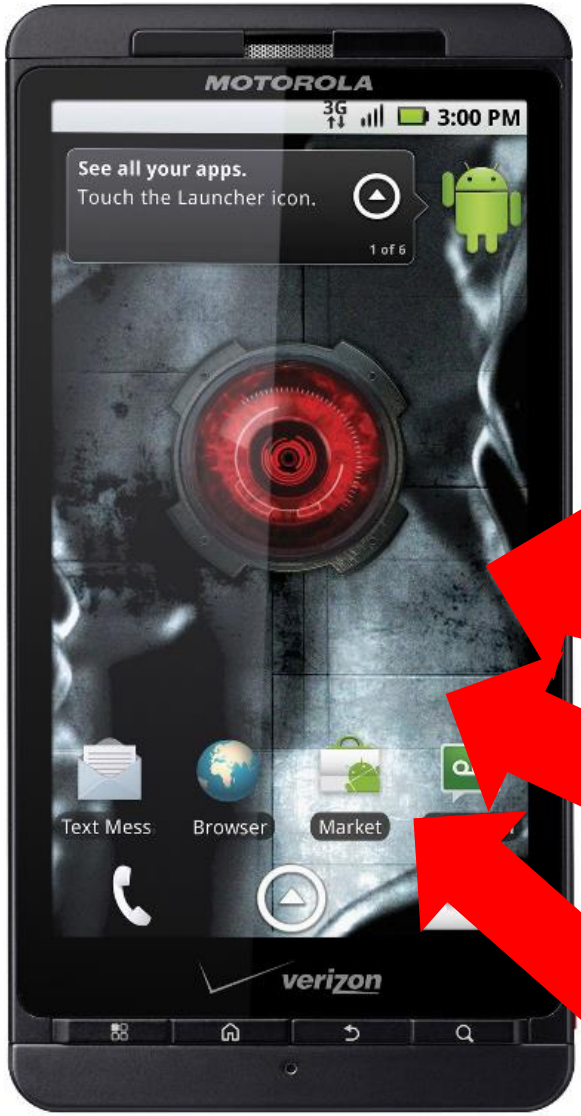
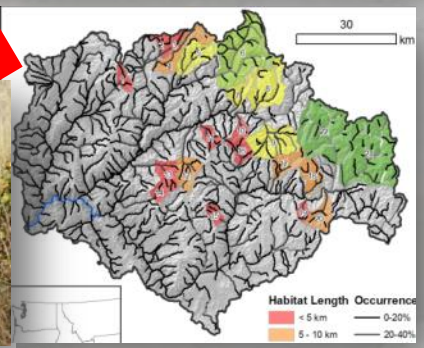
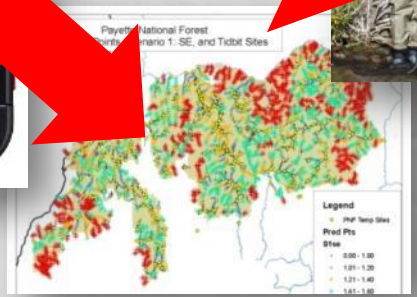
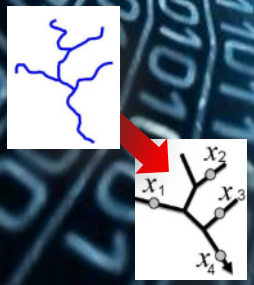
“Killer Apps” & The Stream Internet



Consistent temperature information & stream analytical infrastructure creates huge synergies…

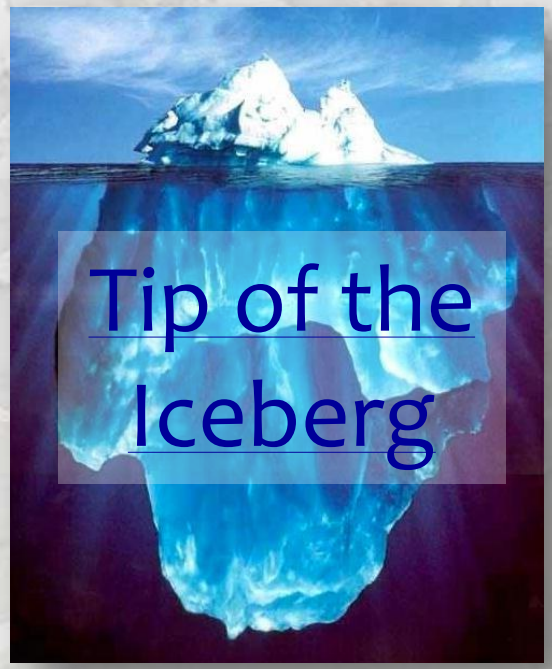


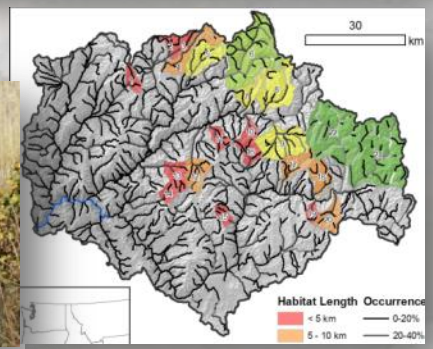


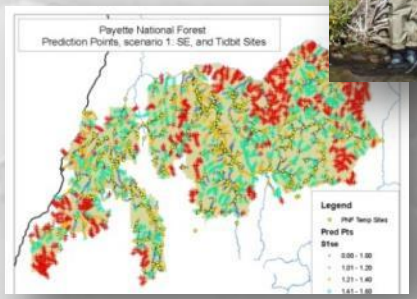


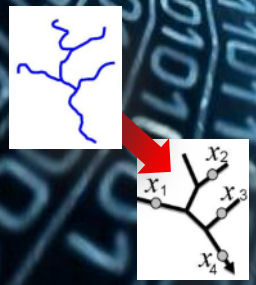
“Killer Apps” & The Stream Internet

- Block-kriging for reference site comparisons & fish population estimates
- Regionally consistent thermal niche criteria using BIG FISH data
- Precise bioclimatic models & vulnerability assessments
- Consistent river basin application of decision support tools
- Efficient temperature & biological monitoring designs









Statistical Models for Data on Stream Networks… FINALLY!

Environ Ecol Stat (2006) 13:449–464
DOI 10.1007/s10651-006-0022-8

ORIGINAL ARTICLE

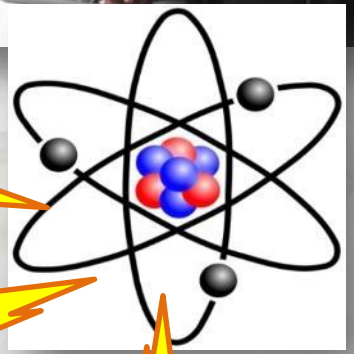
Spatial statistical models that use flow and stream distance

Jay M. Ver Hoef · Erin Peterson · David Theobald

Freshwater Biology (2007) 52, 267–279 doi:10.1111/j.1365-

Geostatistical modelling on stream networks: developing valid covariance matrices based on hydrologic distance and stream flow

ERIN E. PETERSON,* DAVID M. THEOBALD† AND JAY M. VER HOEF‡

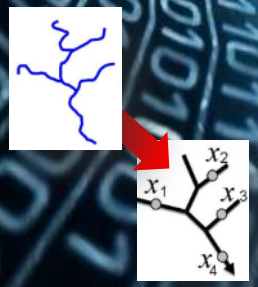


Functional Linkage of Water basins and Streams (FLoWS) v1 User's Guide:

ArcGIS tools for Network-ba

Contact info:

Authors:
David M. Theobald
John B. Norman
E. Peterson
S. Ferraz
A. Wade
M.R. Sherburne

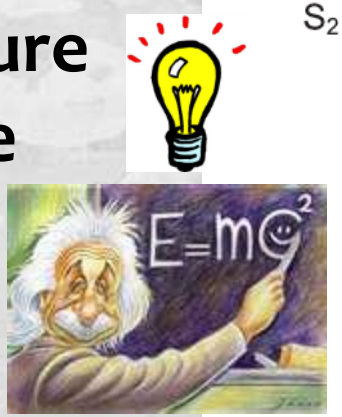


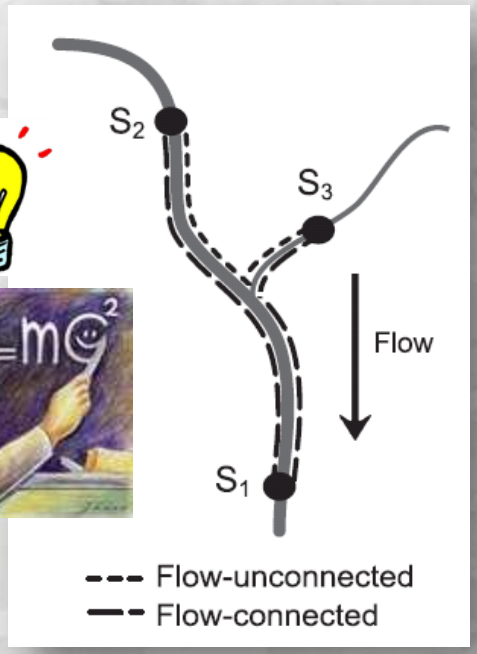
Spatial modelling and prediction on river networks: up model, down model or hybrid?

Vincent Garreta[1*,†], Pascal Monestiez[2] and Jay M. Ver Hoef[3]

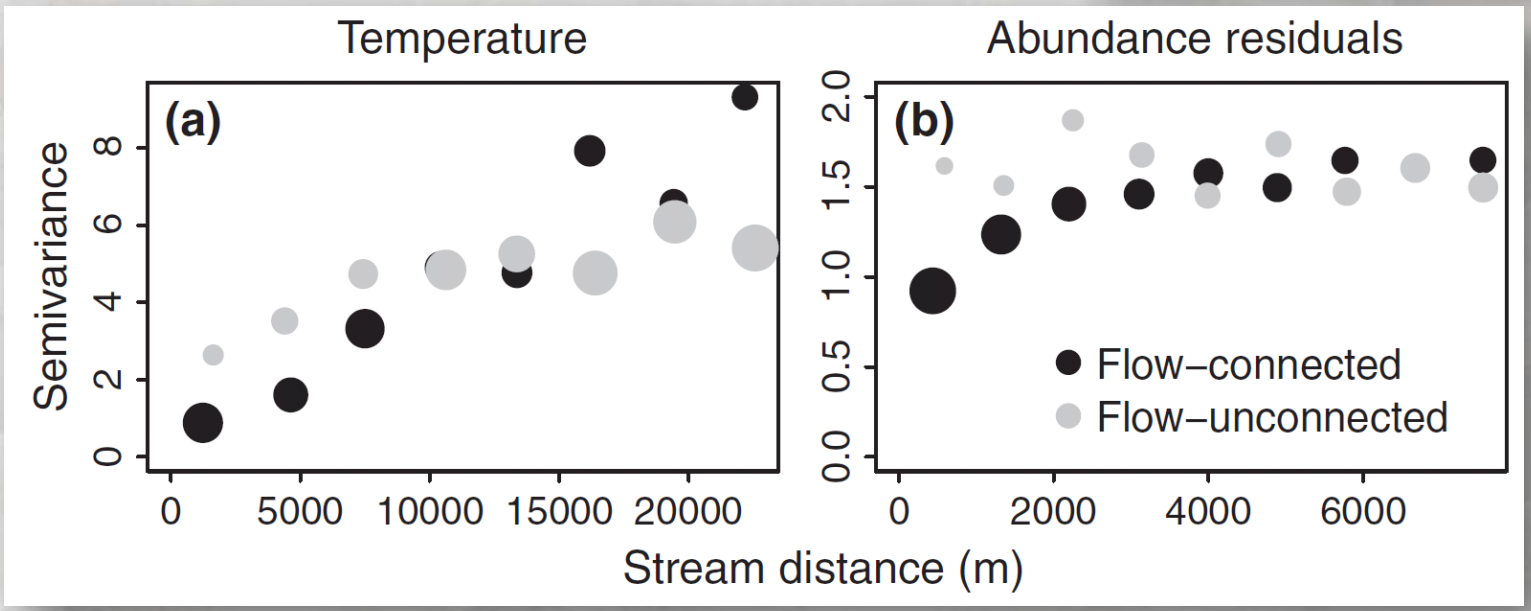
[1]*CEREGE, UMR 6635, CNRS, Université Aix-Marseille, Europôle de l'Arbois, 13545 Aix-en-Provence, France*
[2]*INRA, Unité de Biostatistique et Processus spatiaux, Domaine St Paul, Site Agroparc, 84914 Avignon Cedex 9, France*
[3]*NOAA National Marine Mammal Lab, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA*

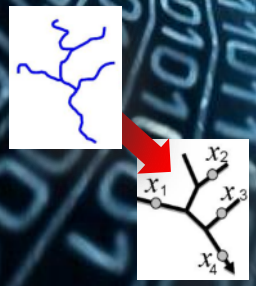
Key Innovation of Stream Models is Covariance Structure Based On Network Structure





Models "understand" how information moves among locations based on network topology



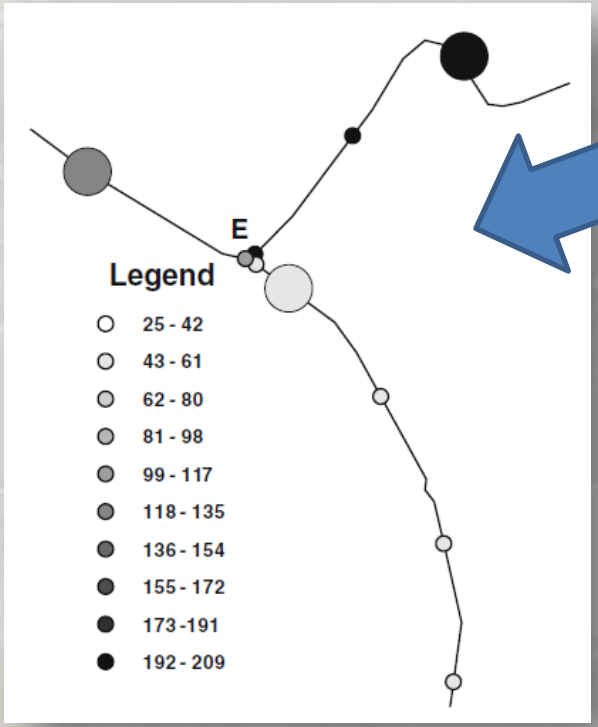


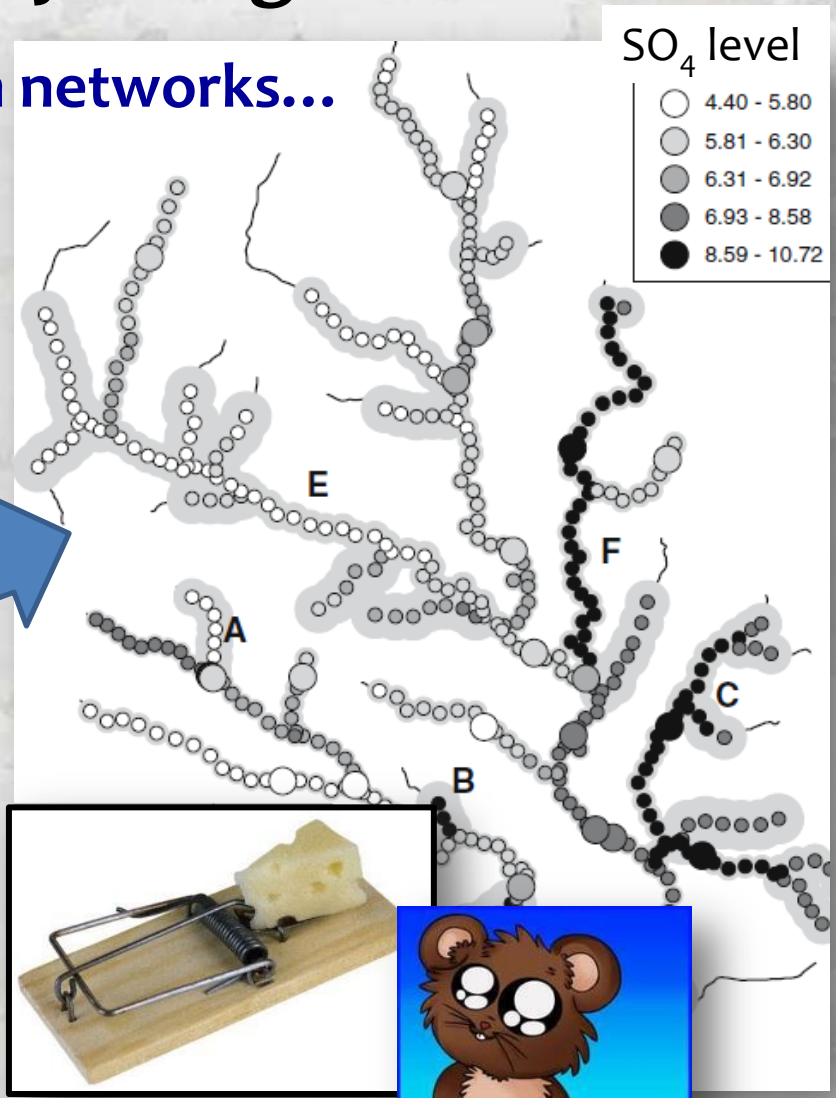
Peterson et al. 2007. *Freshwater Biology* **52**:267-279;
Peterson & Ver Hoef. 2010. *Ecology* **91**:644-651.

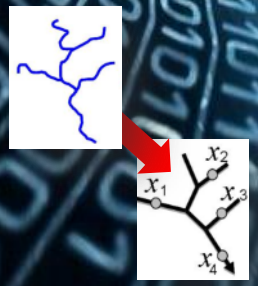
Stream Network Models are Simply Better Mousetraps for Many Things…

Gradual trends within networks…

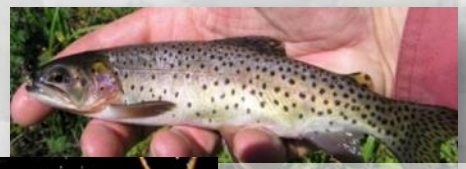
…but also changes at tributary confluences







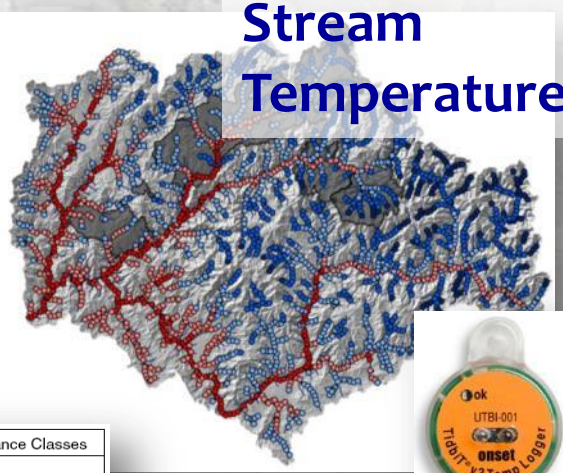
Stream Models are Generalizable…

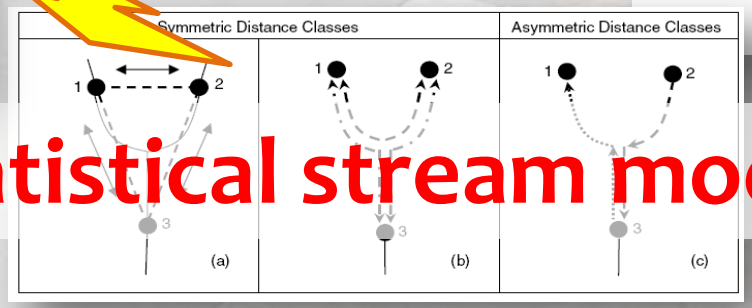


Distribution & abundance

Response Metrics
- Gaussian
- Poissan
- Binomial

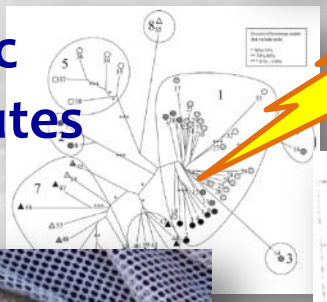
Stream Temperature

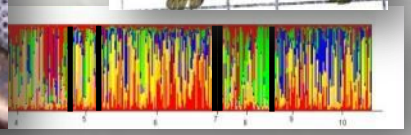




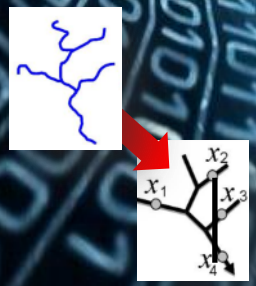
Statistical stream models

Genetic Attributes



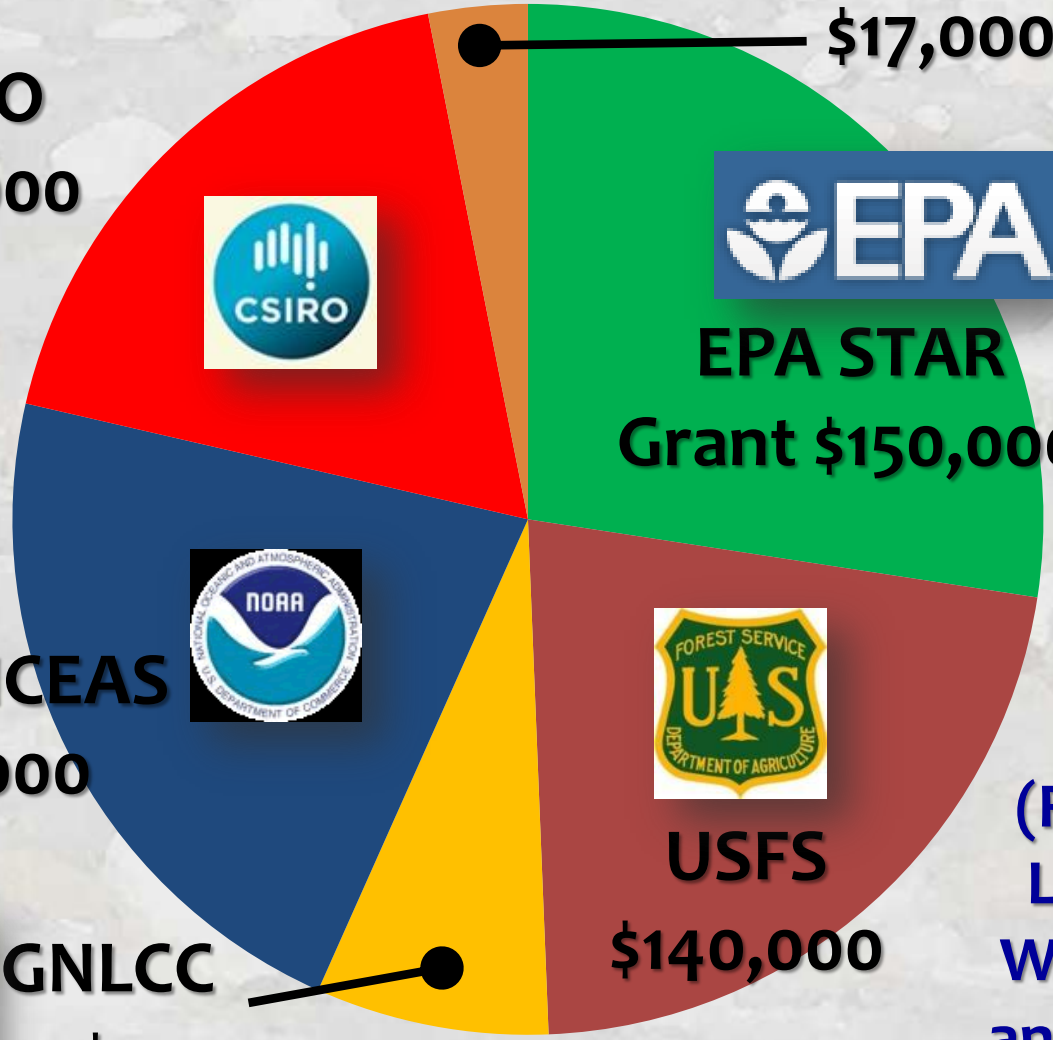


Water Quality Parameters



Development Costs & Lineage

Spatial Network Tools: $560,000



$17,000

CSIRO
$120,000

EPA STAR
Grant $150,000

NOAA/NCEAS
$100,000

USFS
$140,000

GNLCC
$40,000

FLoWS
(Functional
Linkage of
Waterbasins
and Streams)

Spatial Stream Statistics Working Group

NCEAS
National Center for Ecological Analysis and Synthesis

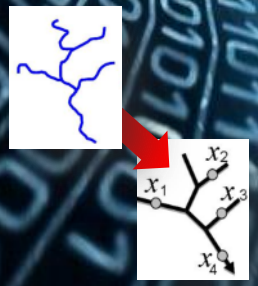
Isaak, D.J., E. Peterson, J. V. Hoef, S. Wenger, J. Falke, C. Torgersen, C. Sowder, A. Steel, M.J. Fortin, C. Jordan, A. Reusch, N. Som, P. Monestiez. 2014. Applications of spatial statistical network models to stream data. ***WIREs - Water 1***:xxx.

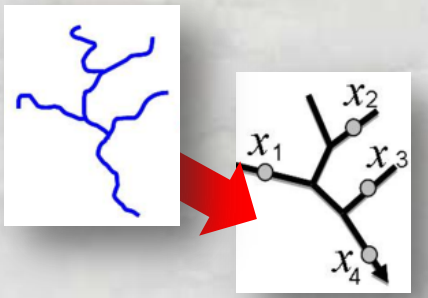
Peterson E.E. & Ver Hoef J.M. 2014. STARS: An ArcGIS toolset used to calculate the spatial information needed to fit spatial statistical models to stream network data. ***Journal of Statistical Software*** 56(2):1-17.

Peterson E.E., Ver Hoef J.M., Isaak D.J., Falke J.A., Fortin M.J., Jordan C., McNyset K., Monestiez P., Ruesch A.S., Sengupta A., Som N., Steel A., Theobald D.M., Torgersen C.T. & Wenger S.J. 2013. Modeling dendritic ecological networks in space: an integrated network perspective. ***Ecology Letters*** 16:707-719.

Som N.A., Monestiez P., Zimmerman D.L., Ver Hoef J.M. & Peterson E.E. In Press. Spatial sampling on streams: Principles for inference on aquatic networks. ***Environmetrics*** x:xxx.

Ver Hoef J.M., Peterson E.E., Clifford D. & Shah R. 2014. SSN: An R package for spatial statistical modeling on stream networks. ***Journal of Statistical Software*** 56(3):1-45.



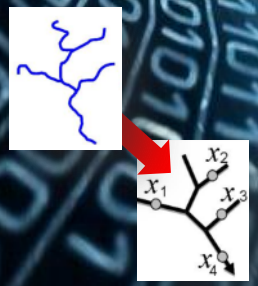


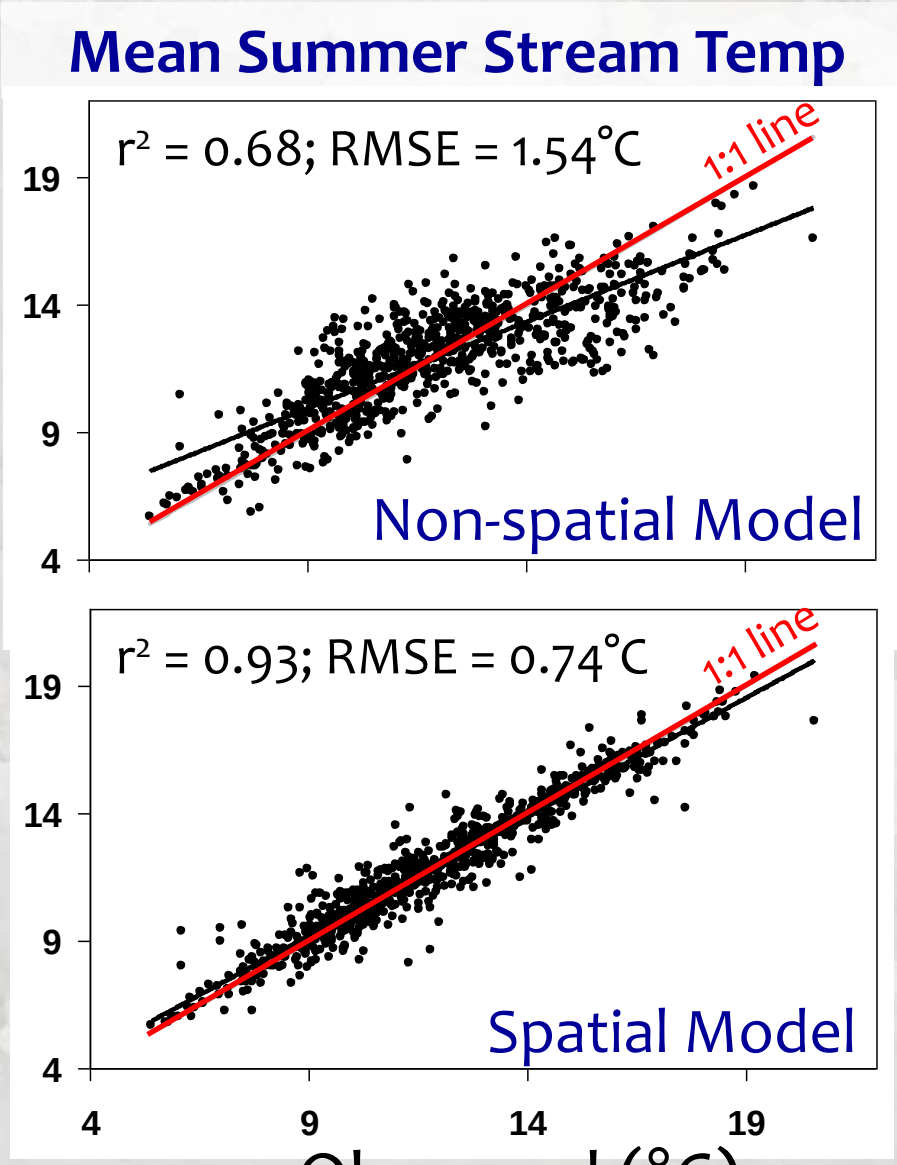
Statistically Valid, Unbiased Information from Aggregated Data

Non-spatial Stream Temp =
– 0.0064*Elevation (m)
+ 0.0104*Radiation
+ 0.39*AirTemp (°C)
– 0.17*Flow (m^3/s)

Parameter estimates are different because of autocorrelation in database

Spatial Stream Temp =
– 0.0045*Elevation (m)
+ 0.0085*Radiation
+ 0.48*AirTemp (°C)
– 0.11*Flow (m^3/s)



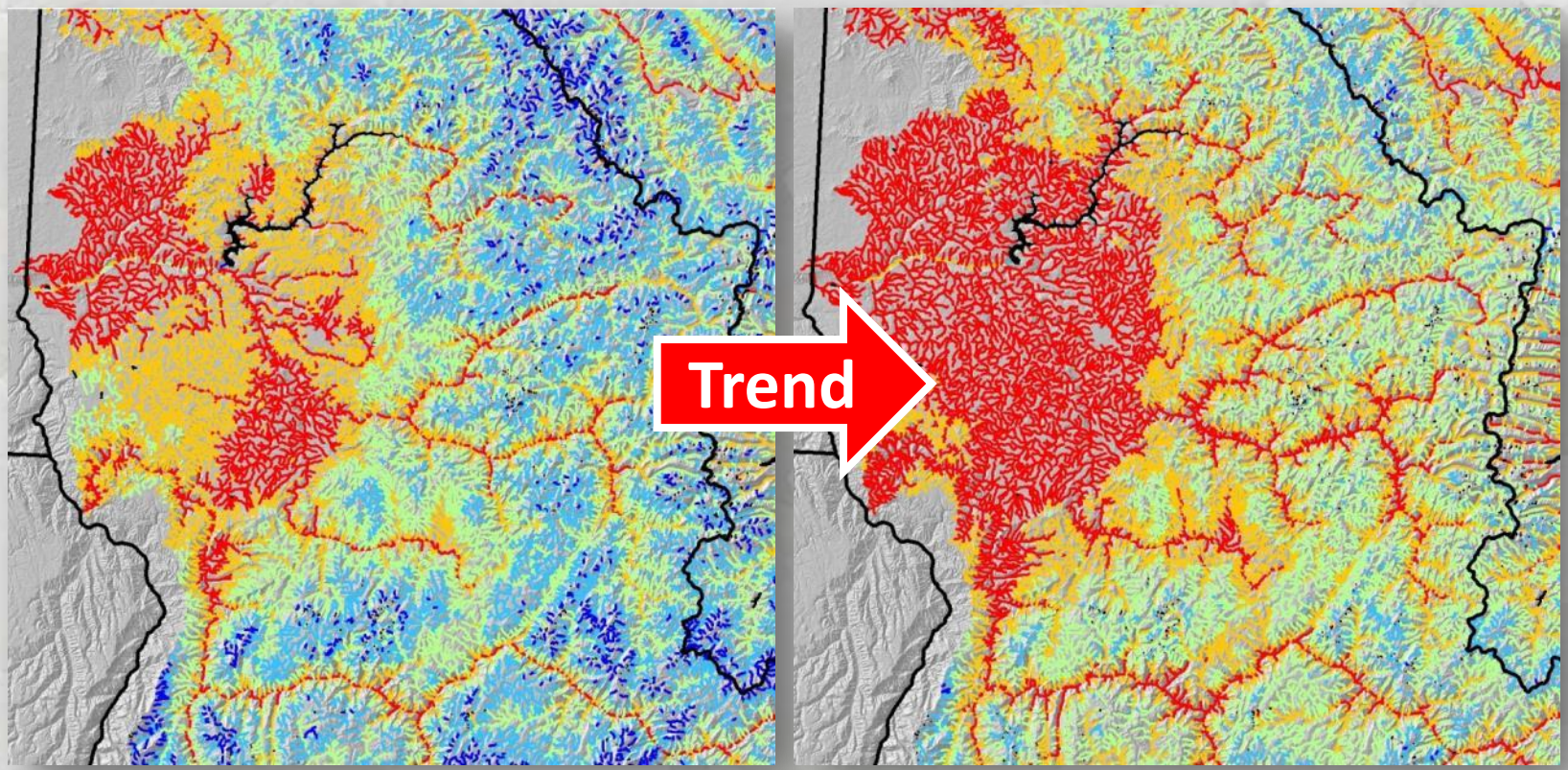


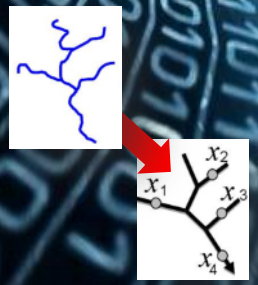
Isaak et al. 2010. *Ecol. Apps.* 20:1350-1371

Model Interpolations Provide High-Resolution Network *Status* Maps

Time 1

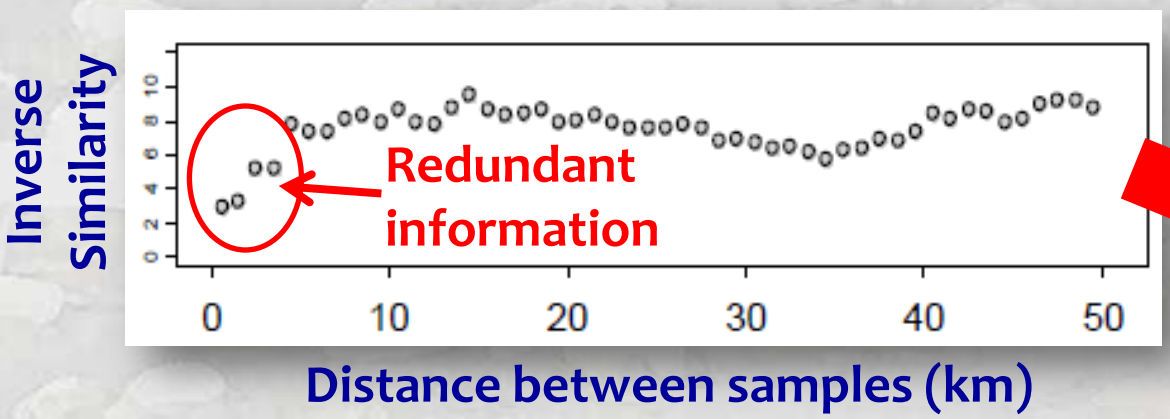
Time 2



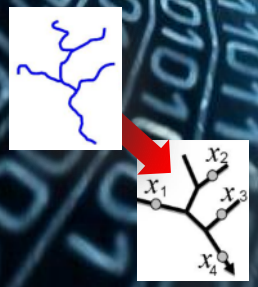


Which then facilitate *trend* assessments…

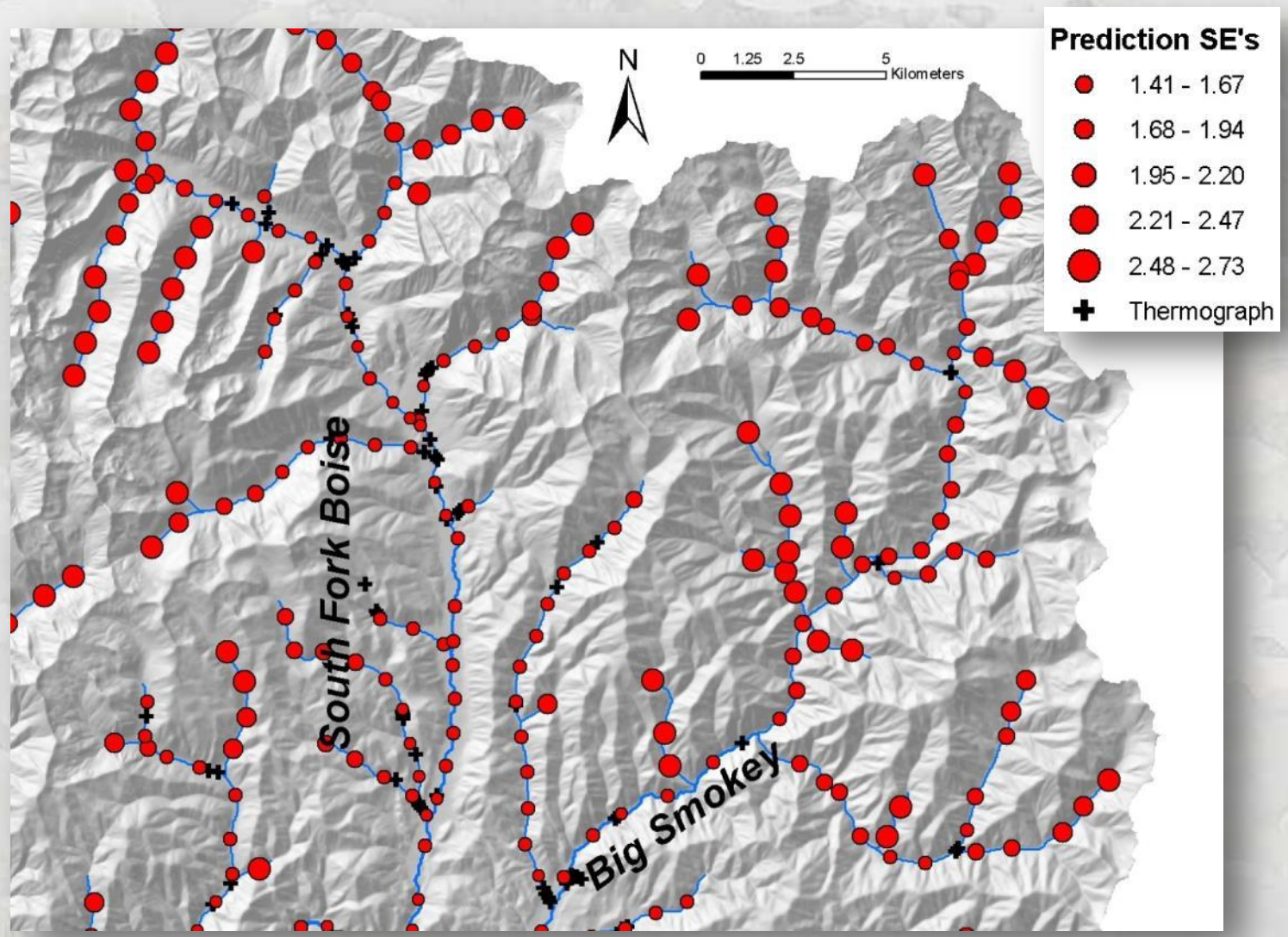
Models Describe Autocorrelation Distances

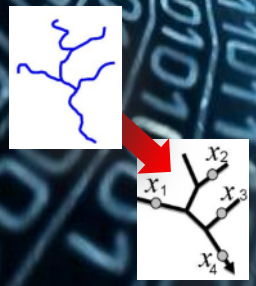


Planning of Efficient Monitoring Designs…

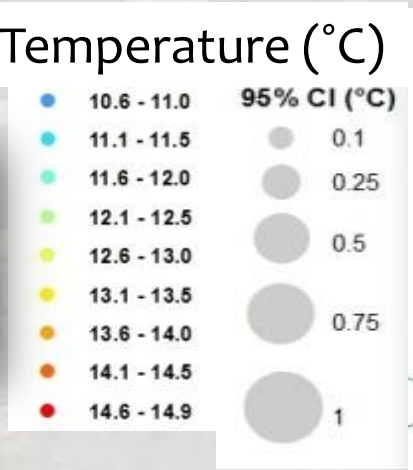


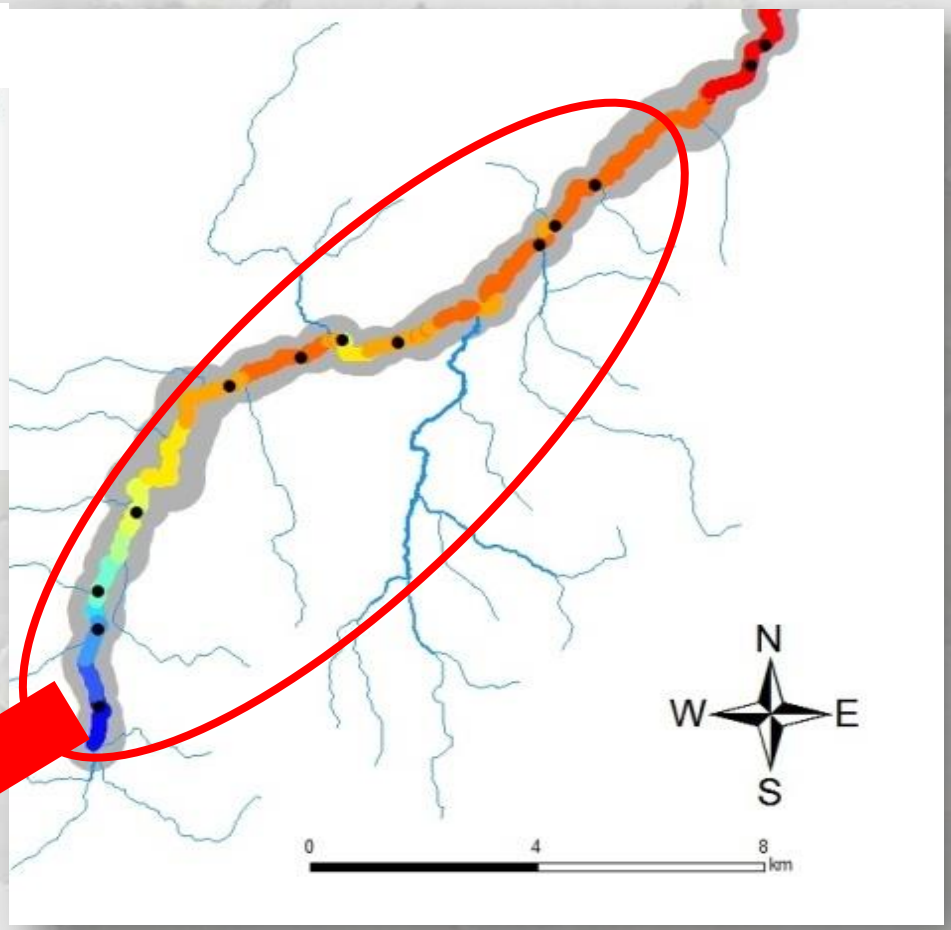
Spatial Variation in Prediction Precision



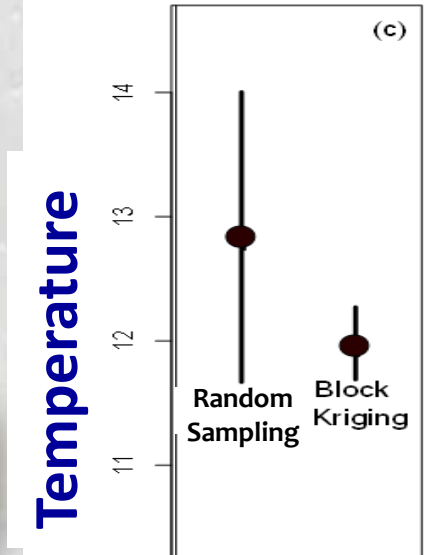


Block-krige Estimates of Mean & Variance at User-Defined Scale



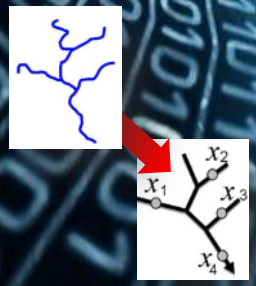


Bear Valley Creek Mean Temperature



Precise & unbiased estimates

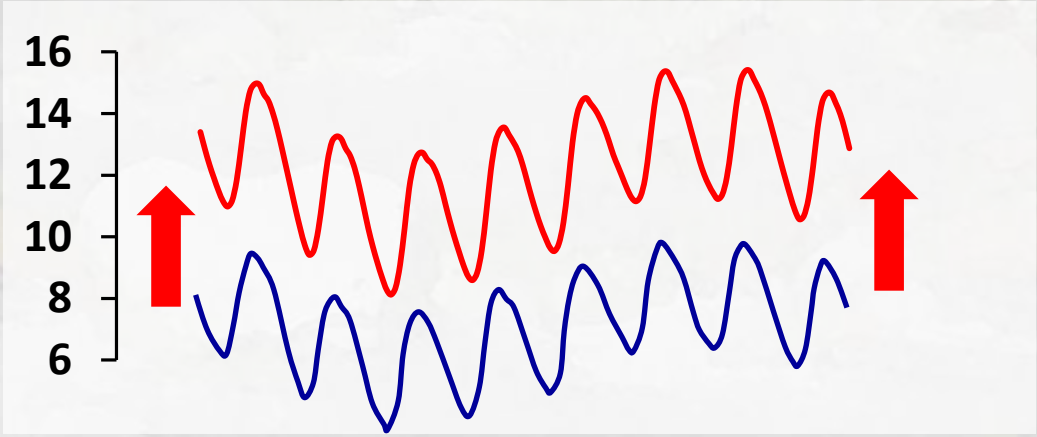
Does this reach meet the TMDL standard?

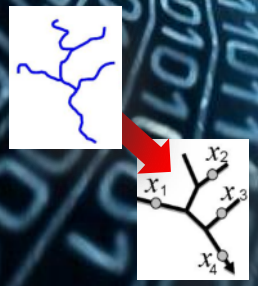


Reference Site Comparison Approach

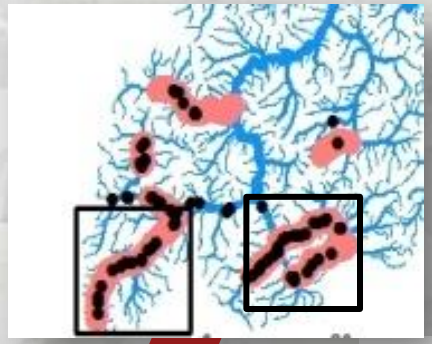
Pick “degraded” & “healthy” streams to compare

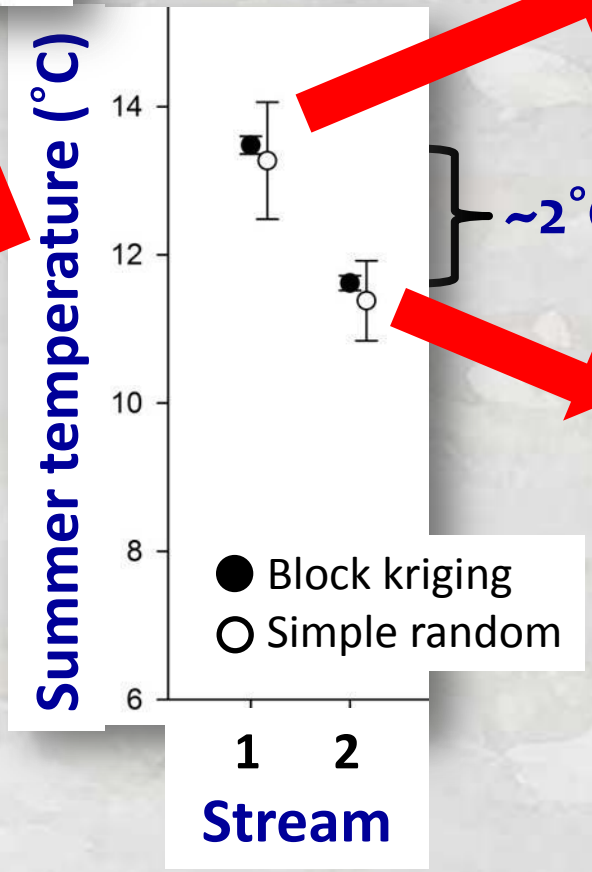
How altered is this stream?



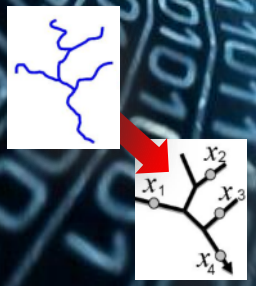


Block-Krige Estimates for Both Streams

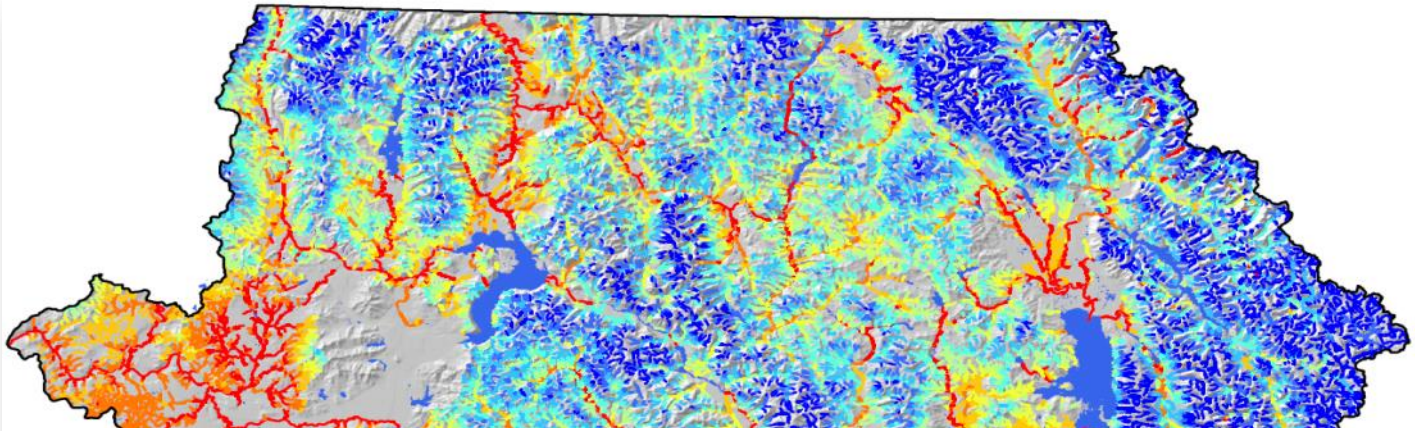




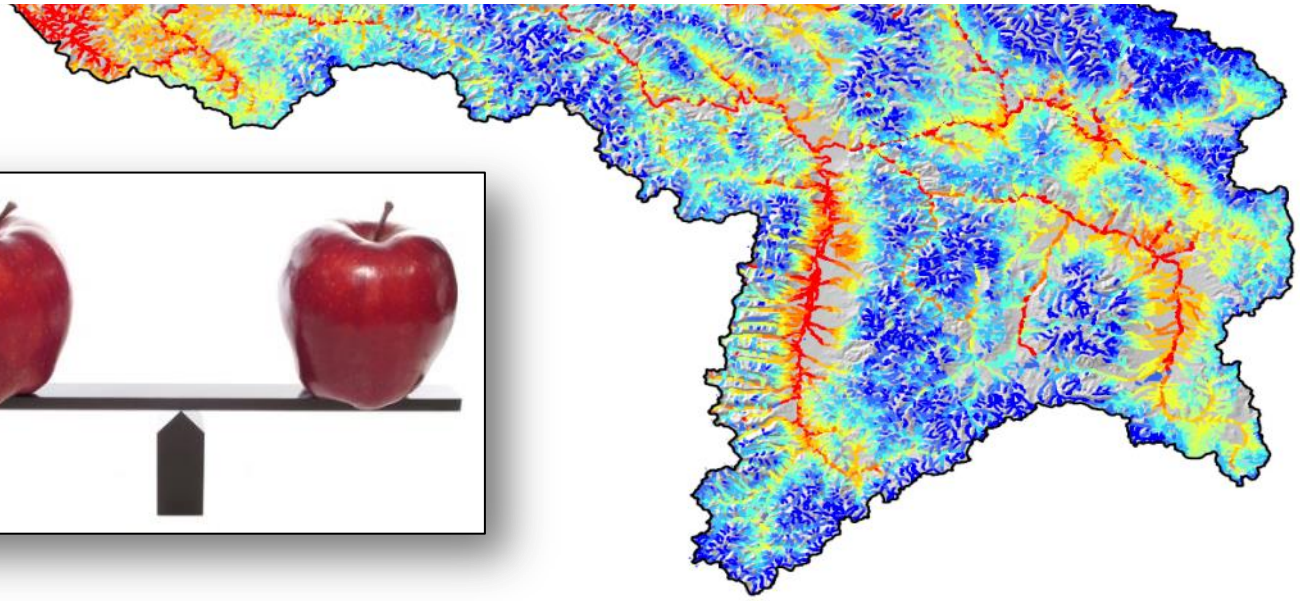
~2°C difference

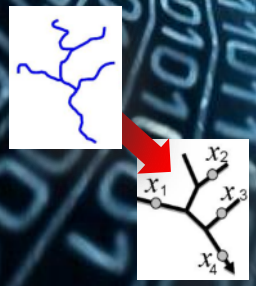


Block-Krige Estimates for Both Streams



Do so anywhere within a river network





Block-Kriging of Water Quality Maps Could Improve Impact Assessments for…

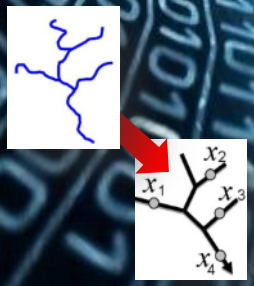
Sediment…

Urbanization…

Wildfires…

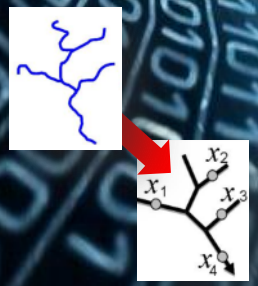
Landuse…

Mining…



Block-Kriging Fish Population Estimates

How Many Fish Live Here?



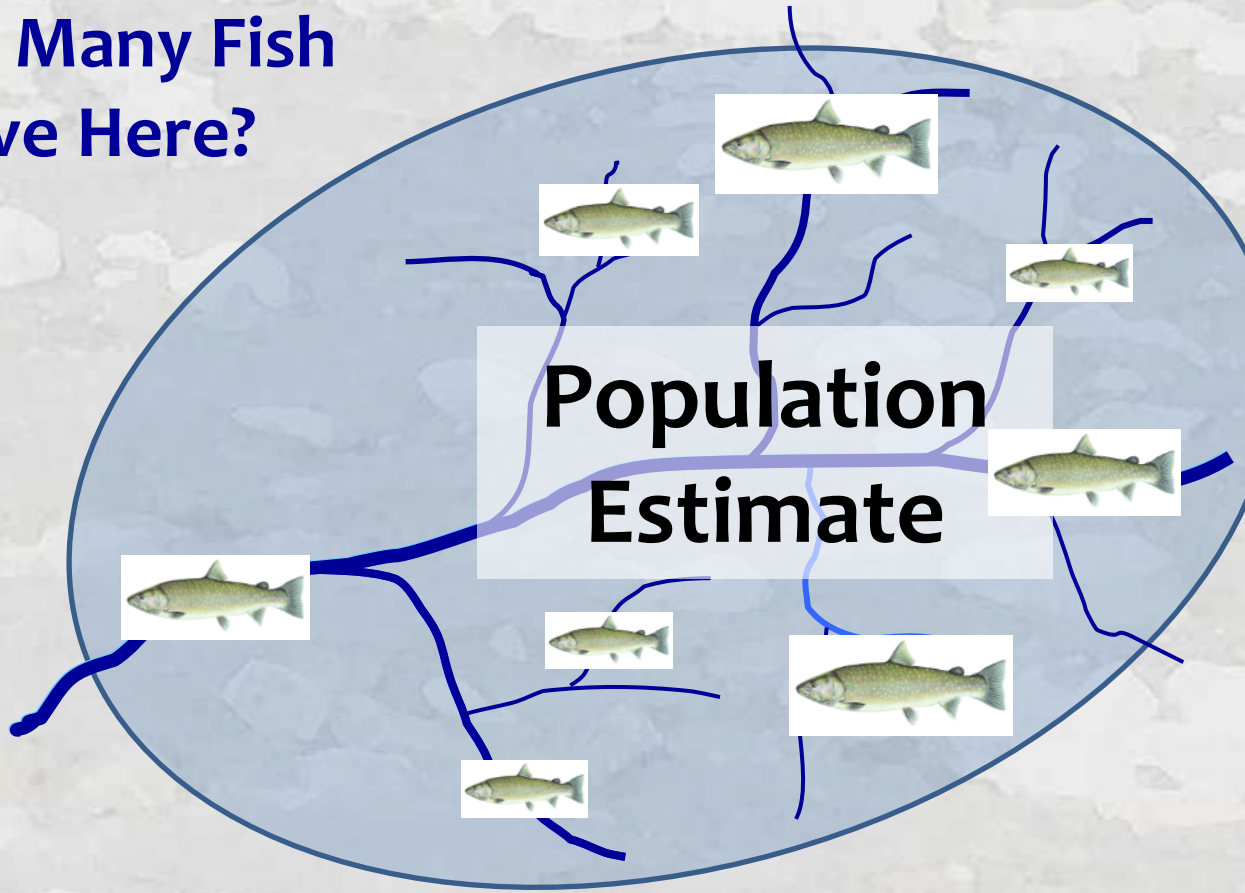
Sample Reach

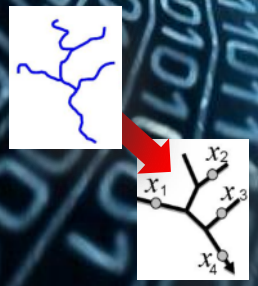
Population Estimate

Traditional Estimation Scale = Reach (10's – 100's meters)

Block-Kriging Fish Population Estimates

How Many Fish Live Here?





Desired Estimation Scale =
Stream & Network (1000's – 10,000's meters)

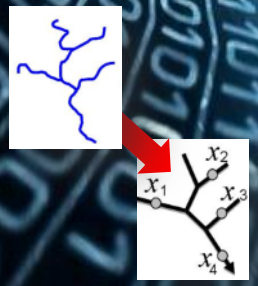
Block-Kriging Fish Population Estimates

Environ Ecol Stat (2008) 15:3–13
DOI 10.1007/s10651-007-0035-y

Spatial methods for plot-based sampling of wildlife populations

Jay M. Ver Hoef

- Terrestrial applications are common
- Theory now exists for streams



ulation

imate

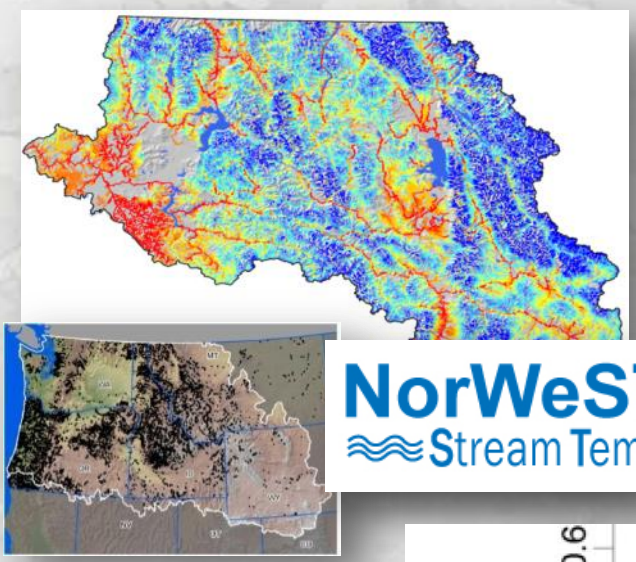
Desired Est

Stre

,000's meters)

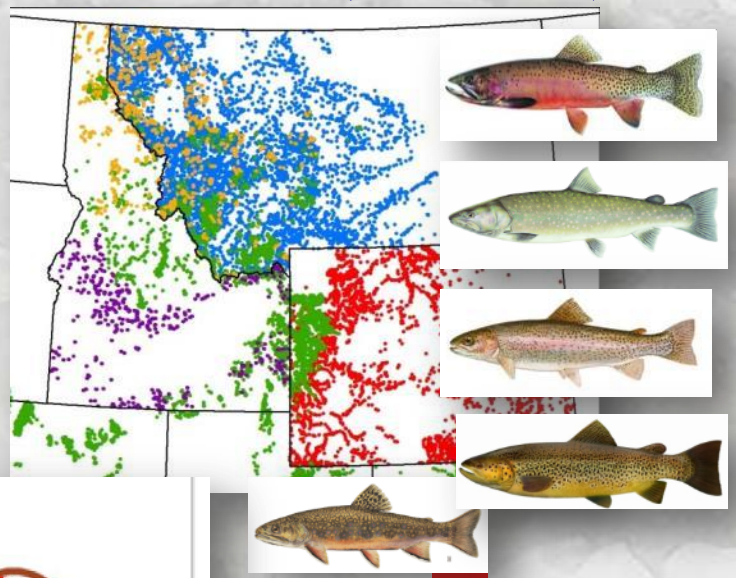
Development of Regionally Consistent Thermal Criteria

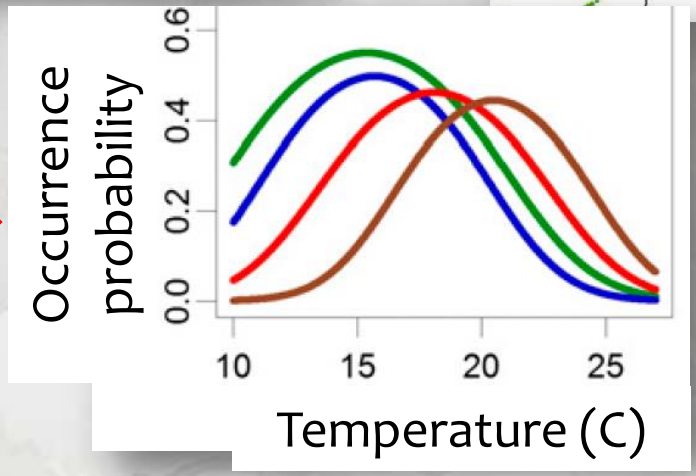
Stream temperature maps

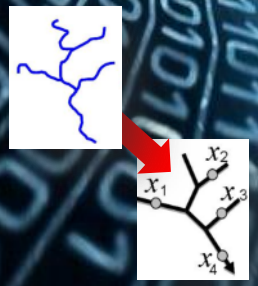


NorWeST Stream Temp

Regional fish survey databases (n ~ 20,000)





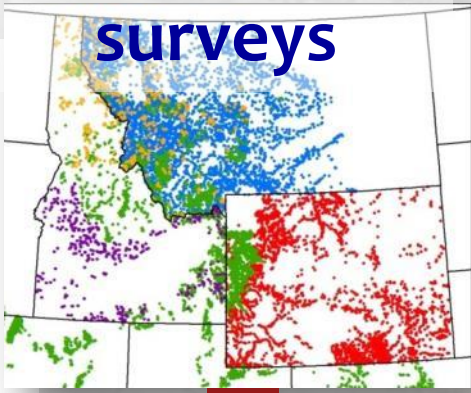


Wenger et al. 2011a. *PNAS* **108**:14175-14180

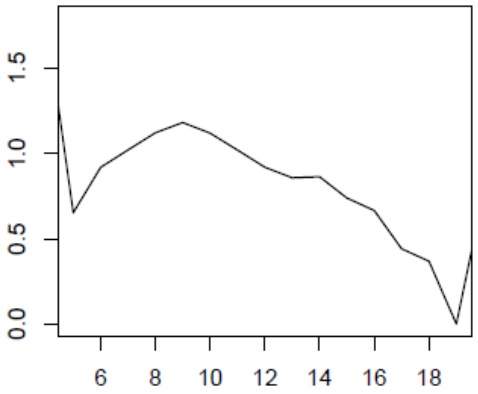
Wenger et al. 2011b. *CJFAS* **68**:988-1008; Wenger et al., *In Preparation*

Preliminary Results…

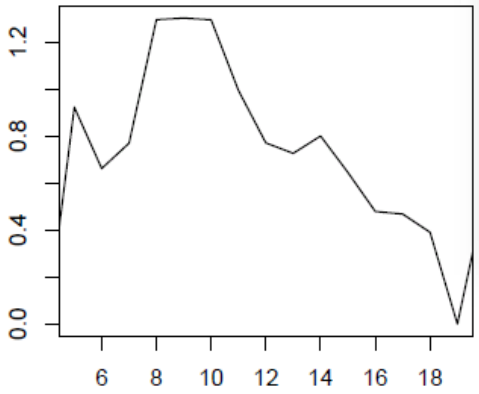
~20,000 fish surveys



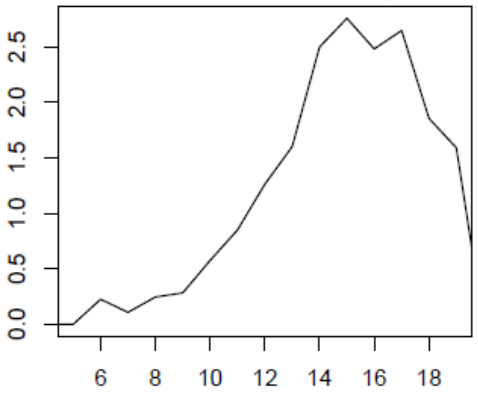
Cutthroat



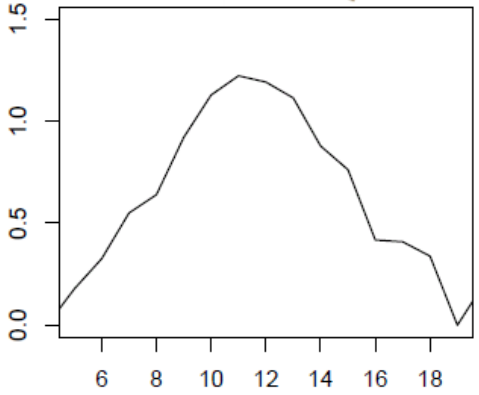
Bull



Rainbow

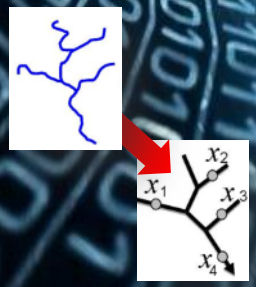


Brook



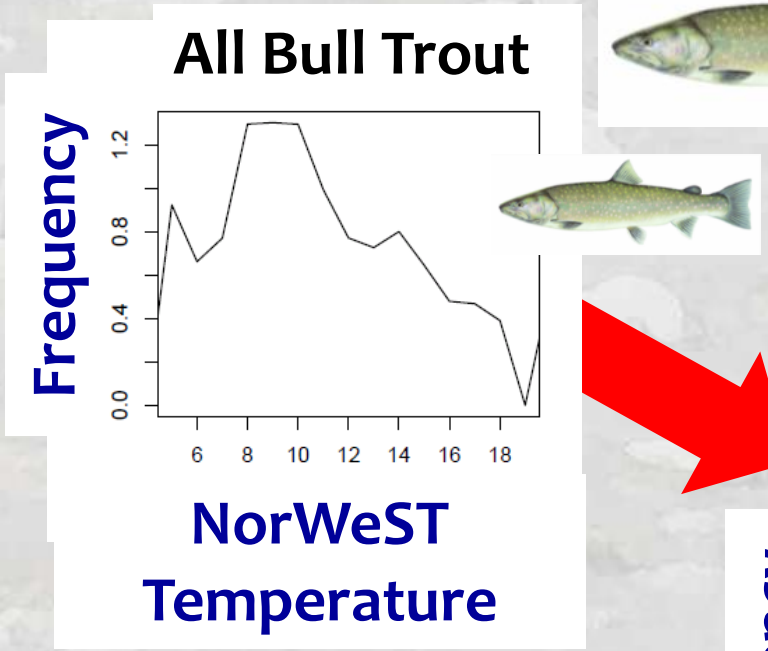
Frequency of Occurrence

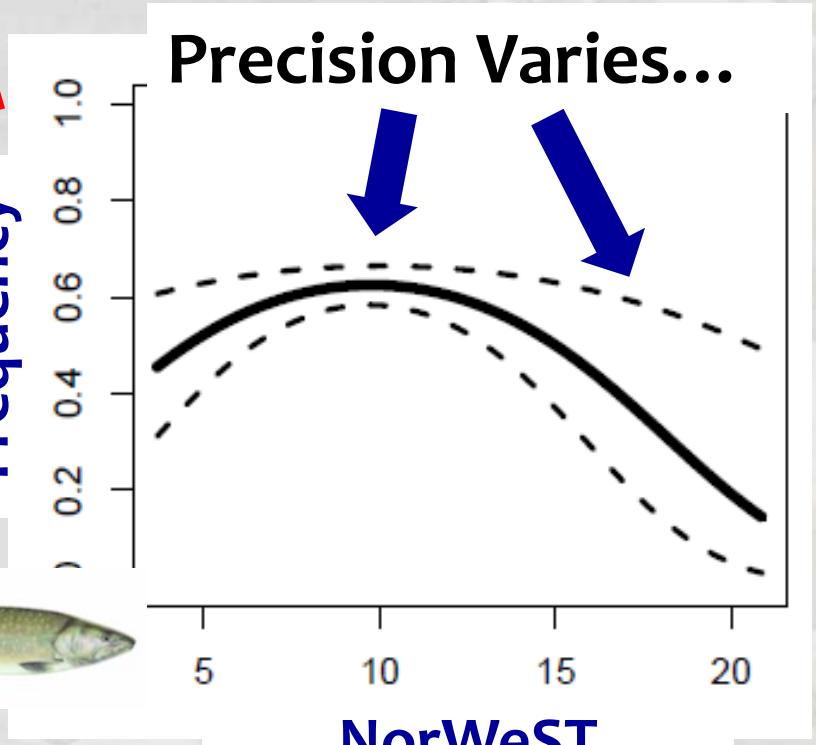
NorWeST Stream Temperature (S1)

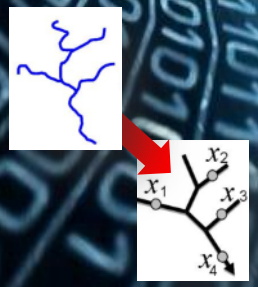


Wenger et al., *In Preparation*

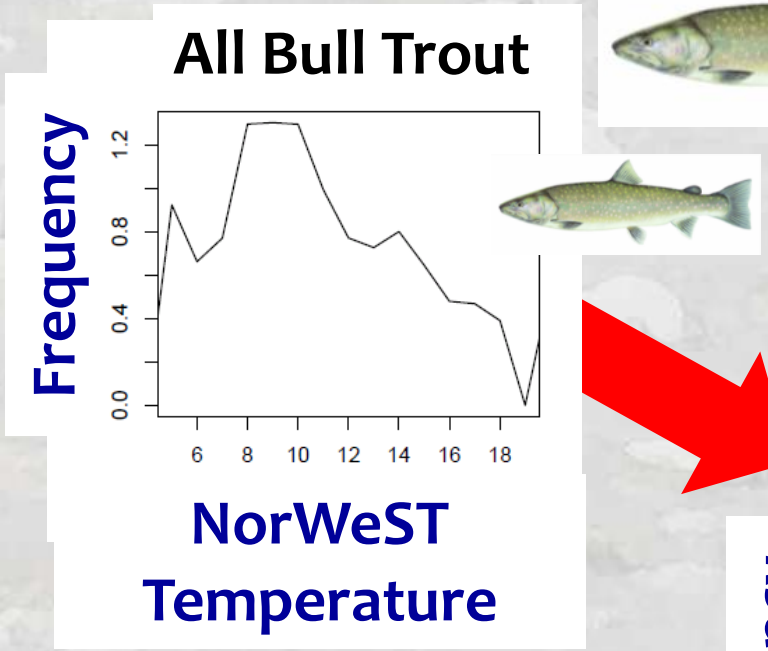
Thermal Niche Nuances…

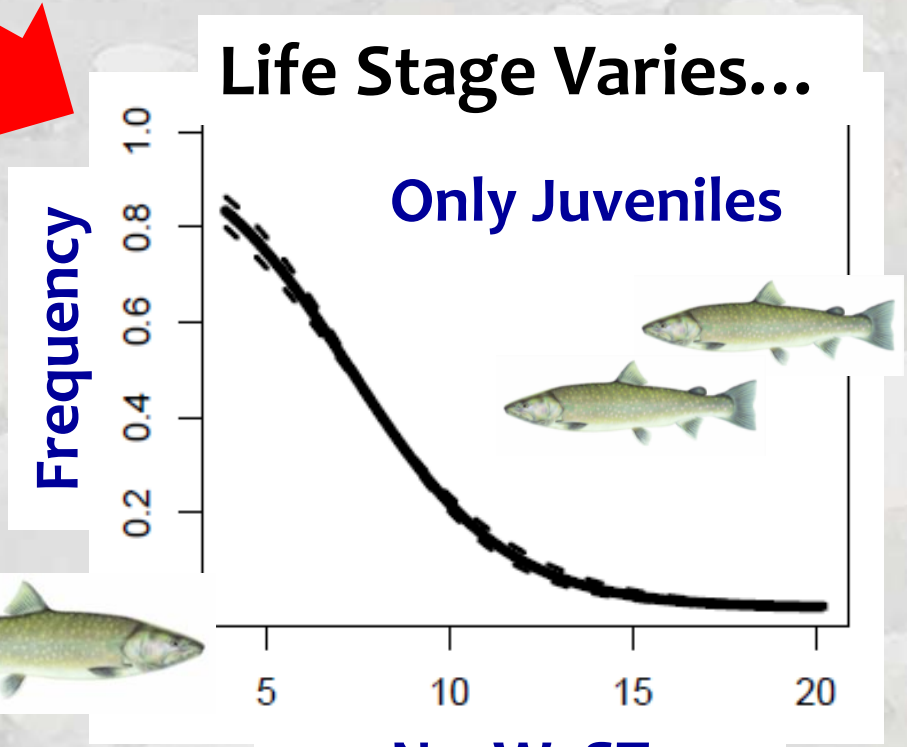


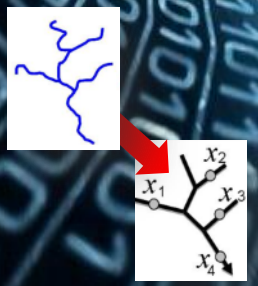




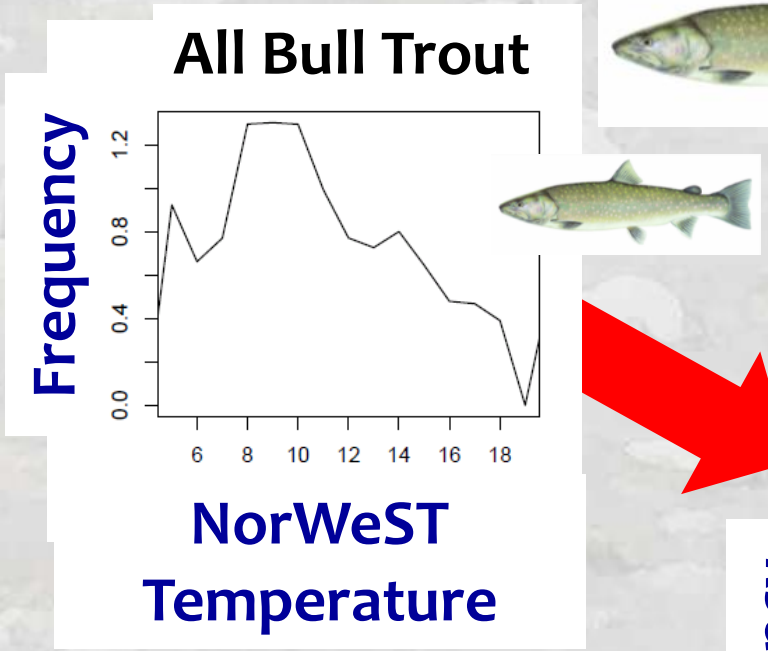
Thermal Niche Nuances…

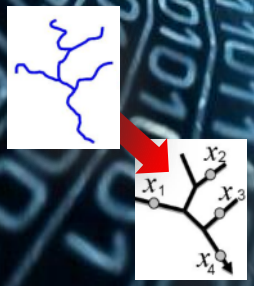






Thermal Niche Nuances…





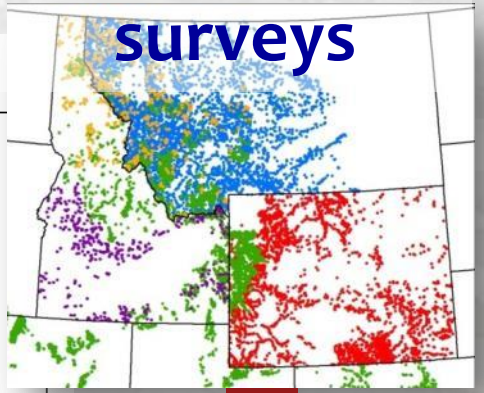
Thermal Criteria For Any Stream Critter

Just need georeferenced biological survey data

Too warm…Too cold… Just right

Preliminary Results…

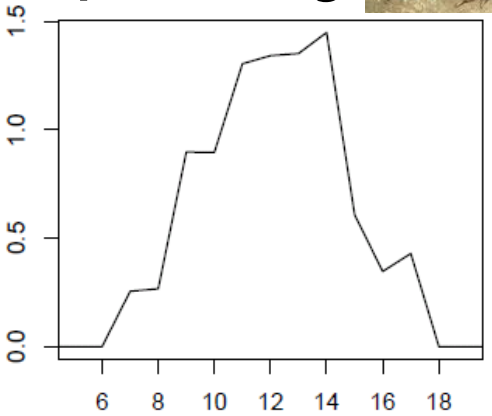
~20,000 fish surveys



Sculpin spp.

Tailed frog

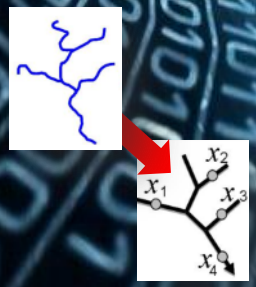
Spotted frog



Pearlshell mussell

Frequency of Occurrence

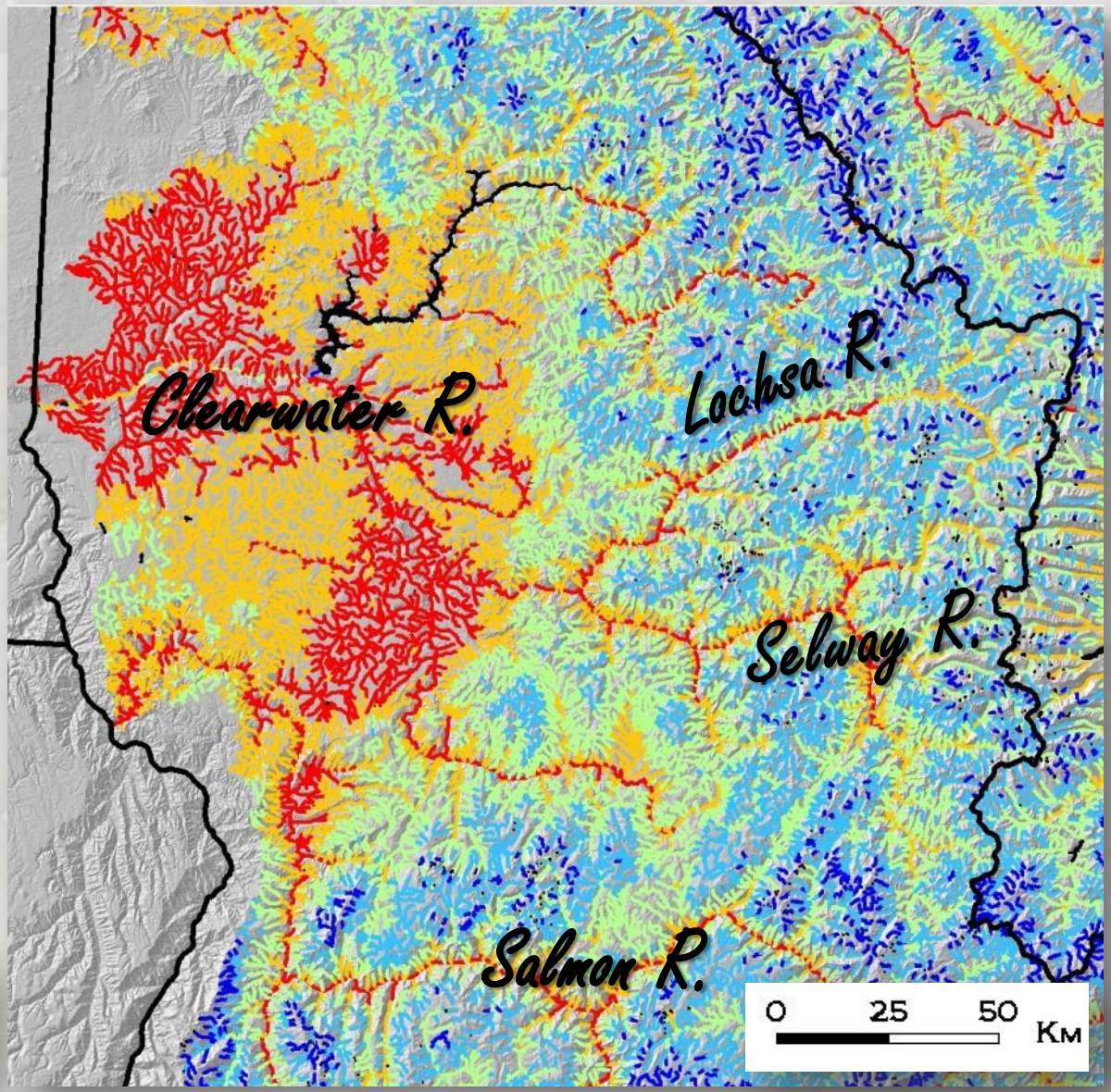
NorWeST Stream Temperature (S1)



Wenger et al., *In Preparation*

Clearwater Stream Temperature Scenario

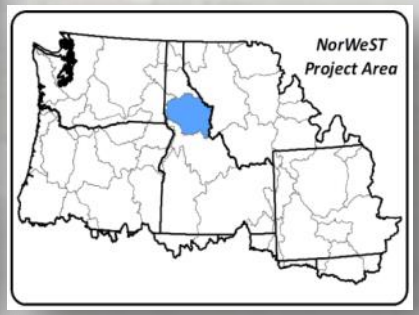
Historic (1993-2011 Average August)

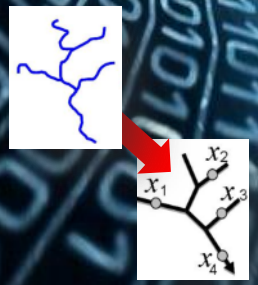


Temperature (°C)

- 0.0 - 8.0
- 8.1 - 10.0
- 10.1 - 12.5
- 12.6 - 15.0
- > 15

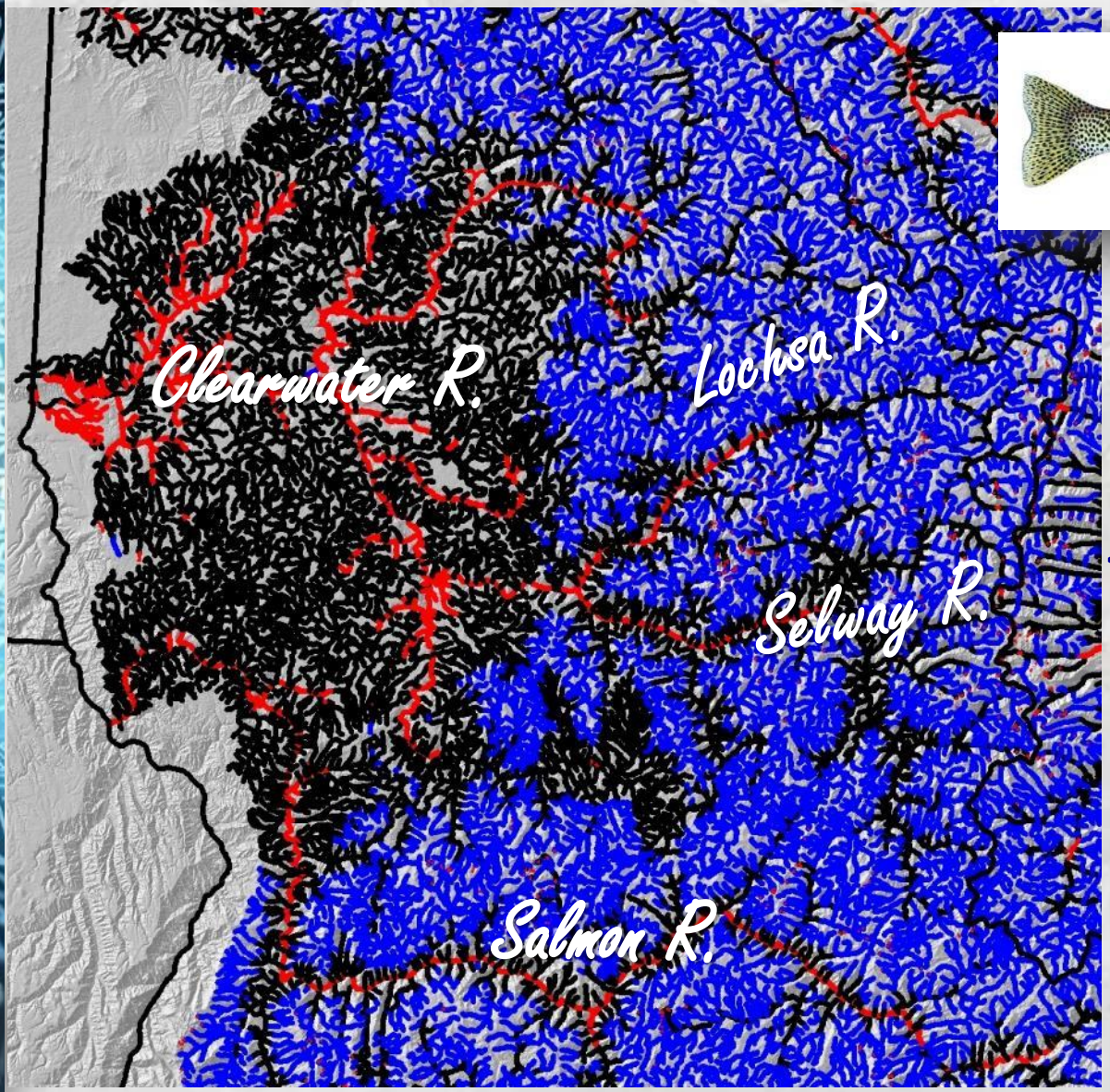
1 kilometer resolution





Climate Effects on Cutthroat Thermal Habitat

Historic (1993-2011 Average August)

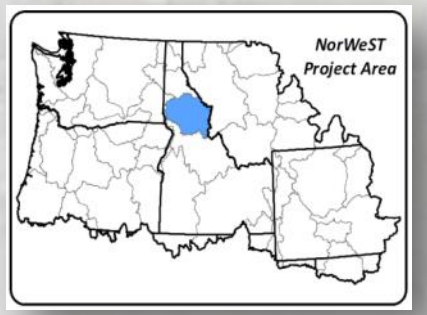


Suitable

Too Hot

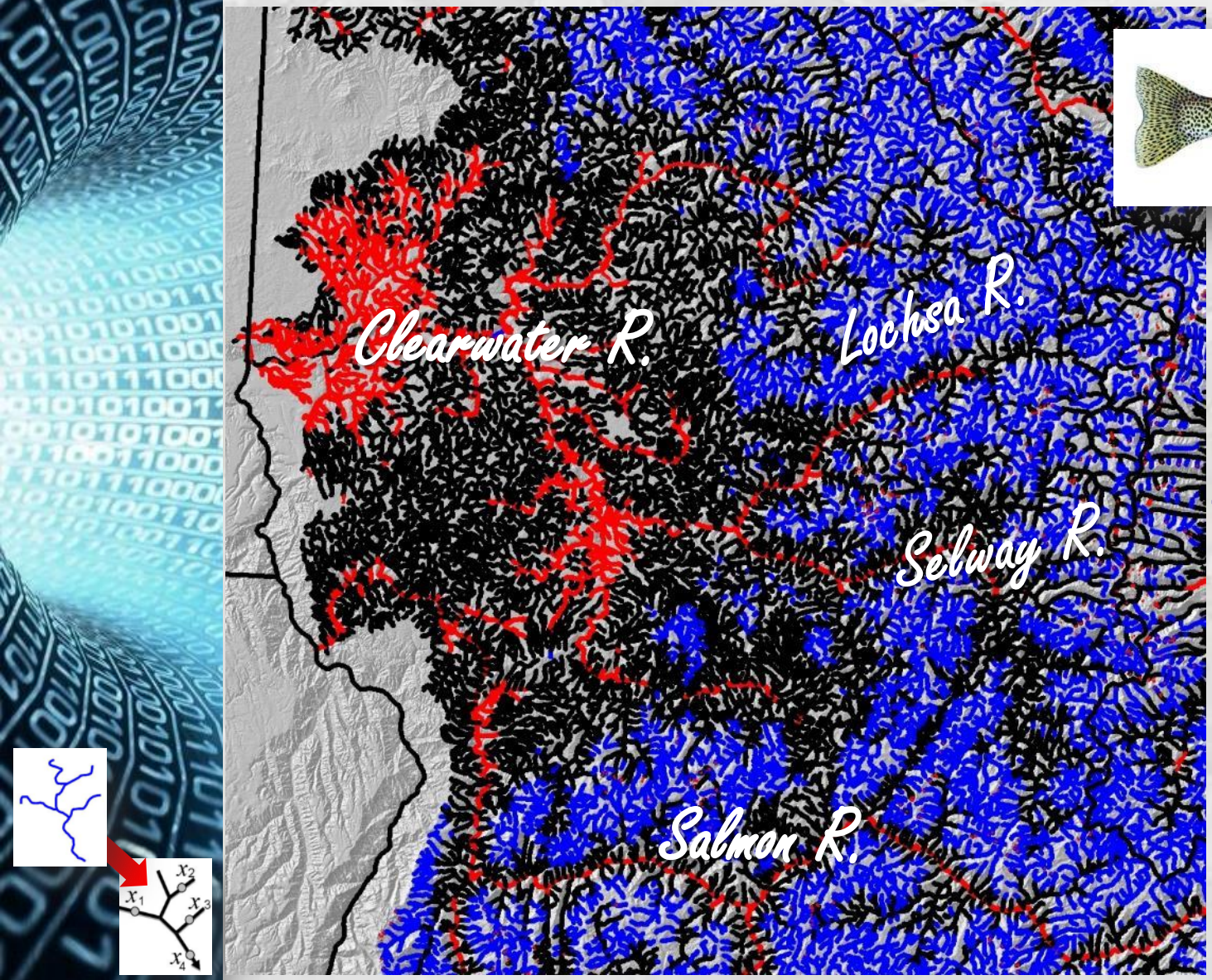
Too Cold

<17.0˚C & >11.0 ˚C



Climate Effects on Cutthroat Thermal Habitat

+1.50˚C Stream Temp (~2040s)

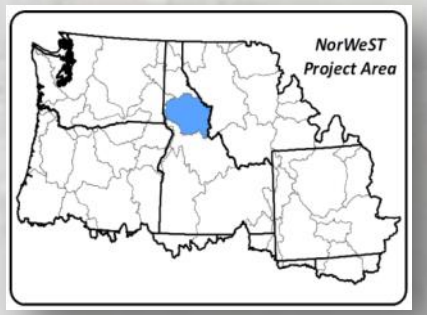


Suitable

Too Hot

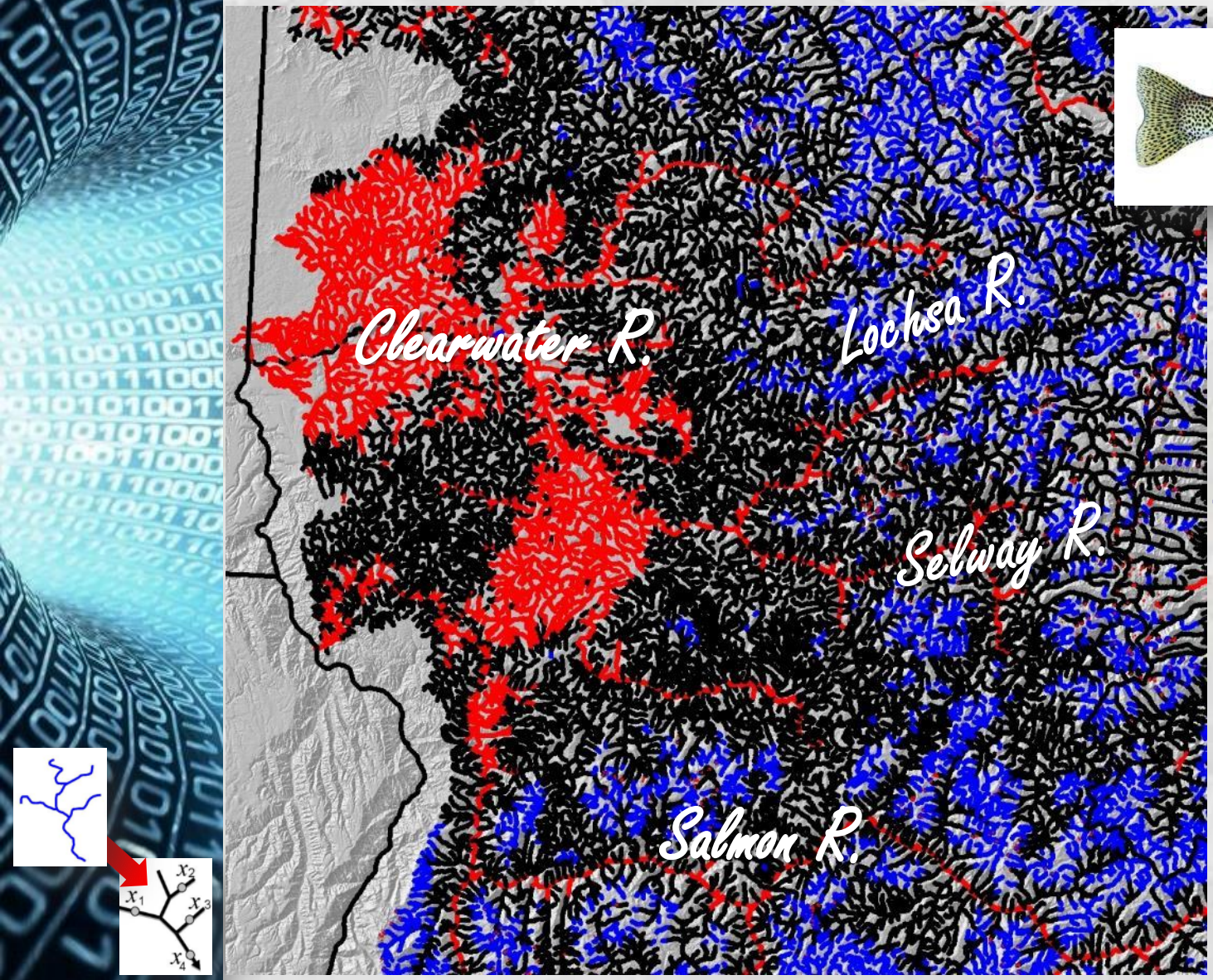
Too Cold

<17.0˚C & >11.0 ˚C



Climate Effects on Cutthroat Thermal Habitat

+3.00˚C Stream Temp (~2080s)

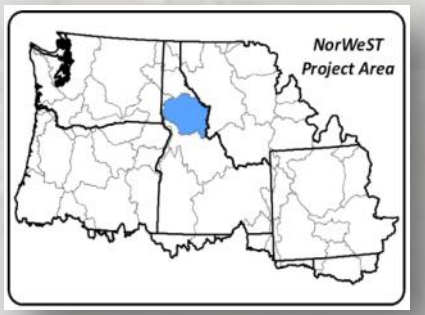


Suitable

Too Hot

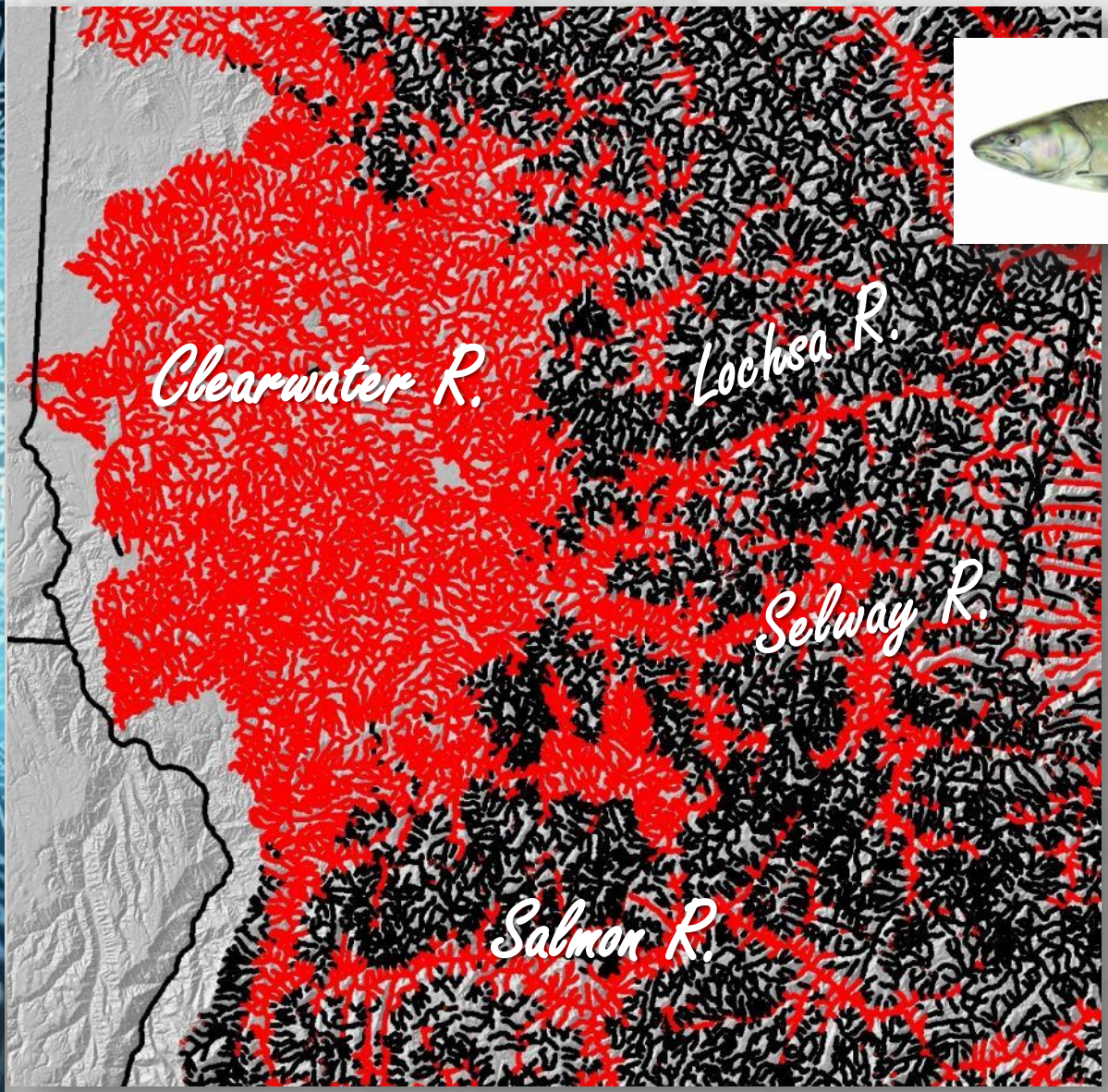
Too Cold

<17.0˚C & >11.0 ˚C



Climate Effects on Bull Trout Thermal Habitat

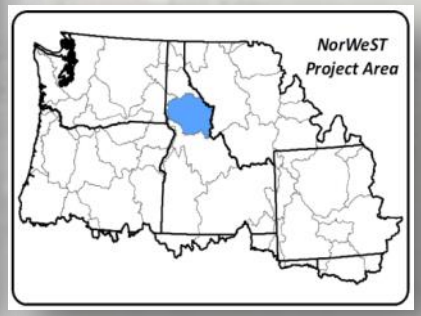
Historic (1993-2011 Average August)



Suitable

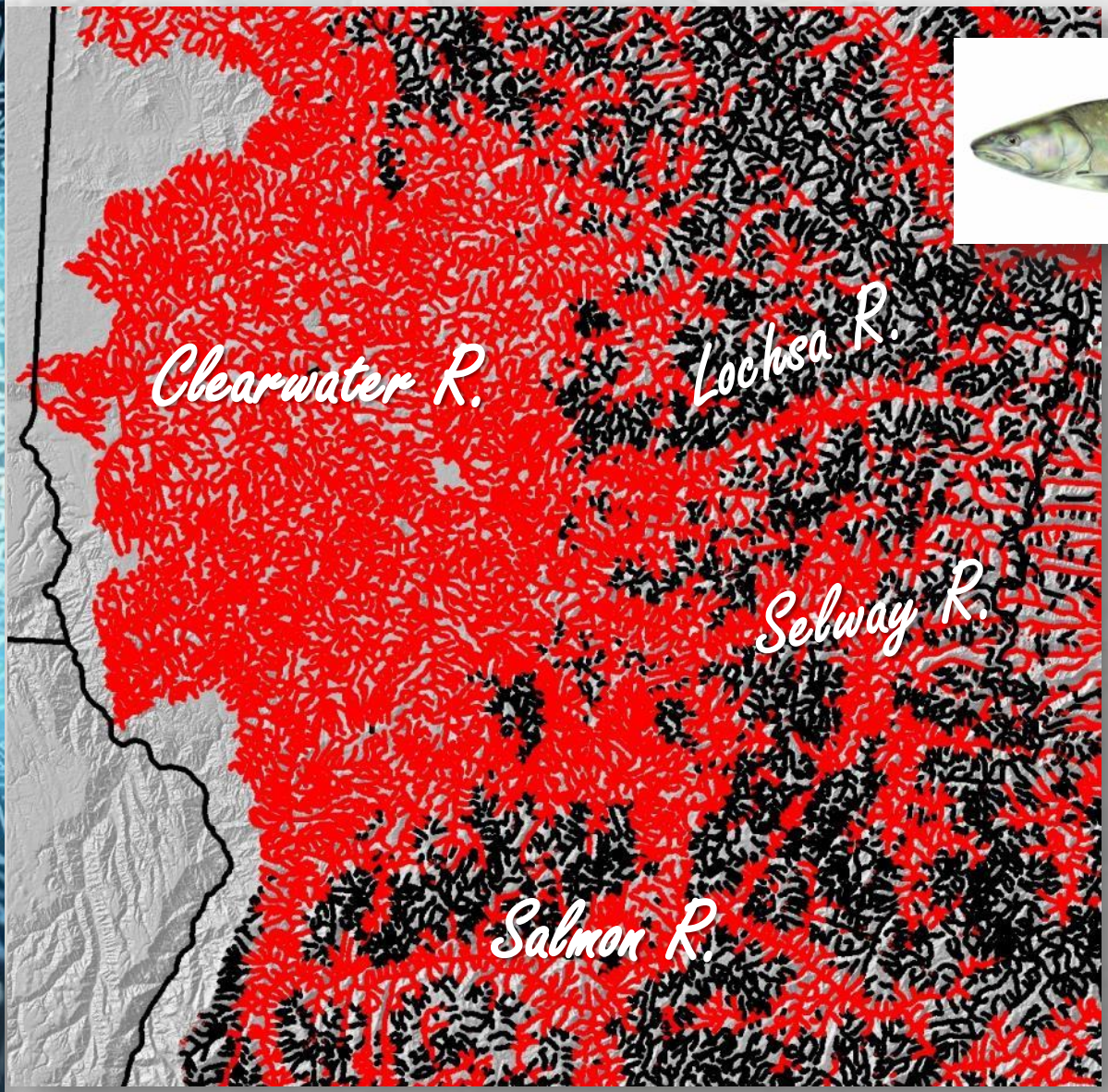
Unsuitable

< 11.0°C



Climate Effects on Bull Trout Thermal Habitat

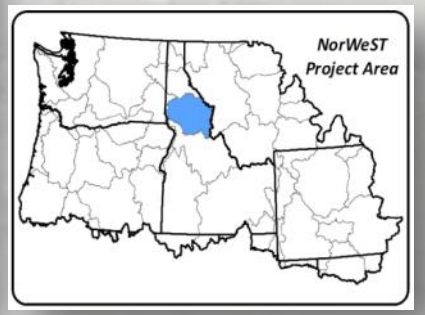
+1.50˚C Stream Temp (~2040s)



Suitable

Unsuitable

< 11.0˚C



Climate Effects on Bull Trout Thermal Habitat

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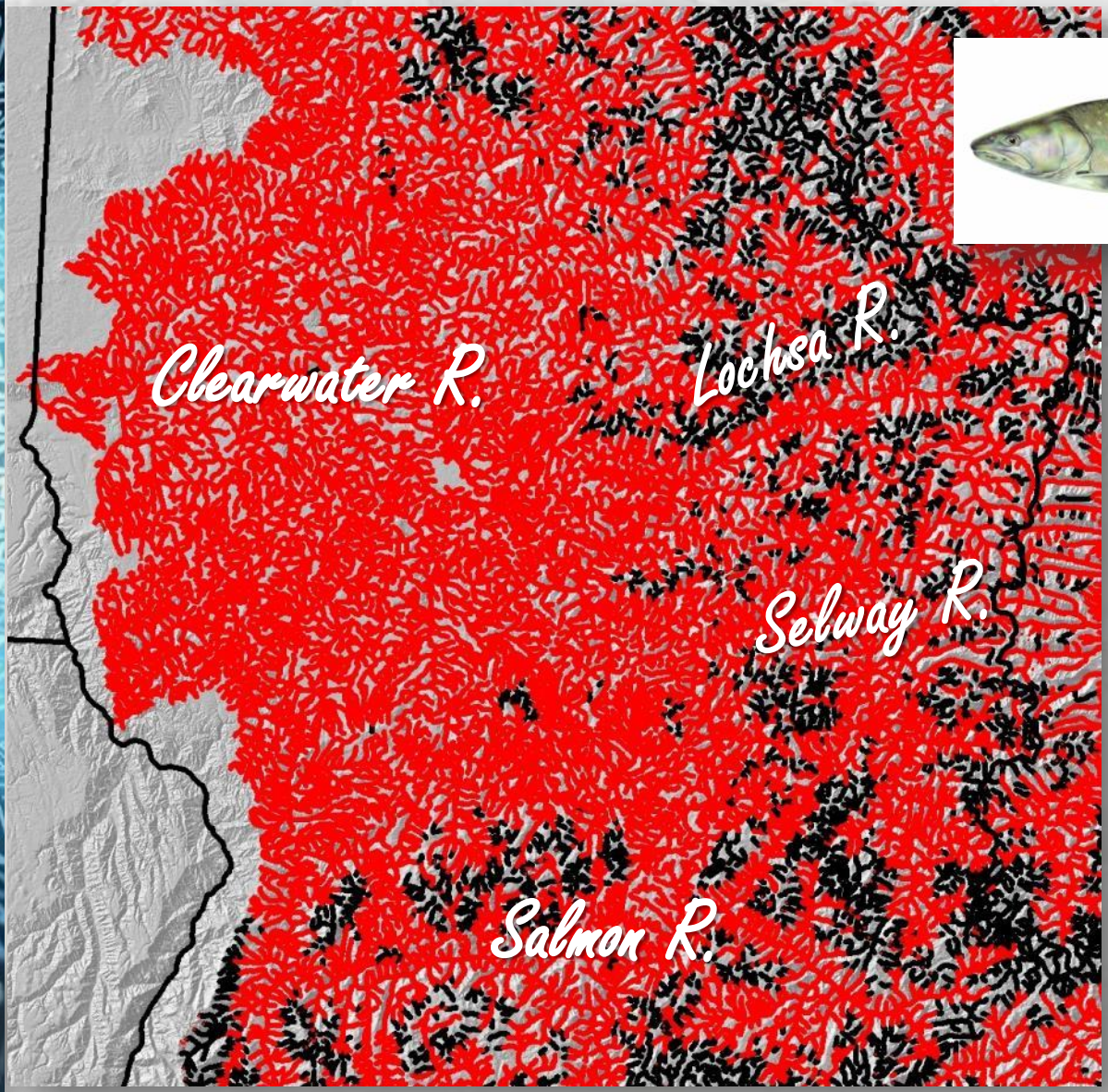
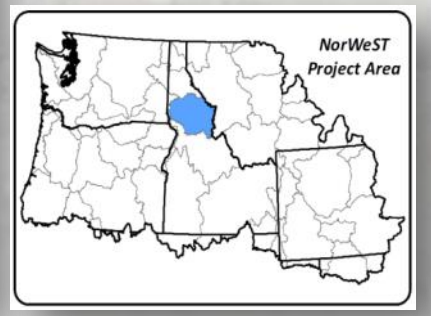


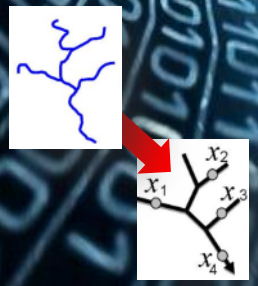
Suitable

Unsuitable

< 11.0˚C

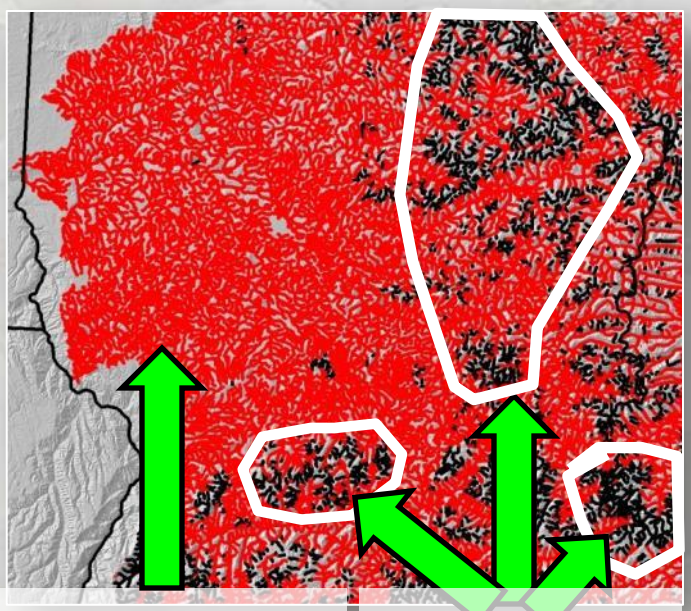


Climate-Smart Prioritization of Habitat Restoration



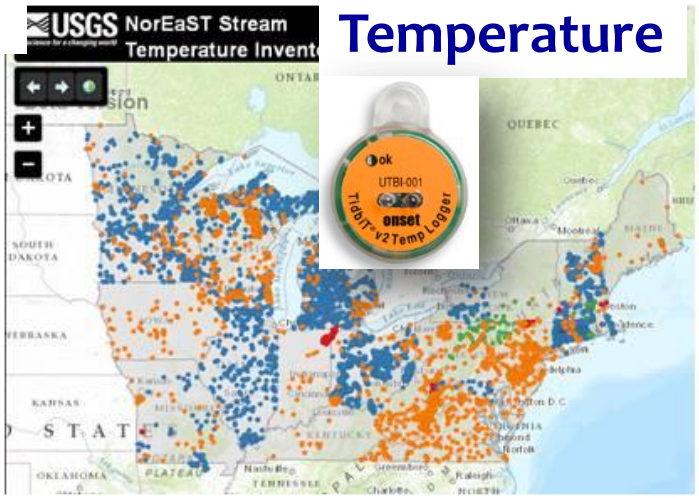
Lots of things we can do…

- Maintaining/restoring flow…
- Maintaining/restoring riparian…
- Restoring channel form/function…
- Prescribed burns limit wildfire risks…
- Non-native species control…
- Improve/impede fish passage…



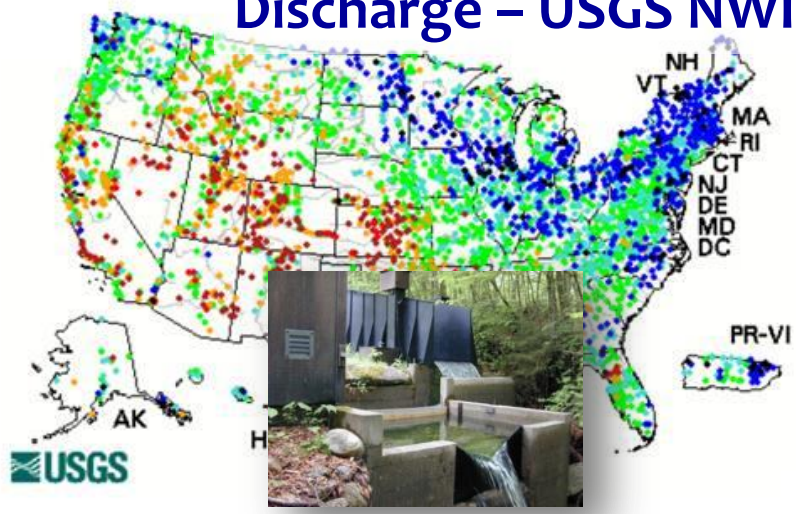
Low Priority **High Priority**

Mountains of Data Could be Mined for Valuable "Information"

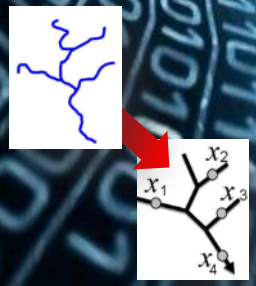


Temperature

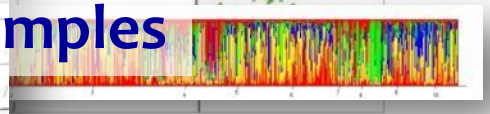
Discharge – USGS NWIS

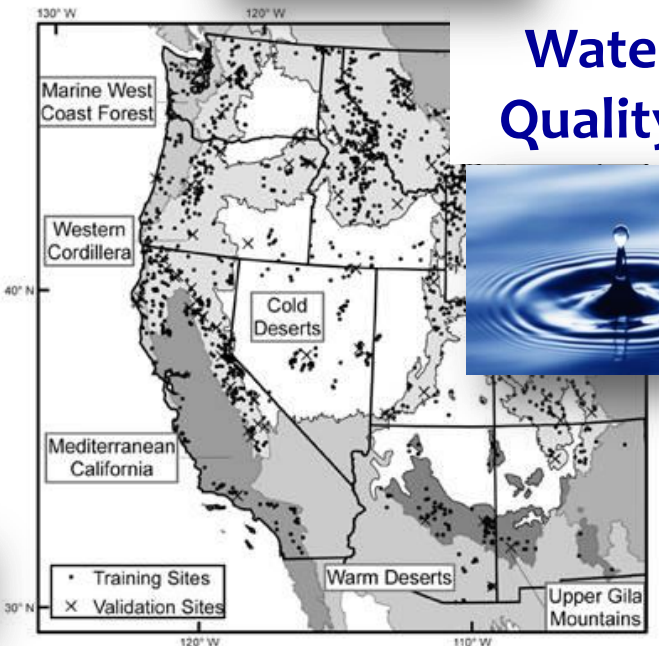


Species distributions



Genetic Samples



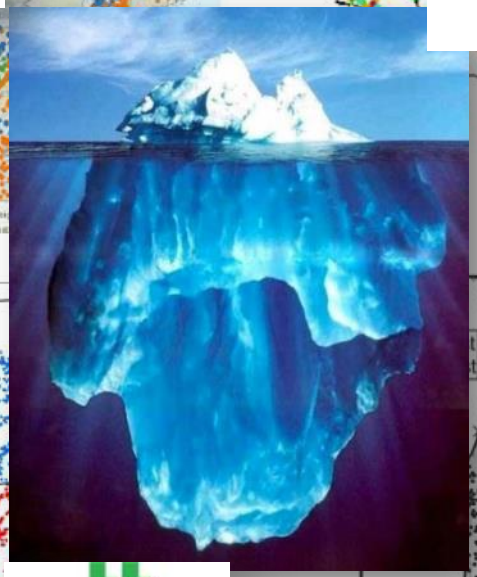


Water Quality

Mountains of Data Could be Mined for Valuable "Information"

Free millions!

Temperature



Discharge – U

Free millions!

Free millions!

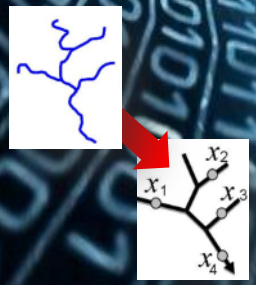
Water Quality

Sp di

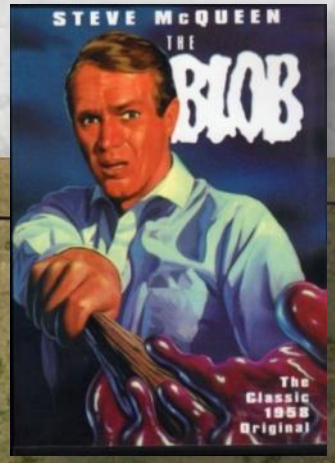
Free millions!

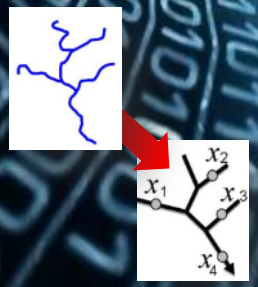
Genetic Samples

Free millions!



The BLOB Had a Dream…





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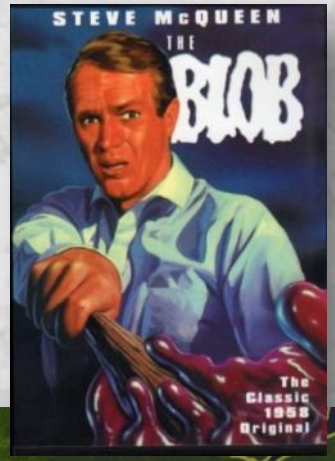
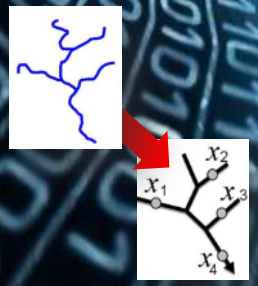


"What if I could eat data everywhere?"

2,500,000 stream kilometers nationally



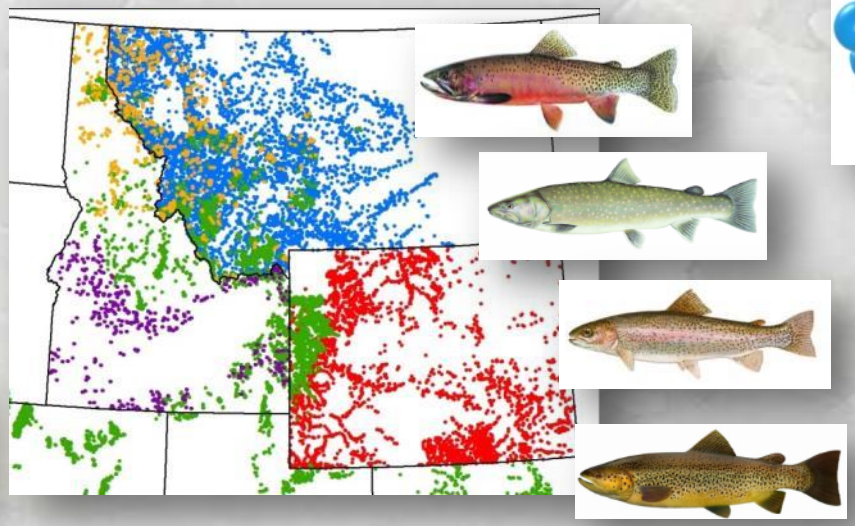
The National Stream Internet Project

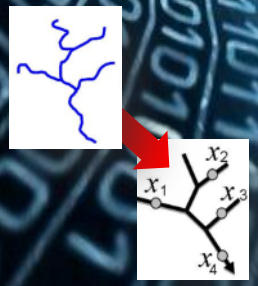
An analytical framework for creating new information from old data on stream networks

Dan Isaak, Erin Peterson, Dave Nagel, Jay Ver Hoef, Jeff Kershner

BIG DATA =

BIG POSSIBILITIES





LANDSCAPE CONSERVATION COOPERATIVES

What's a Stream Internet?

A network of people, data, digital information systems & analytical techniques that interact synergistically to create & transmit massive amounts of "information"

Data (what's being "clicked" on?)

People on landscapes collecting data using standard protocols

Google Servers & Databases

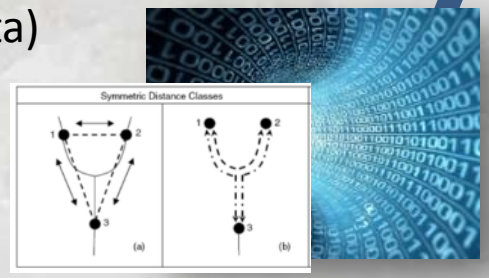
Google

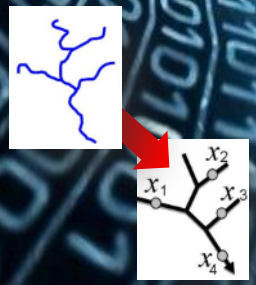
Corporate databases & institutional memory

WQX
WATER QUALITY EXCHANGE

Search algorithms find signal in noise (information from data)

New stream analyses & research activities

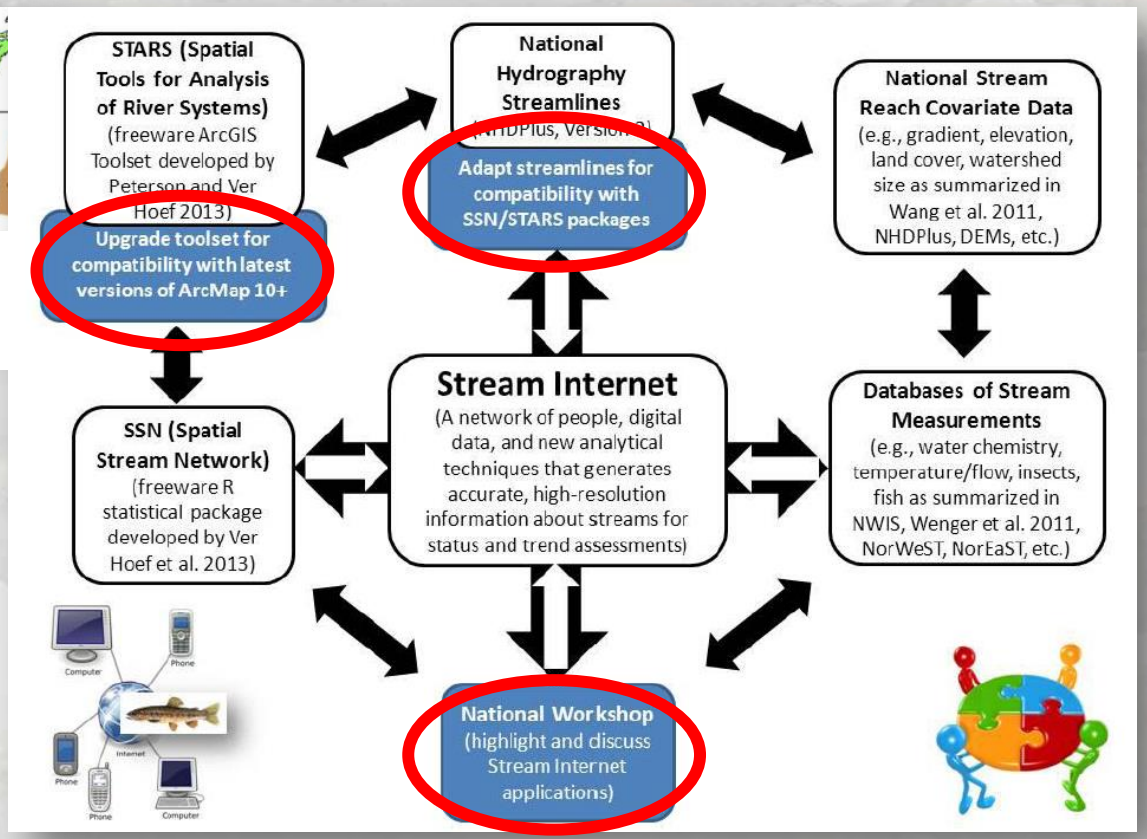




Stream Internet Project Objectives

1) Develop compatibility between spatial stream analysis tools and national hydrography layer (NHDPlus, v2)
2) Update STARS stream analysis tools to ArcMap 10.2
3) Host national workshop in 2015 to engage key researchers & leaders from aquatic programs (i.e., power-users)

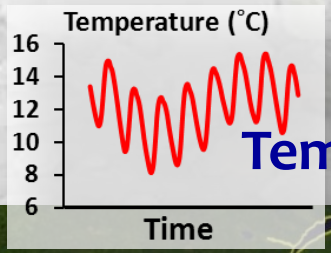
Projects like NorWeST done routinely & incentives exist for database aggregation



Using the Stream Internet is Easy…

Step 1. Develop a Stream Database…

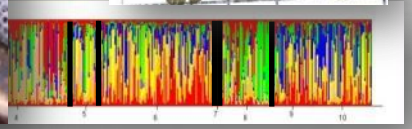
Distribution & abundance



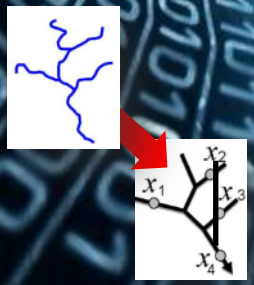
Stream Temperature

Anywhere in the country…

Genetic Attributes

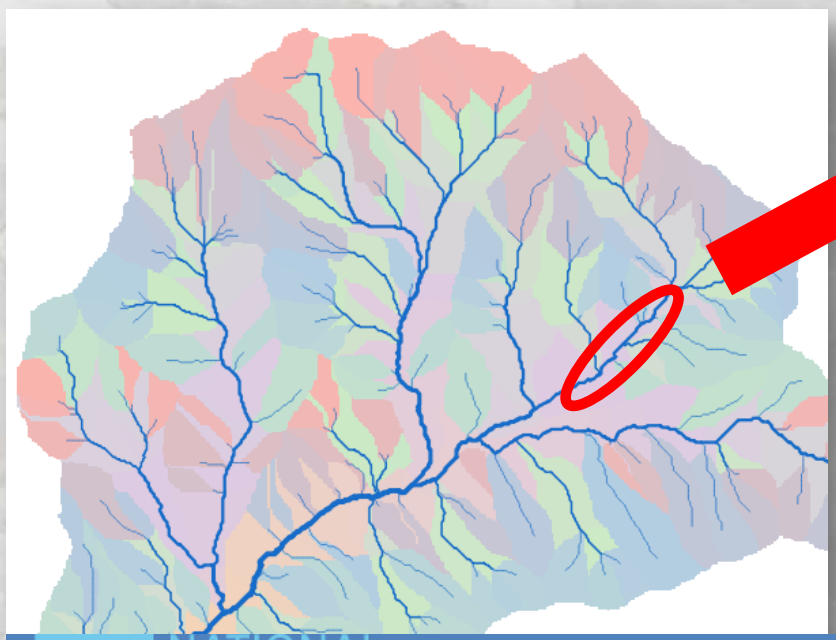


Water Quality Parameters



Step 2. Link to NHDPlus Streams

Nationally consistent geospatial stream database

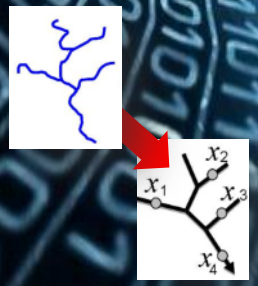


Reach Descriptors:

- Elevation
- Slope
- %Landuse
- Precipitation

100's more…

NATIONAL FISH HABITAT PARTNERSHIP



Cooter et al. 20[illegible]. A nationally consistent NHDPlus framework for identifying interstate waters: I[illegible]lications for integrated assessments and interjurisdictional TMDLs. *Environ[illegible]ntal Management* **46**:510-524.

Wang et al. 2011. A Hierarchical Spatial Framework and Database for the National River Fish Habitat Condition Assessment. *Fisheries* **36**:436-449.

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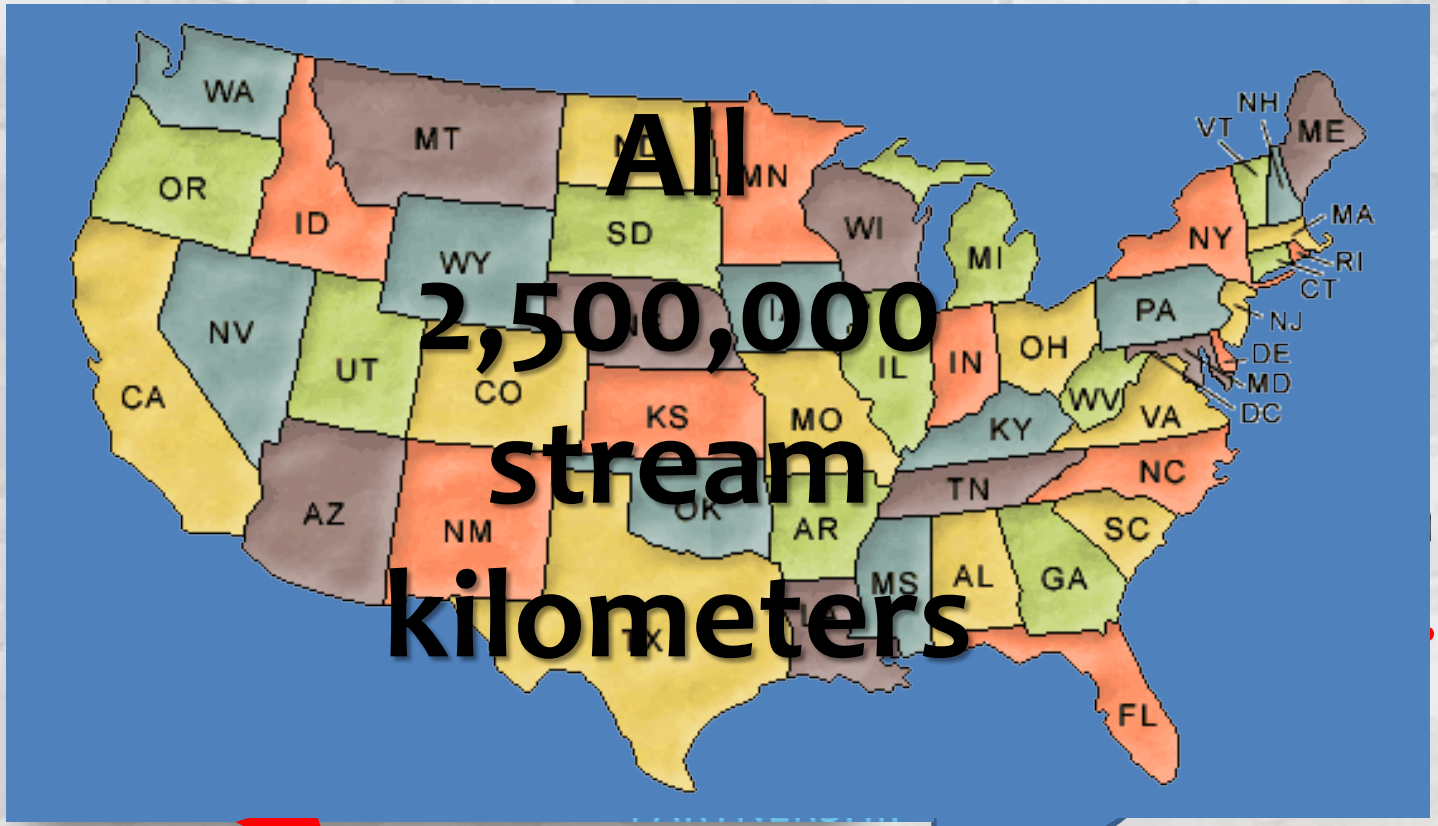

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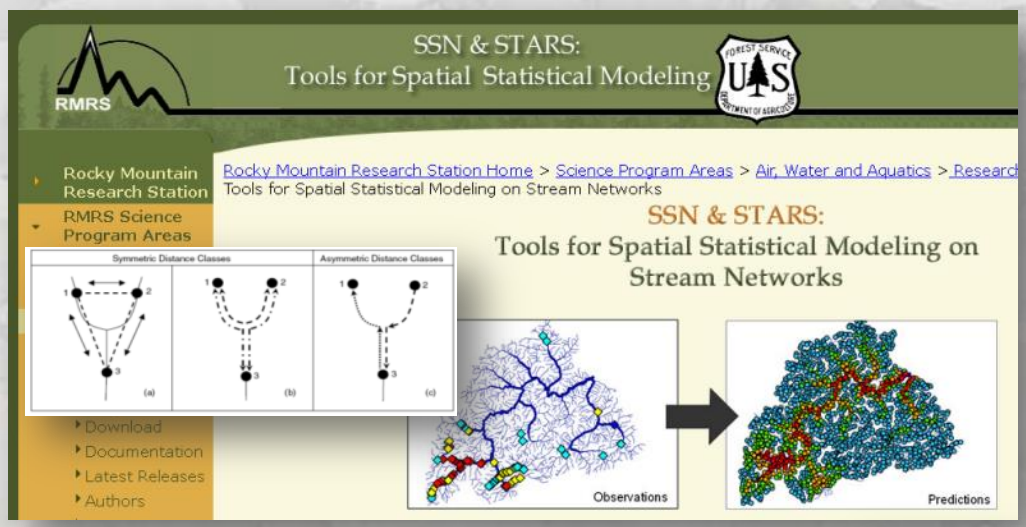
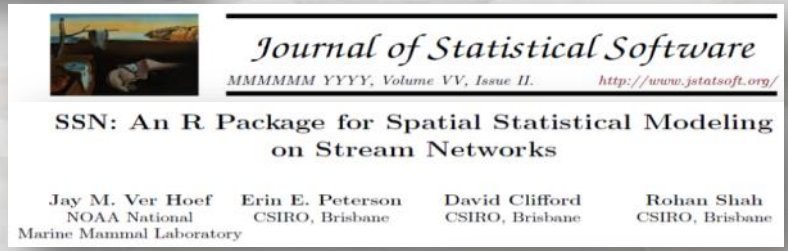
Step 3. Stream Statistical Analysis

SSN/STARS Website – Free Software



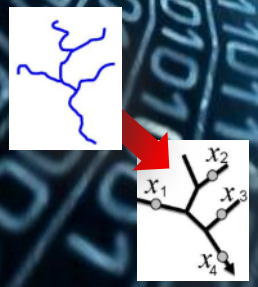
Spatial Stream Networks (SSN) Package for R

- **Software**
- **Example Datasets**
- **Documentation**

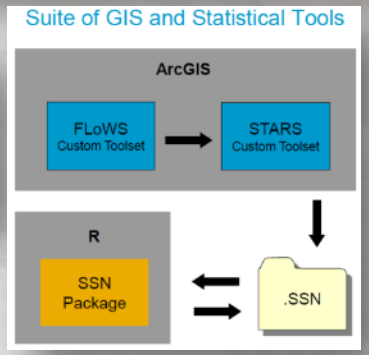


A Moving Average Approach for Spatial Statistical Models of Stream Networks

Jay M. VER HOEF and Erin E. PETERSON



STARS: An ArcGIS toolset used to calculate the spatial data needed to fit spatial statistical models to stream network data



An InterNet Requires a User Community

Rapidly Developing at Grassroots Level

>14,000 Visits to SSN/STARS website in first year

>500 software downloads

Locations of visits to SSN/STARS website in last month

2nd Annual Stream Statistics Training Workshop in Boise

May 15 – 17

>100 Participants from U.S. & 1 from Egypt!

2nd Annual: Spatial Statistical Network Models Workshop

Co-sponsored by
NOAA, CSIRO, USFS, IDAFS

WORKSHOP OVERVIEW

- Provide an overview of spatial statistical modeling on stream networks, including a discussion of when they are, or are not, useful
- Share two sets of free user-friendly tools:
  - STARS ArcGIS toolset
  - SSN package for R Statistical Software
- Demonstrate the GIS tools and the steps necessary to calculate the spatial information needed to fit a spatial statistical model in R
- Demonstrate the statistical tools and their functionality, using an existing stream temperature dataset:
  - spatial regression and prediction for continuous, presence/absence, and count data;
  - block kriging and prediction;
  - uncertainty estimation;
  - simulation; and
  - visualization techniques for spatio-temporal stream data

THE LATEST SCIENCE

Exciting new research questions have recently emerged in aquatic ecology; questions that are related to biological, ecological, and physical processes at multiple scales. Sparsely sampled locations make it difficult to recognize multi-scale patterns, and it is prohibitively costly to collect a continuous sample throughout space. Spatial statistical methods

FREE SOFTWARE PACKAGES

STARS ArcGIS toolset
SSN package for R statistical software
http://www.fs.fed.us/rm/boise/AWAE/projects/SpatialStreamNetworks.shtml

AGENDA

Day 1: Overview of spatial statistical network models: theory, software, and applications (webinar & attendees)

Days 2 & 3: Work 1-on-1 with instructors to apply the spatial models to your datasets (attendees only)

COST	$300 (attendees) $60 (webinar viewers)
DATE	May 15 - 17
TIME	8:30 - 5:00
LOCATION	Idaho Water Center ½ mi from Grove Hotel 322 E Front Street Boise, Idaho

TO REGISTER, Go Here:
http://www.idahoafs.org/
or email Dan Isaak
(disaak@fs.fed.us)

Attendance limited to 15 participants
Webinar viewers are unlimited!

SCIENCE CONTACTS

Dr. Jay M. Ver Hoef
NOAA Fisheries
Alaska Fisheries Science Center
support@spatialstreamnetworks.com

Dr. Erin E. Peterson
CSIRO Division of Mathematics, Informatics & Statistics
support@spatialstreamnetworks.com

Dr. Daniel J. Isaak
US Forest Service
Rocky Mountain Research Station
disaak@fs.fed.us

Idaho Water Center

3 day workshop

1st day: overview of spatial stream models (webinar)

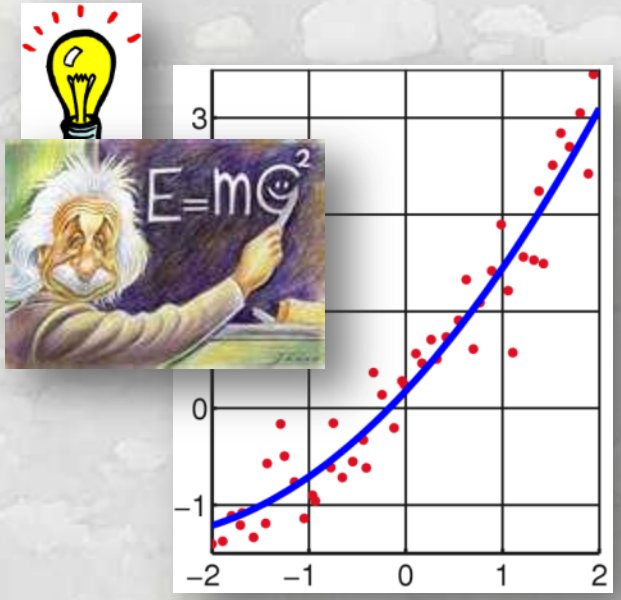
2nd/3rd days: work 1-on-1 with Jay/Erin to model your data

Attendees (15 people); 1st day webinar viewers (unlimited)

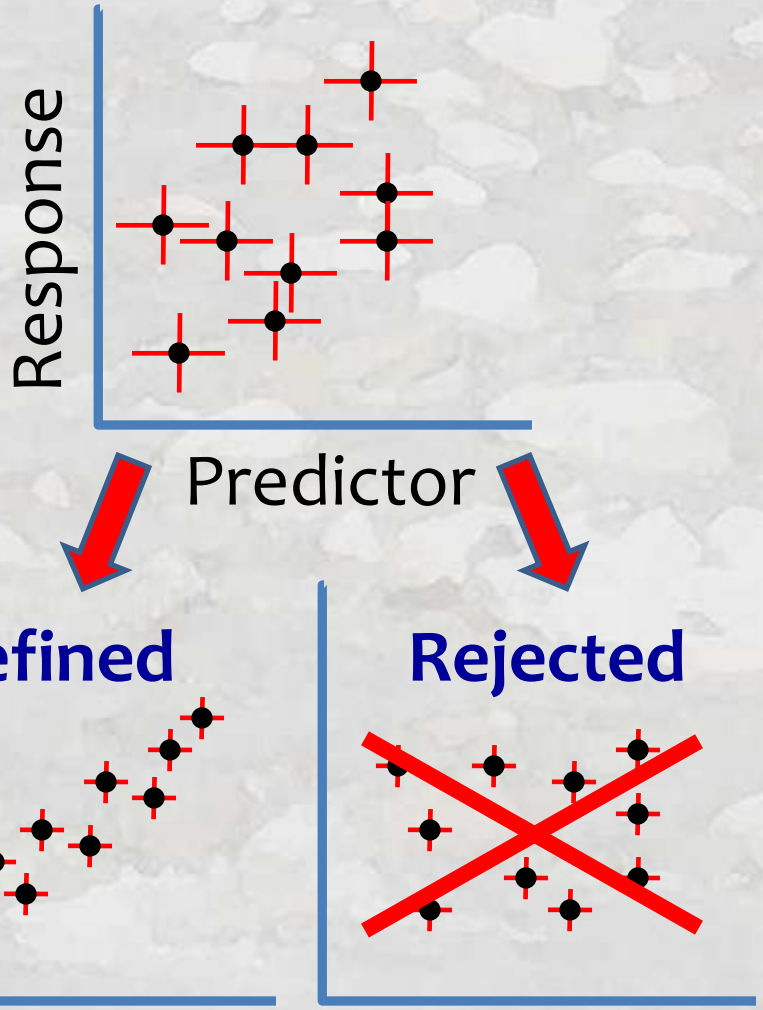
If Interested, contact Dan Isaak (disaak@fs.fed.us) or go to the SSN/STARS website for registration details

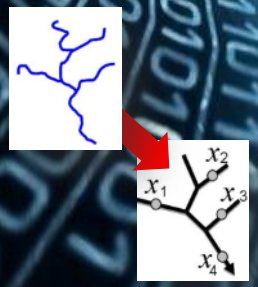
A New Era of Better Prediction & Understanding for Stream Things…

New relationships described

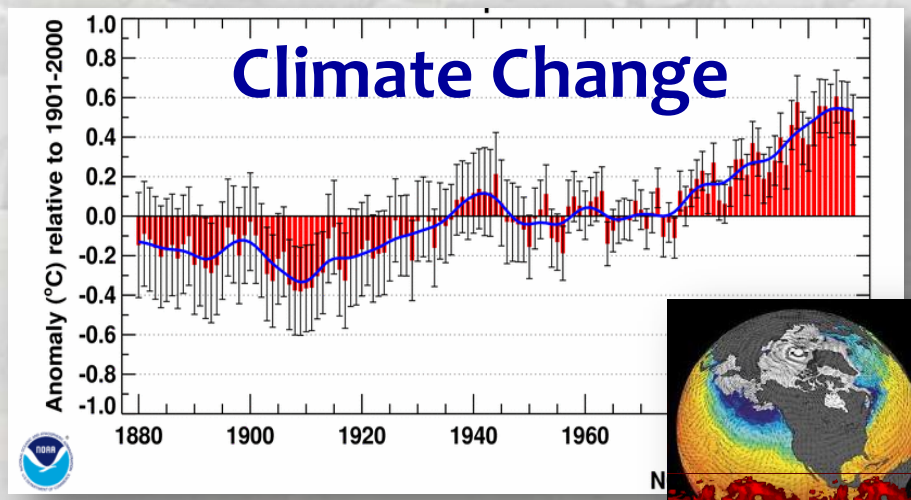


Old relationships tested



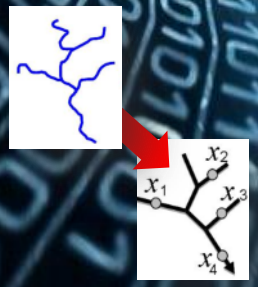


More Pressure, Fewer Resources



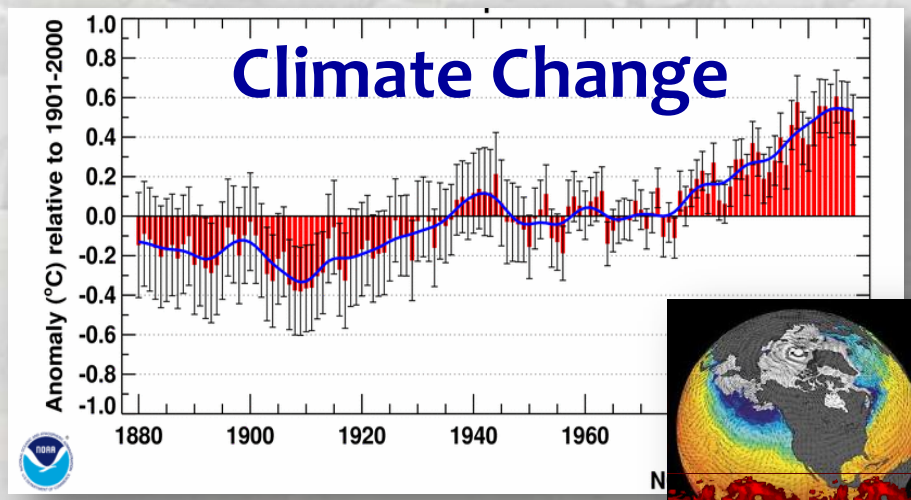
Urbanization & Population Growth

Shrinking Budgets



Need to do more with less

More With Less, but What If…
It was Massively More?



Urbanization & Population Growth

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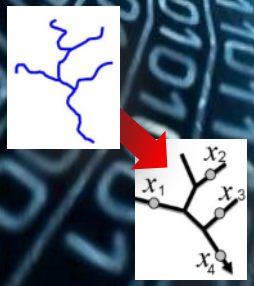


Additional Resources…

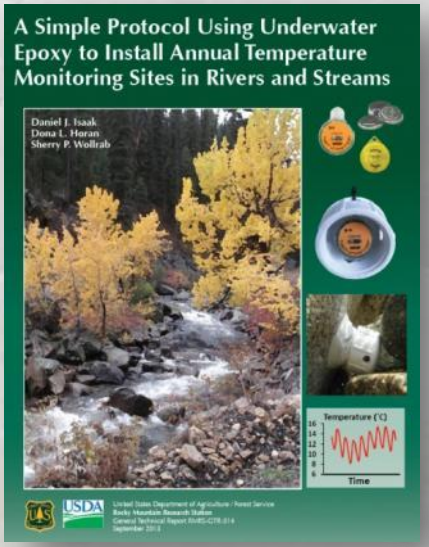
Websites (Google Search On…)

1) ***SSN/STARS*** – statistical modeling of data on networks

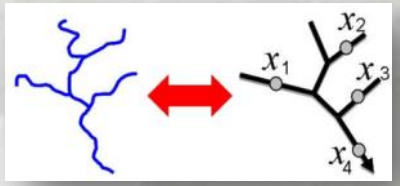
2) ***NorWeST*** – regional stream temperature database & climate scenarios

3) **Stream Temperature Modeling & Monitoring**

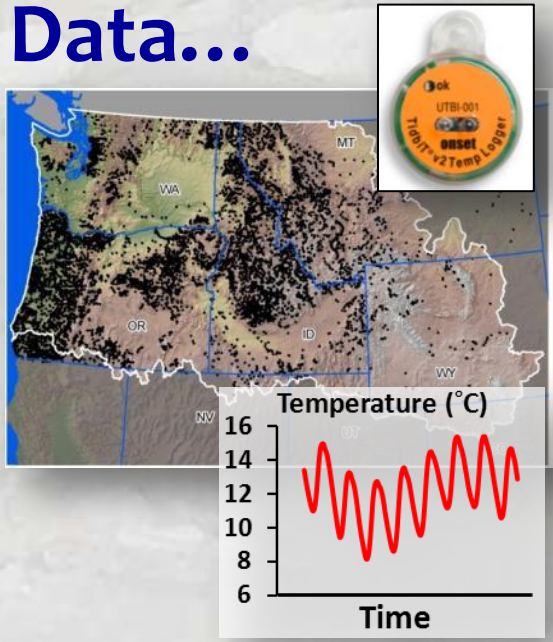
Publications…

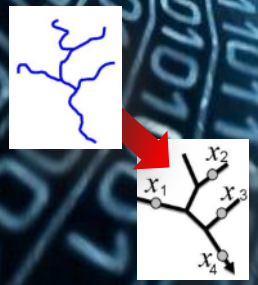


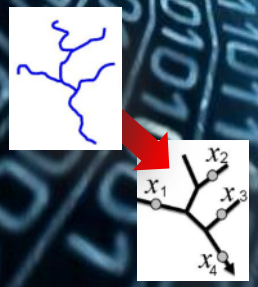
Software…



Data…







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