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

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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
Oregon Coast Range

Southern Yemen

Photo from NASA; Ganio et al. 2005
Features of a Stream Network

- Interconnected
- Directionality of flow for biotic and abiotic elements
- All elements of the network are related to one another
Ecological Concepts: Landscapes to Riverscapes

Wiens 2002
Similar Challenges in Analysis of Rivers and Landscapes

1. Scale-dependence

Wiens 1989 Functional Ecology
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
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

(a) Studies evaluating connectivity

(b) Connectivity studies in aquatic systems

Fullerton et al. 2010, Freshwater Biology 55:2215-2237
Spatial Extent in River Networks

Sub-Network

Segment

Sub-Catchment

Network

Catchment

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
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

PCA 2002 Network Variables

- △ Decrease
- △ Increase

Size of triangle corresponds to distance to spawning.

- smaller ← Distance to spawning → greater
- smaller ← Distance to rearing → greater
Statistical Innovations Network Structure

Ganio et al. 2005
Frontiers in Ecology
Variogram Patterns

North Fork Alsea (73.53 km)
Alsea River Basin
Detrended Juvenile Coho Salmon Density

Estimated Range

95% Confidence Interval

Distance (m)

gamma

Distance (m)

0 2000 4000 6000 8000 10000 12000

0.0 0.2 0.4 0.6
Nested Spatial Structure?

Five Rivers (299.95 km)
Alsea River Basin
Detrended Juvenile Coho Salmon Density

gamma

Distance (m)

0 5000 10000 15000

0.0 0.2 0.4 0.6 0.8

2001

“Hump”
(Ettema and Wardle 2002)
Extent Matters

Ganio et al. 2005
Frontiers in Ecology
Flow Routing

Peterson and Ver Hoef 2010 – connectivity metrics
Network Based Prediction

Peterson et al. 2013 Ecology Letters
Graph Theory
Stream Hierarchy

Eros et al. 2011 Landscape Ecology
Fragmentation

Eros et al. 2011 Landscape Ecology
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

Map showing fire effects with color codes:
- High
- Low

17°C

Image of fire in forest.
External Recolonization Potential

Internal Recolonization Potential

Patch Size
- Large (> 70 km)
- Moderate (7-70)
- Small (0-7 km)
Patch and Fire Size

- **Regional fire size**

- **Mean**

- **Median**

**Pre-fire patch size (km)**

**Scenario**

- 17
- 16
- 15
- 14
Combining Upslope with In-Stream

Probability of Sediment Delivery to High Intrinsic Potential Stream

- > 0
- > 10%
- > 50%

Olson and Burnett 2009
Linkage Areas for Amphibian Dispersal
Multispecies management across scales

Salmon linkage areas: Managed for natural debris flow rates and characteristics

Amphibian linkage areas

Active Management

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.