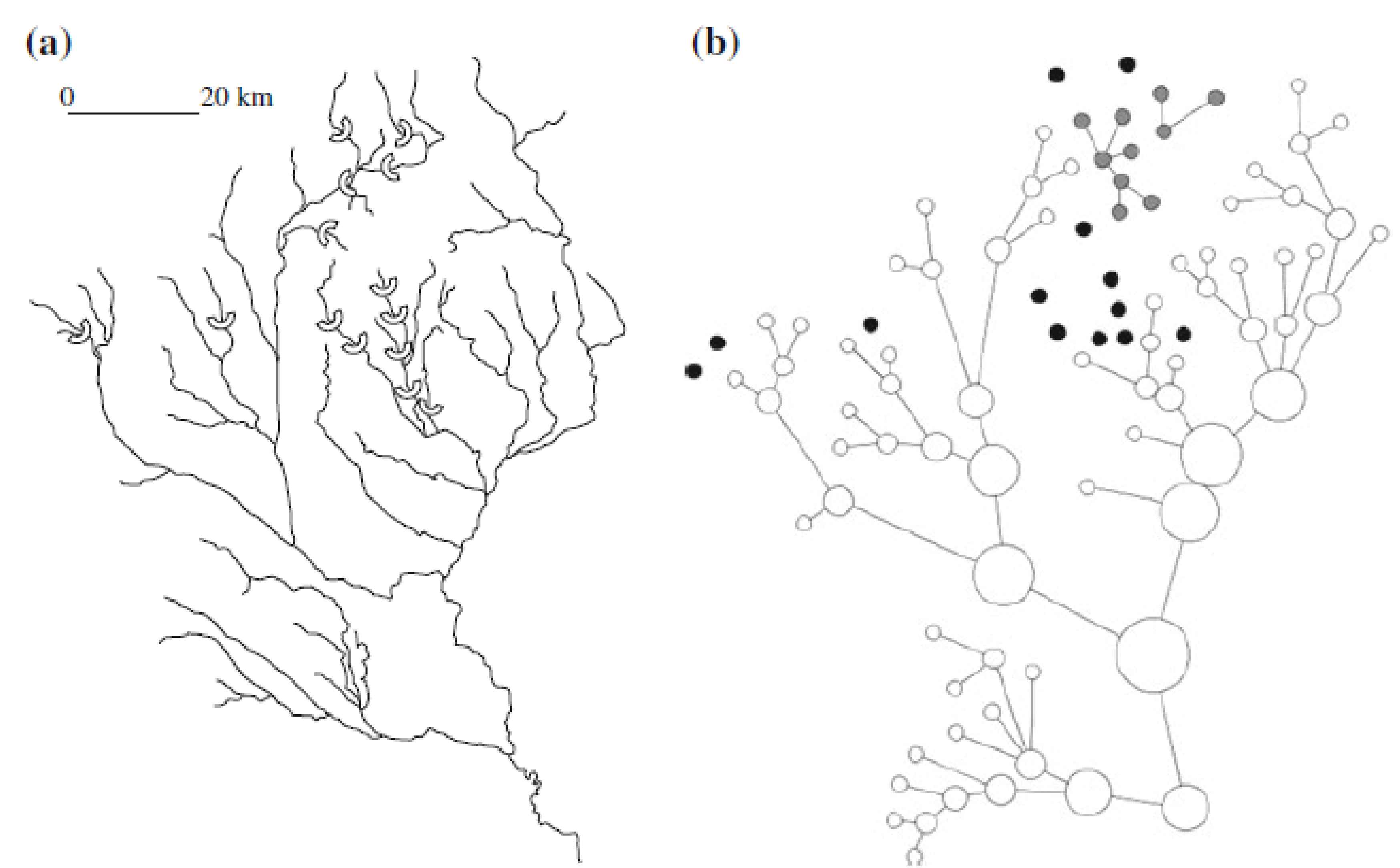
Eros et al. 2011 Landscape Ecology



Eros et al. 2011 Landscape Ecology

Fragmentation

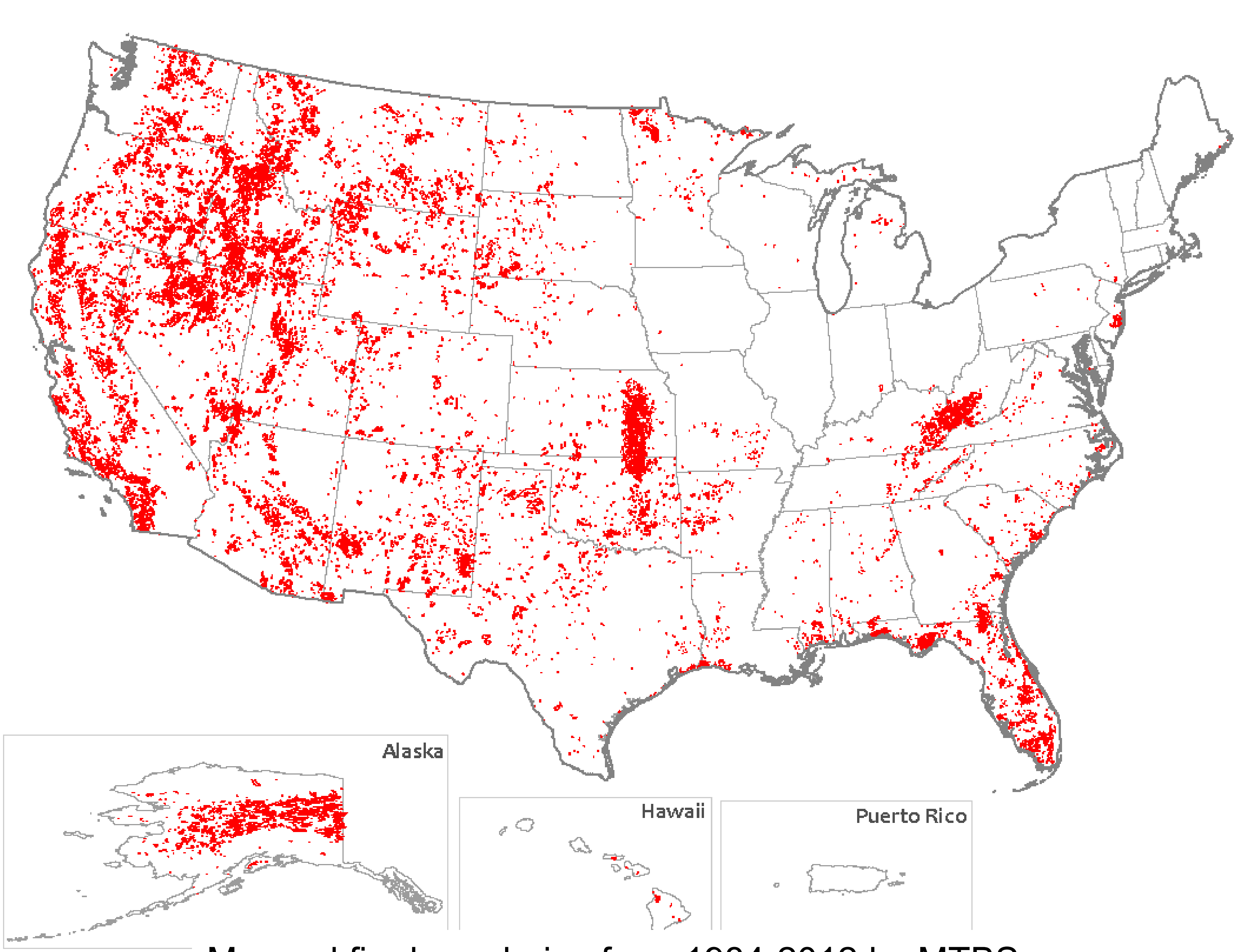
Weighted Graphs



Eros et al. 2011 Landscape Ecology

Why this matters

- So *ecology* drives analysis, rather than available statistics.

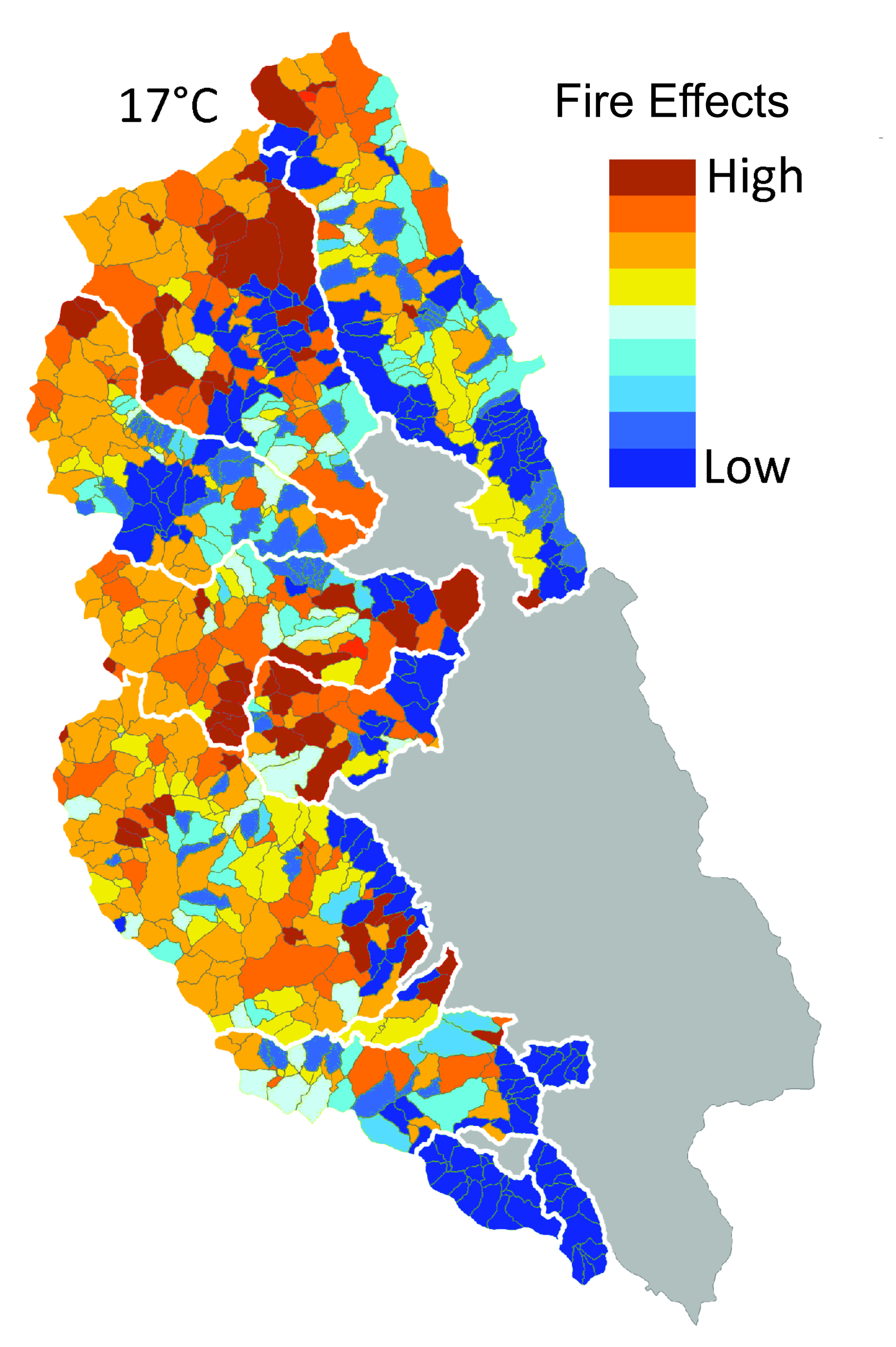


Mapped fire boundaries from 1984-2012 by MTBS

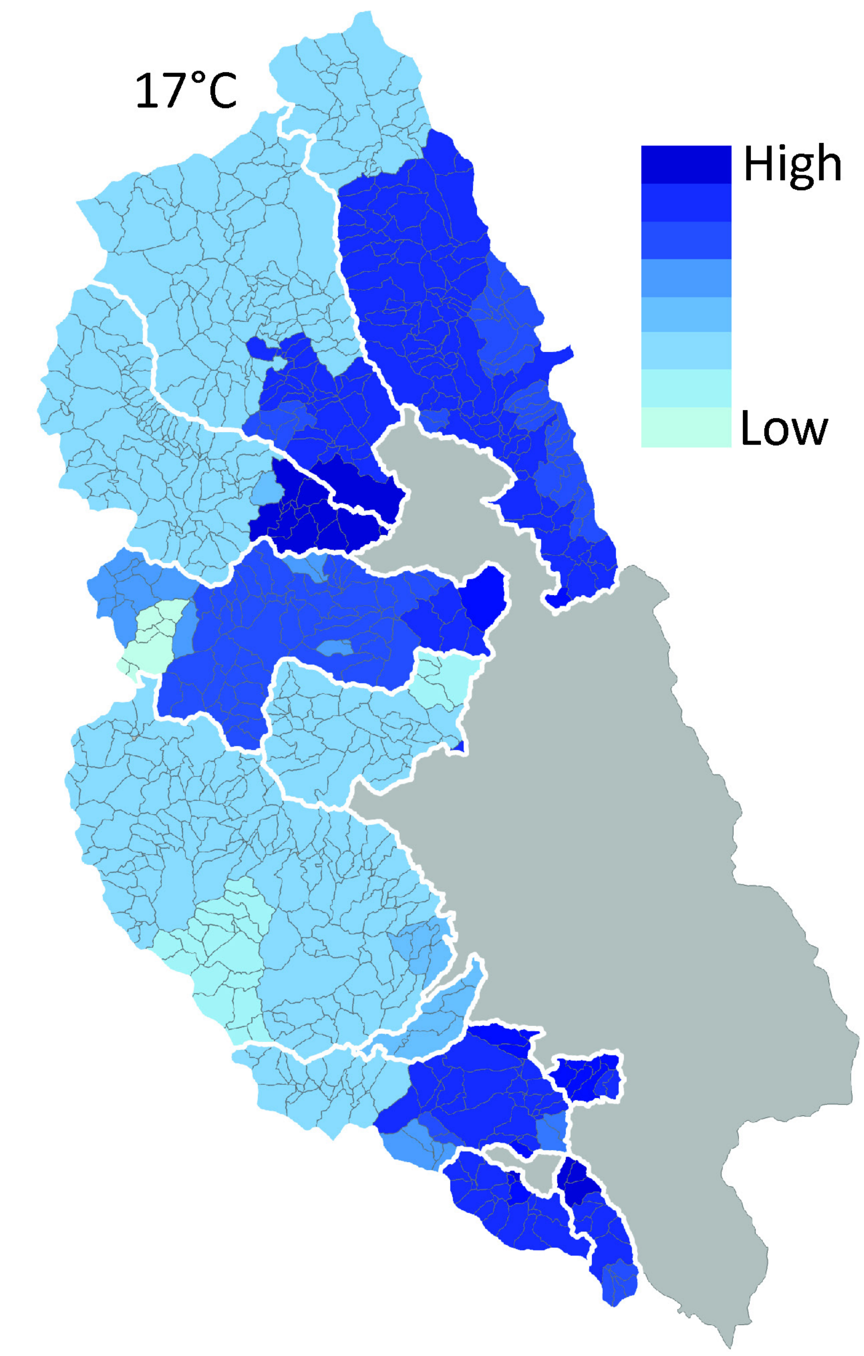
Bull Trout Fire Effects

-Fire likelihood
-Pre-fire Habitat

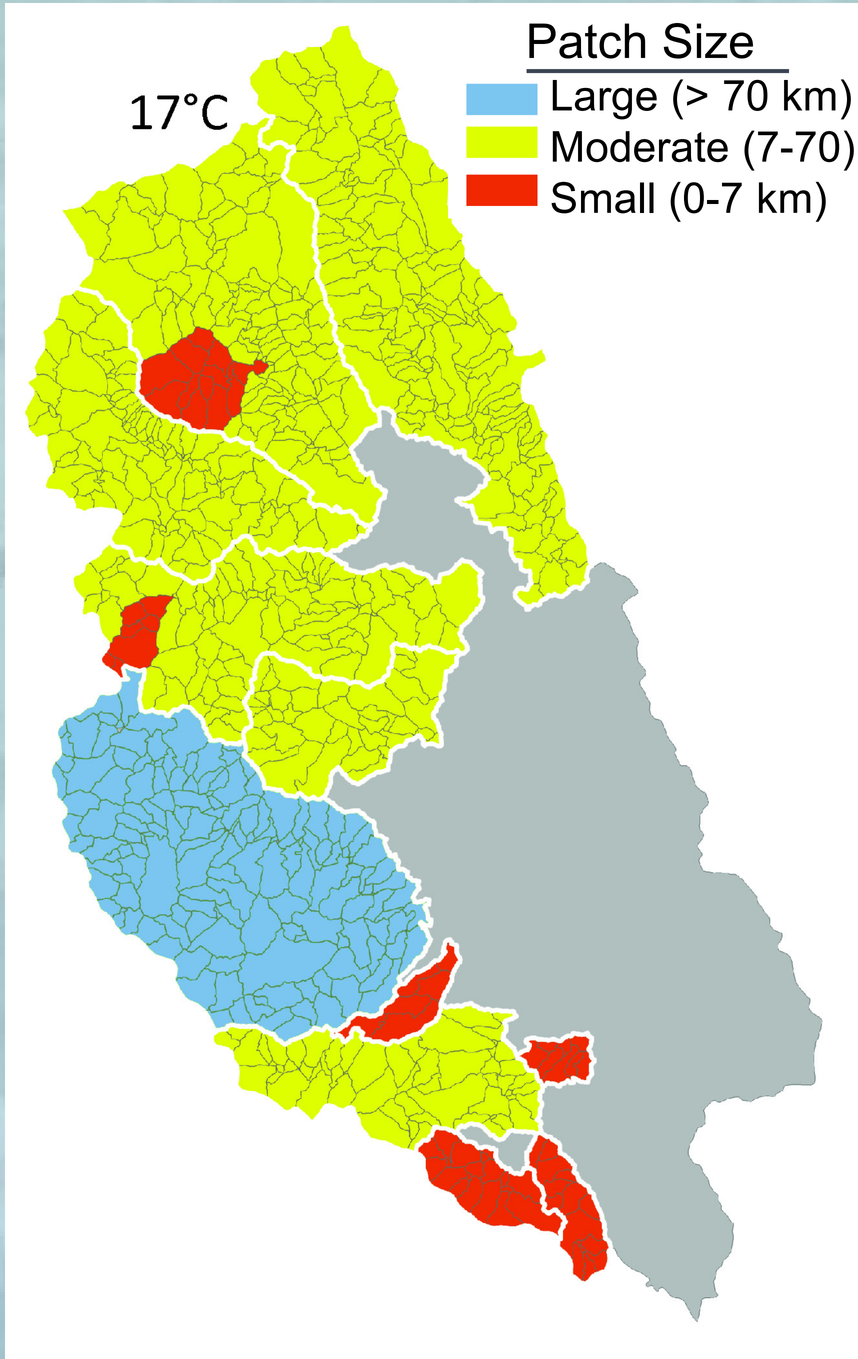
Post-Fire Habitat



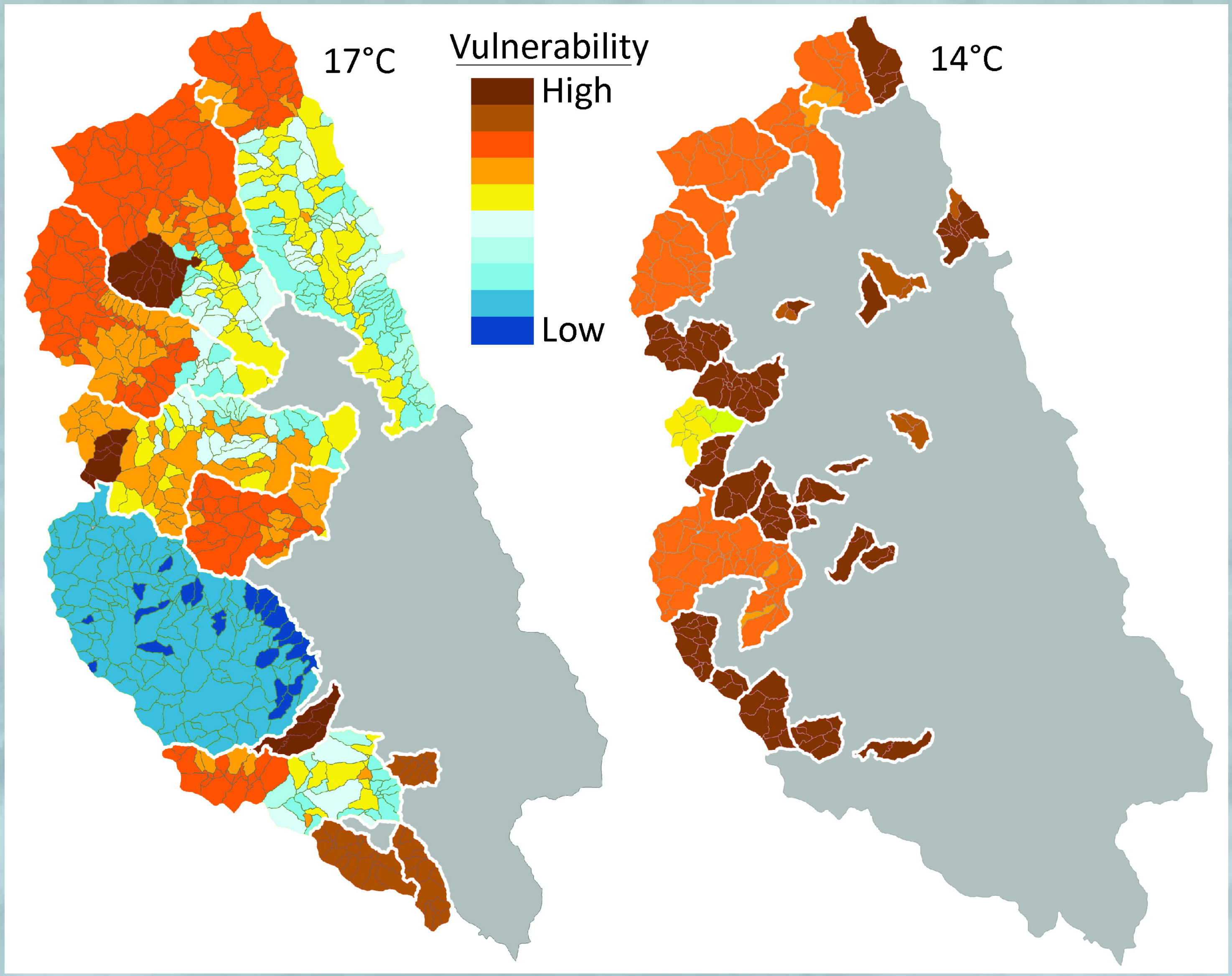
External Recolonization Potential



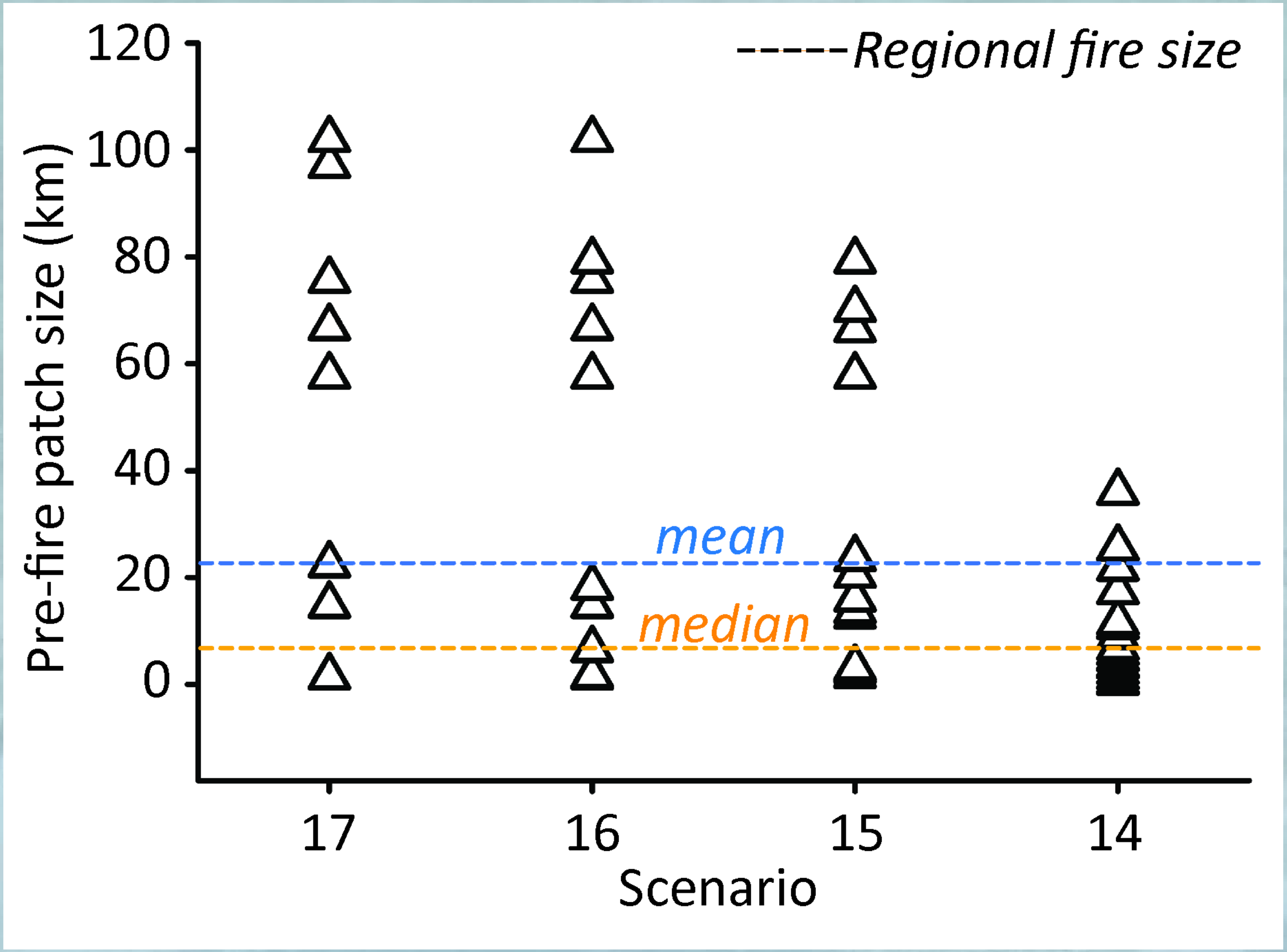
Internal Recolonization Potential



Vulnerability

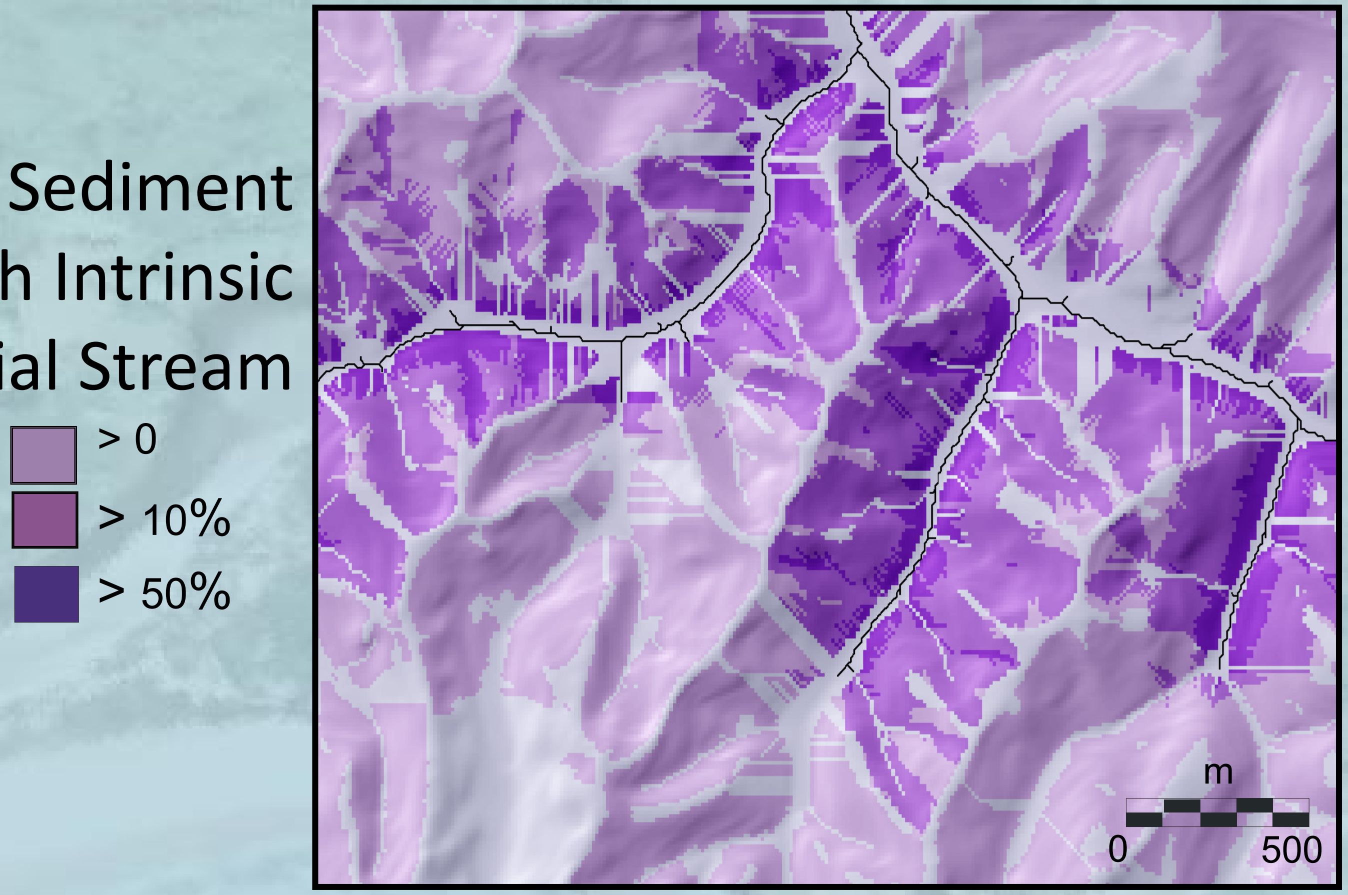


Patch and Fire Size



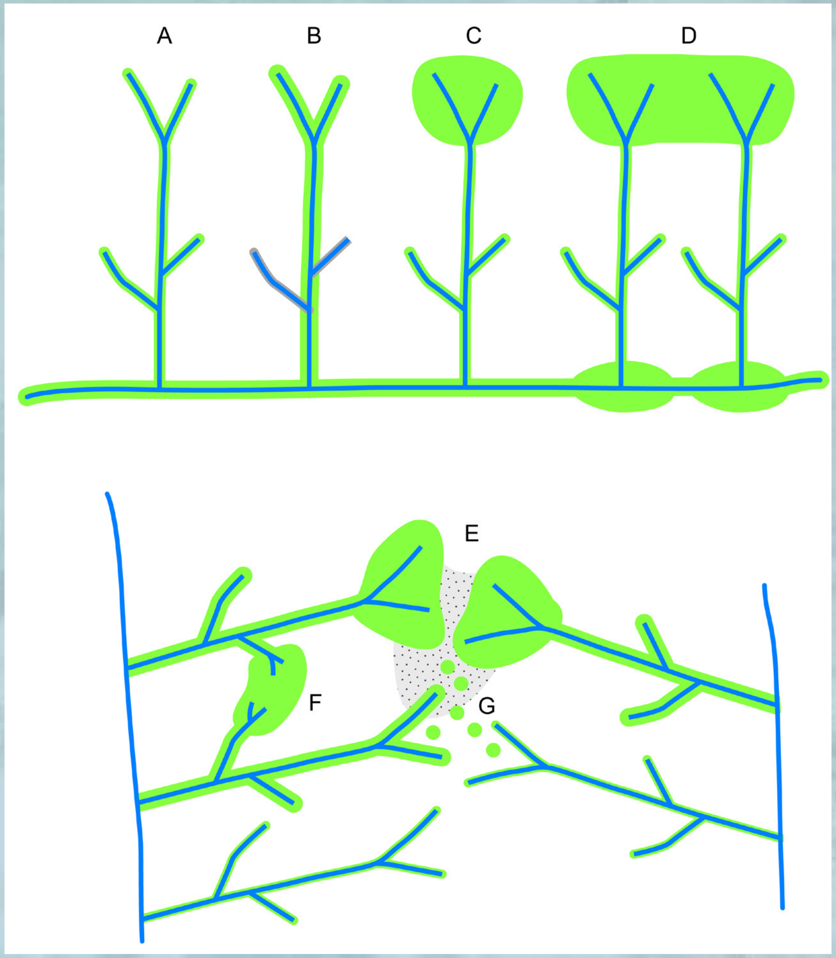
Combining Upslope with In-Stream

Probability of Sediment Delivery to High Intrinsic Potential Stream

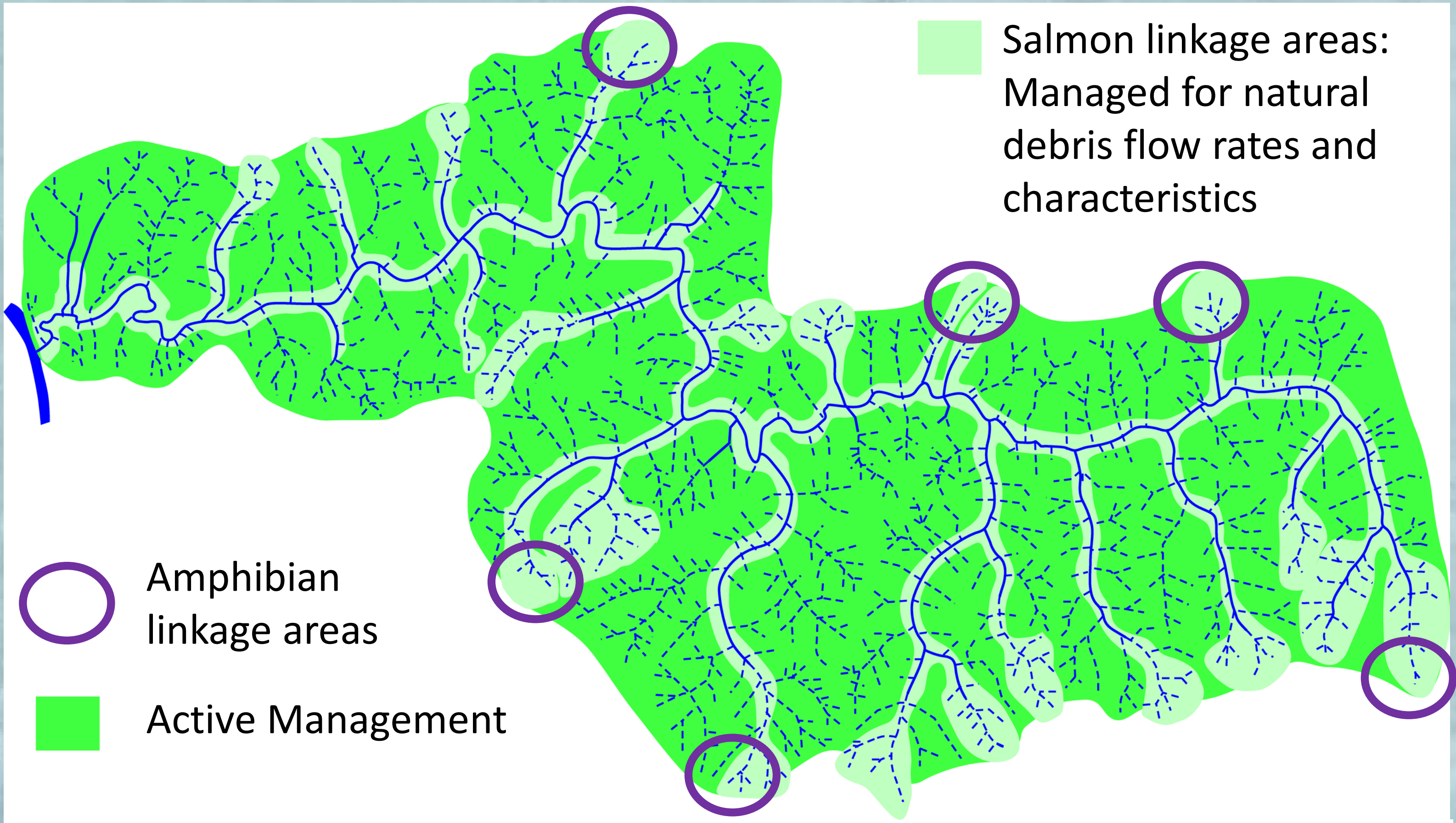


Olson and Burnett 2009

Linkage Areas for Amphibian Dispersal



Multispecies management across scales



Olson and Burnett 2009

Conclusions

- The complexity of issues surrounding freshwater systems requires the development of new, innovative, and creative analytical and managerial approaches.
- While continuing to challenge our thinking, multi-scale spatial and temporal work focusing on entire stream networks is an expanding area of research.