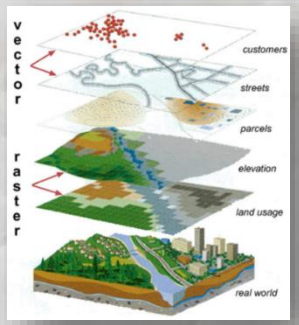
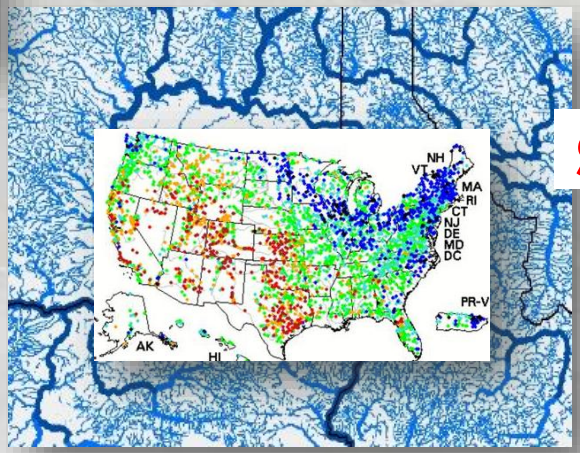
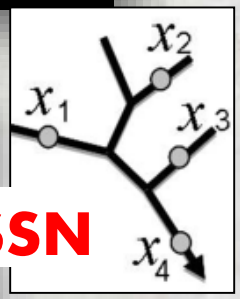
The Global Stream Internet

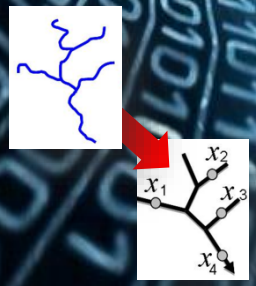
Fusing data, spatial stream models, and social networks for stream science, conservation, and management

Dan Isaak (USFS)
Erin Peterson (QUT)
Jay Ver Hoef (NOAA)
Dave Nagel (USFS)
Mike Young (USFS)







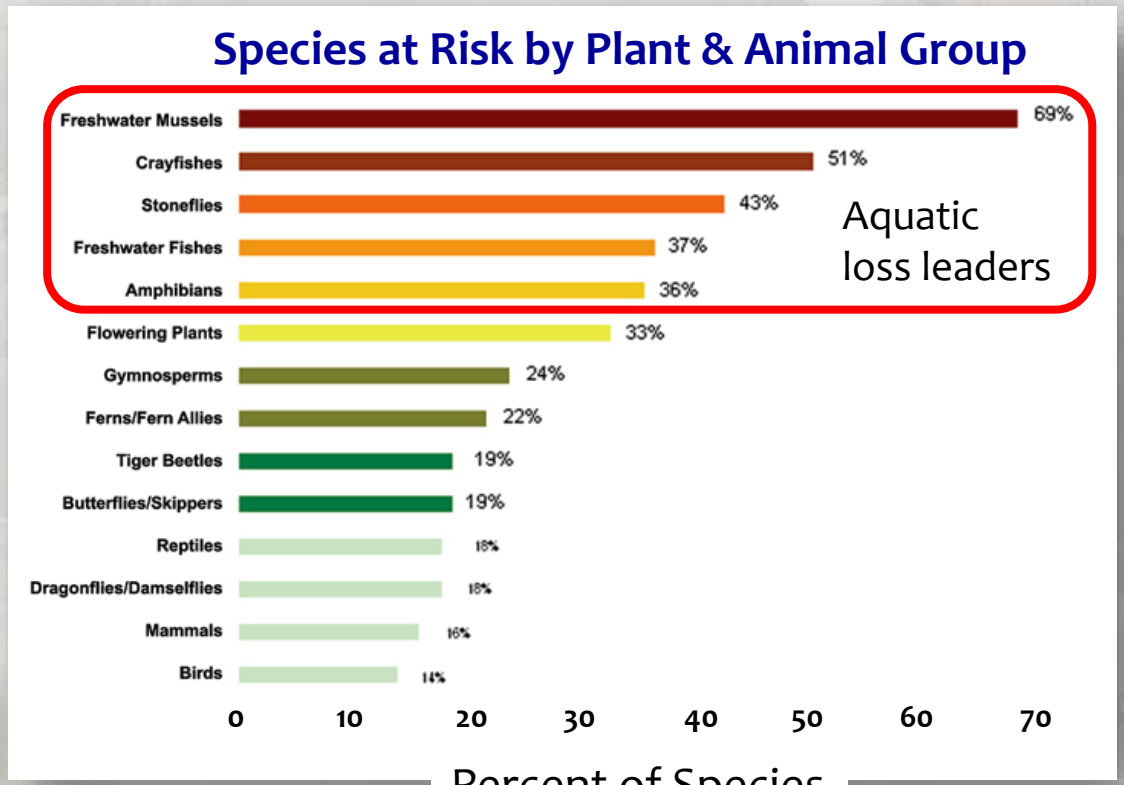


Global Freshwater Ecosystems are Disproportionately Biodiverse

"Freshwater makes up only 0.01% of the World's water and approximately 0.8% of the Earth's surface, yet supports at least 100,000 species – almost 6% of all described species"

Dudgeon et al. 2006

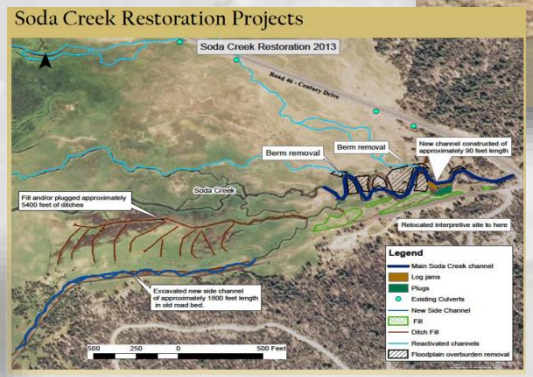
…but are Disproportionately at Risk



Williams et al. 2011

Many Things Can be Done to Improve Habitat & Population Resilience

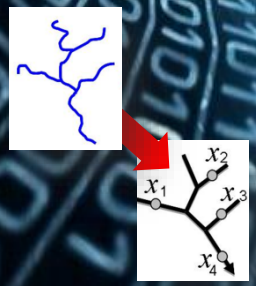
- Maintaining/restoring flow…
- Maintaining/restoring riparian…
- Restoring channel form/function…
- Prescribed burns limit wildfire risks…
- Non-native species control…
- Improve/impede fish passage…



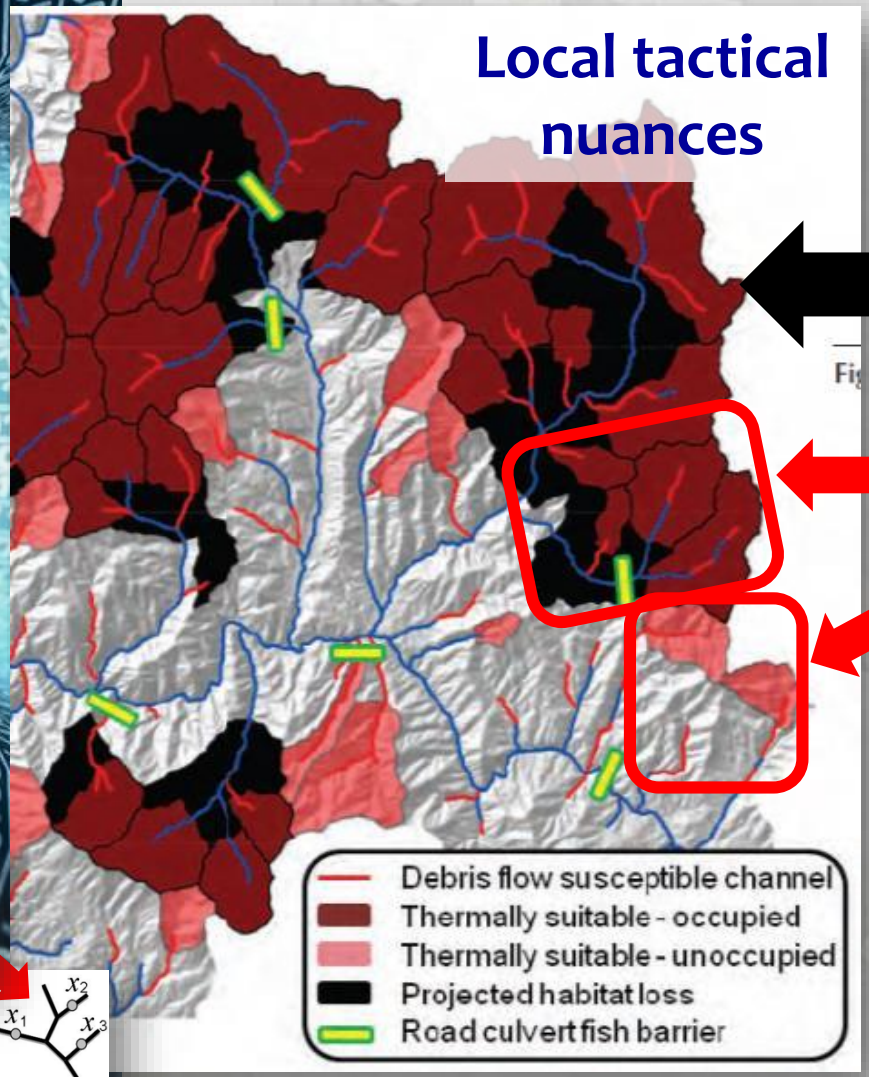
a) Where to do them?

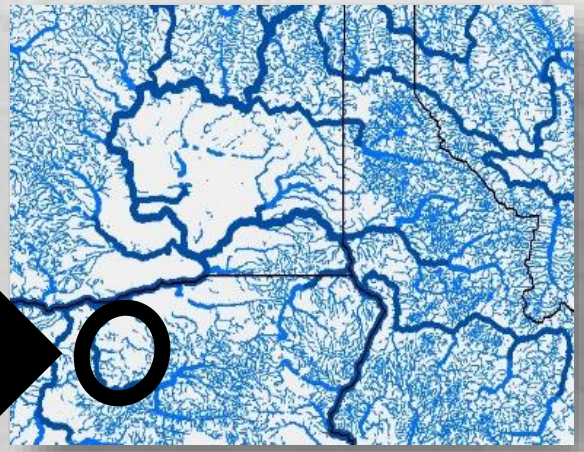
b) Is there a grand strategy?

c) How to maximize bang for the



Precise *Spatial* Information Needed Across Broad Areas for Strategic & Tactical Planning & Investment

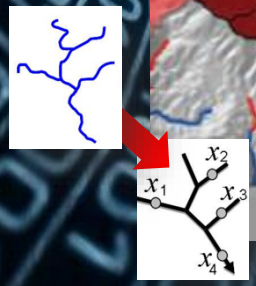




Regional strategic context

I'm going to invest here…

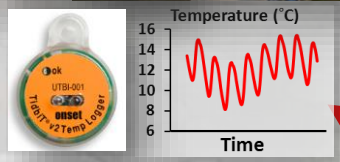
…instead of here



A Global Stream Internet is:

A network of people, databases, digital information systems & analytical techniques that interact synergistically to create & communicate massive amounts of information efficiently

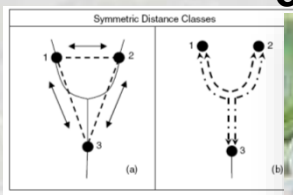
People on landscapes collecting data using standard protocols

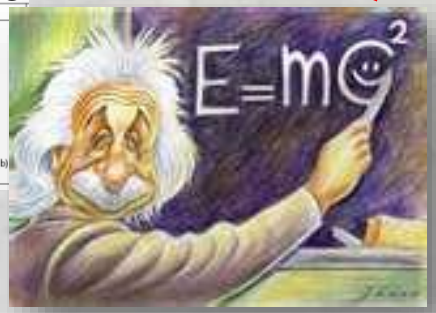


Open access, comprehensive databases

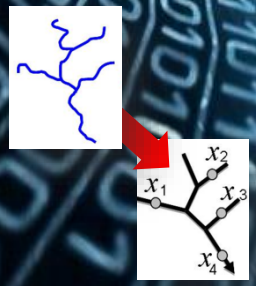
Analysis & new information

$$Y = b_o + b_1 x$$





Modularity & Inter-Compatibility are Key…

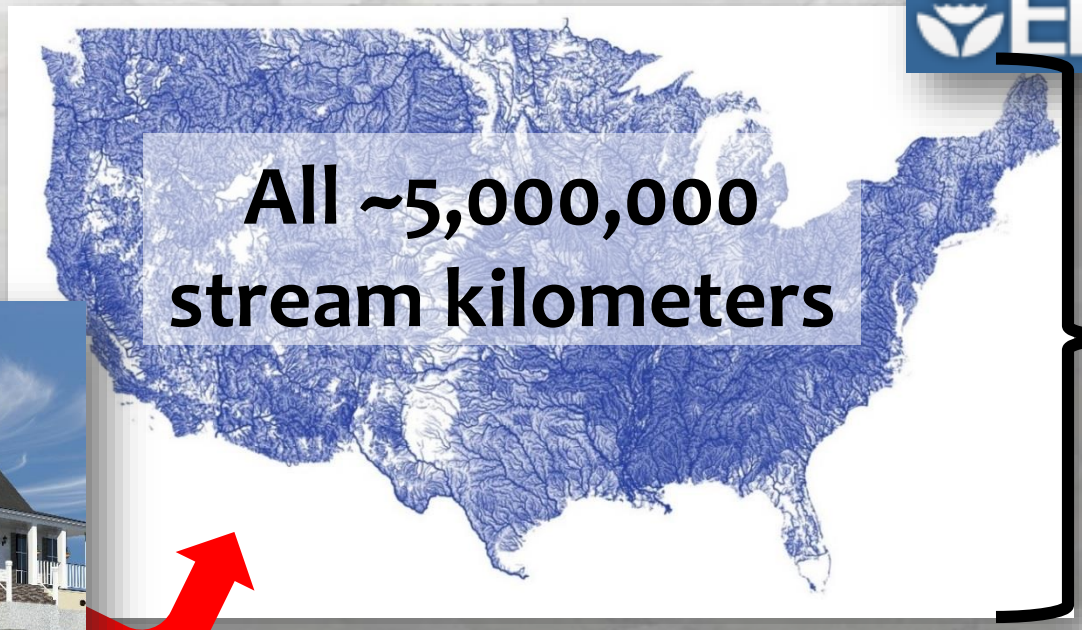


Component #1: Digital Hydrography Datasets

Consistent stream network geodatabases
Regional or national or continental in scope

EPA

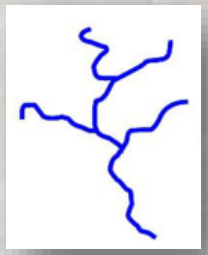
USGS science for a changing world

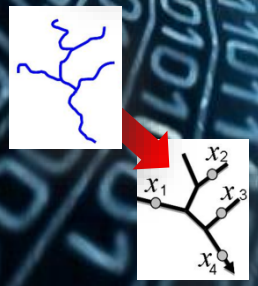


NHDPlus

Arc ESRI GIS

Vector shapefiles & Documentation



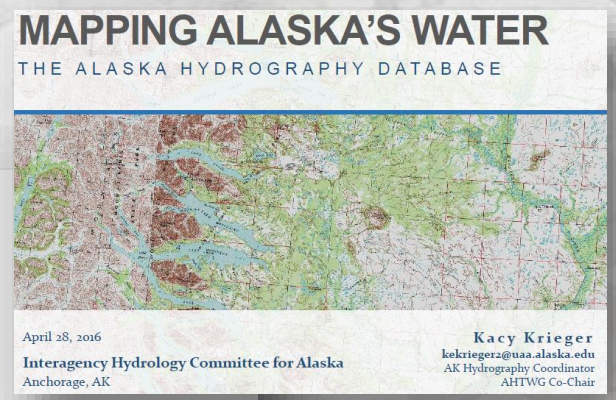


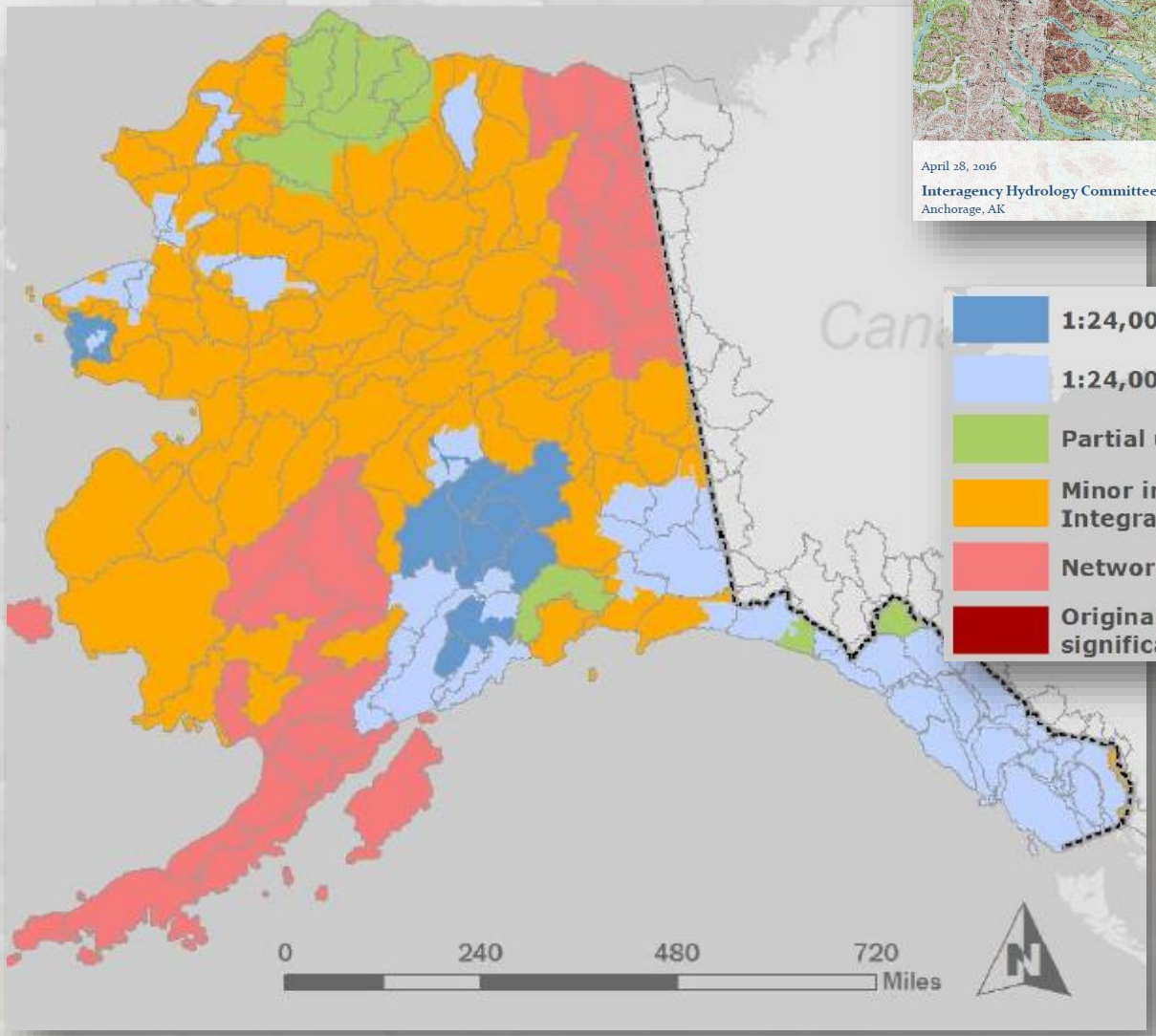
Cooter et al. 2010. A nationally consistent NHDPlus framework for identifying interstate waters: Implications for integrated assessments and interjurisdictional TMDLs. *Environmental Management* **46**:510-524.

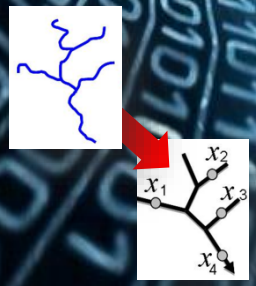
Website: http://www.horizon-systems.com/NHDPlus/NHDPlusV2_home.php

Component #1: Digital Hydrography Datasets

Alaska hydrography network continues to improve

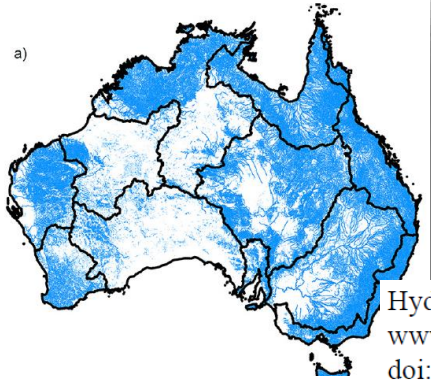






Component #1: Digital Hydrography Datasets

Are increasingly common…



Hydrol. Earth Syst. Sci., 18, 1917–1933, 2014
www.hydrol-earth-syst-sci.net/18/1917/2014/
doi:10.5194/hess-18-1917-2014

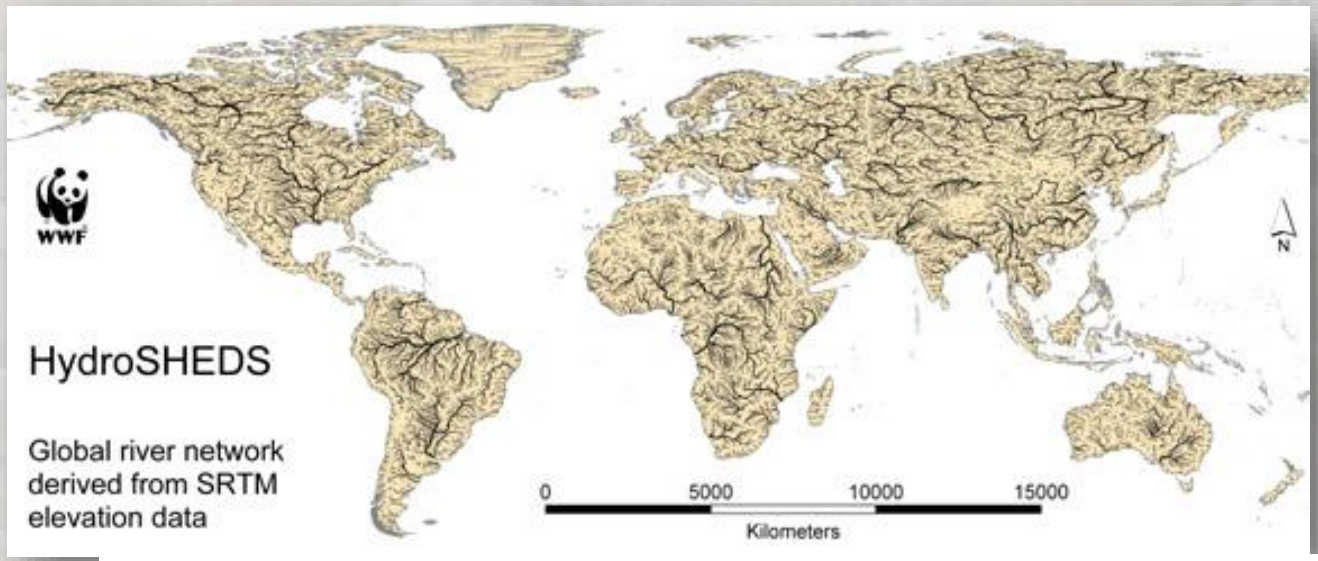
A new stream and nested catchment framework for Australia

J. L. Stein, M. F. Hutchinson, and J. A. Stein

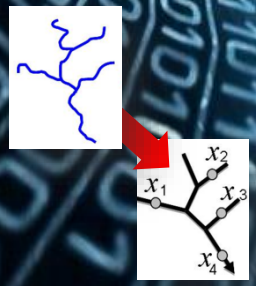
A pan-European River and Catchment Database

Jürgen Vogt

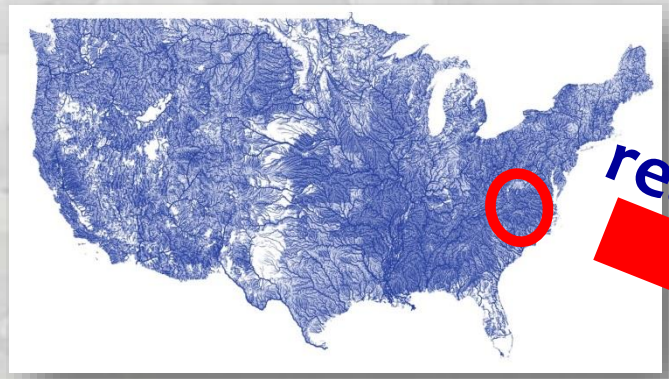
P. So
K. Bó



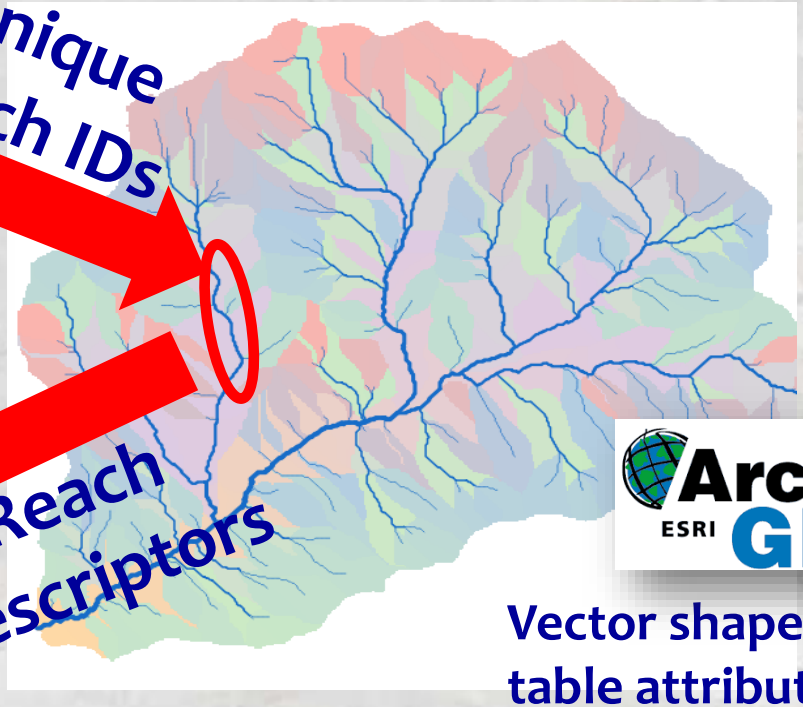
Lehner, B., Verdin, K., Jarvis, A. (2008): New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU, 89(10): 93-94.



Component #2: Stream Reach Descriptors (the "PLUS" part of NHDPlus)



Unique reach IDs



Reach descriptors

- Elevation
- Slope
- %Landuse
- Precipitation

100's more…

Vector shapefile table attributes

Wang et al. 2011. A hierarchical spatial framework and database for the national river fish habitat condition assessment. *Fisheries* **36**: 436-449.
Available at: https://www.researchgate.net/profile/Lizhu_Wang2

Hill et al. 2016. The stream-catchment (StreamCat) dataset: A database of watershed metrics for the conterminous USA. *The Journal of the American Water Resources Association*.
Available at: http://www2.epa.gov/national-aquatic-resource-surveys/streamcat

Component #2: Stream Reach Descriptors

Global dataset

SCIENTIFIC DATA

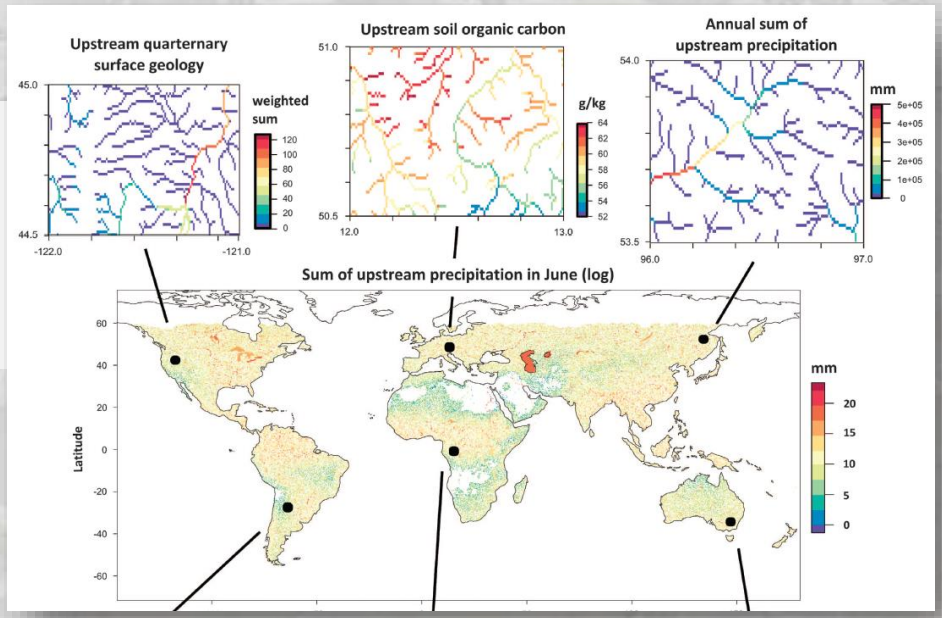
OPEN

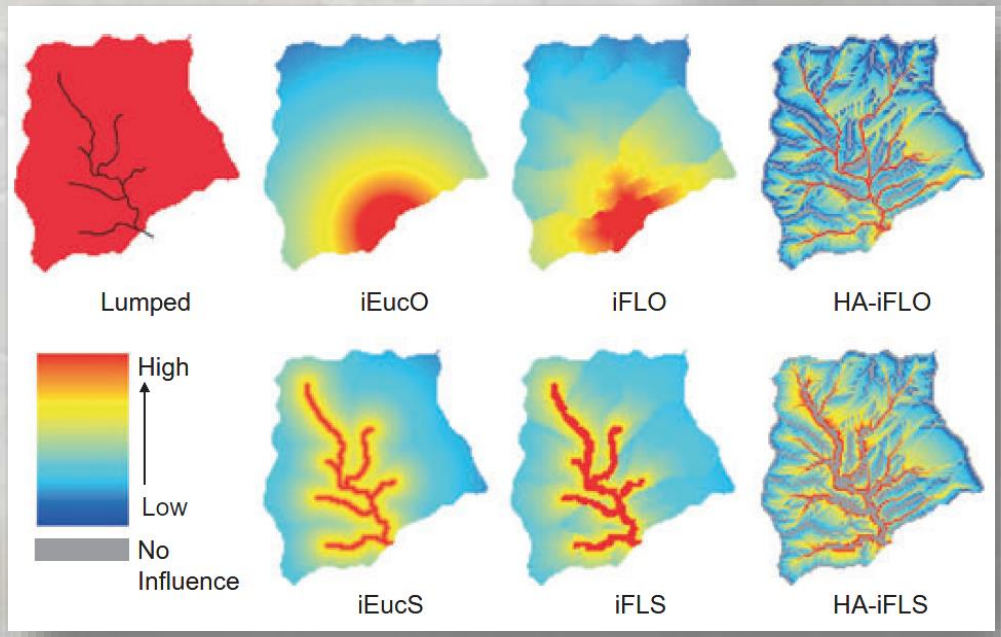
SUBJECT CATEGORIES
» Freshwater ecology
» Biogeography
» Macroecology
» Biodiversity

Near-global freshwater-specific environmental variables for biodiversity analyses in 1 km resolution

Domisch et al. 2015

WWF HydroSHEDS





Custom DIY Descriptors

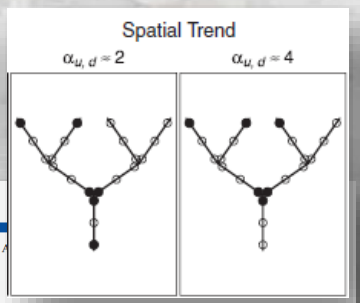
Peterson et al. 2010, 2017

Component #3: Data: a) purposeful designs

Spatially Balanced Sampling of Natural Resources

Don L. STEVENS Jr. and Anthony R. OLSEN

- GRTS designs
- Random
- Systematic
- Stratified



Research Article

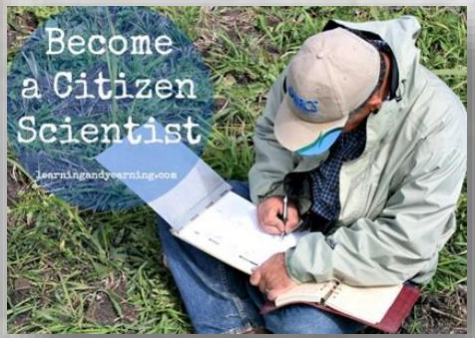
Received: 27 September 2013, Revised: 29 March 2014, Accepted: 21 A

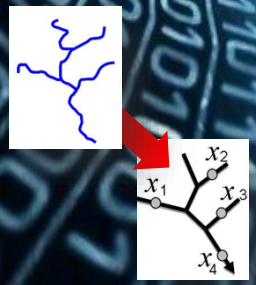
(wileyonlinelibrary.com) DOI: 10.1002/env.2284

Spatial sampling on streams: principles for inference on aquatic networks

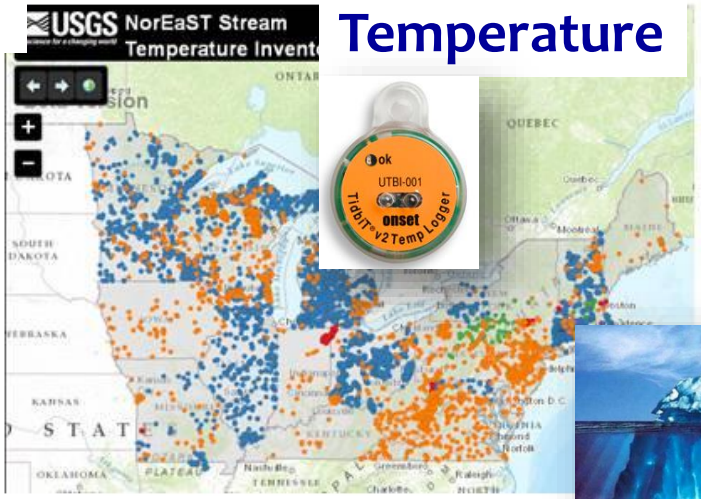
Nicholas A. Som[a*], Pascal Monestiez[b], Jay M. Ver Hoef[c], Dale L. Zimmerman[d] and Erin E. Peterson[e]

b) *ad hoc* crowd-sourced, citizen science endeavors



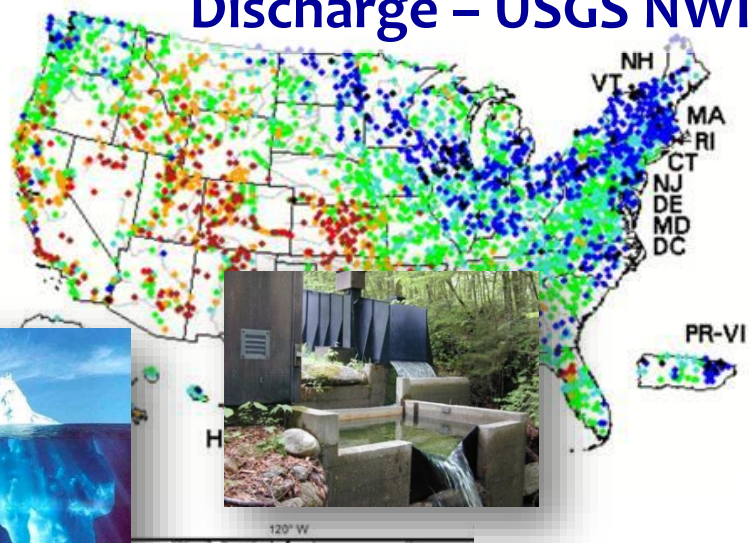


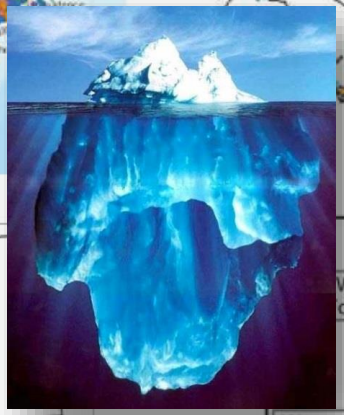
Component #3: Data: c) Existing Sources



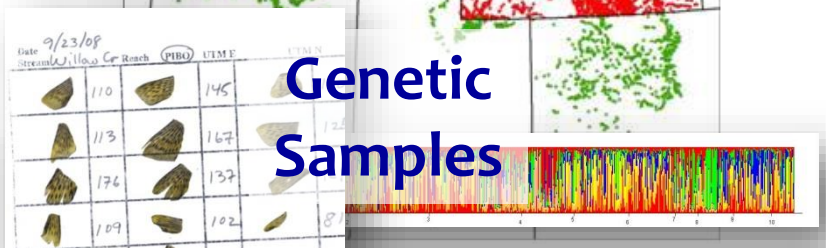
Temperature

Discharge – USGS NWIS

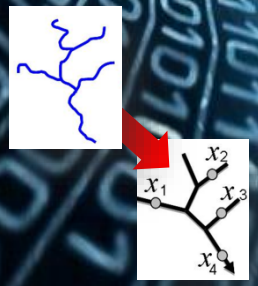




Species distributions



Genetic Samples

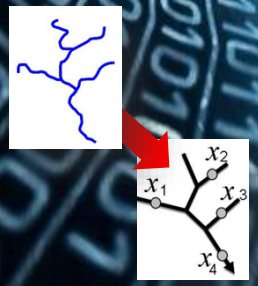


Water Quality

Challenge: Organizing & digitally archiving big datasets

Database Teams Often Required

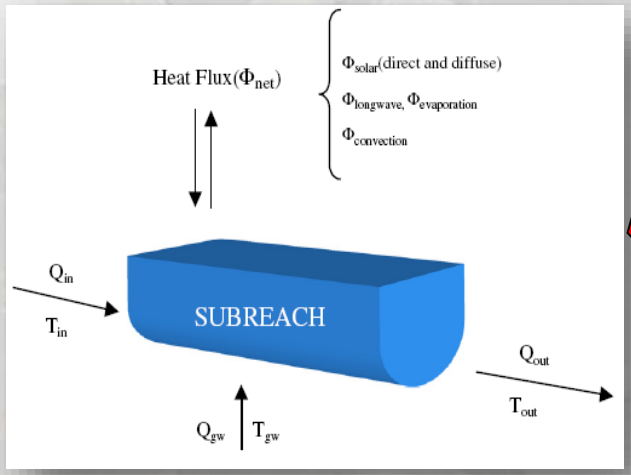
Opportunity: Researchers work with managers to use their data & social networks are strengthened



Component #4: Models & Inference

Data feeds All Models…

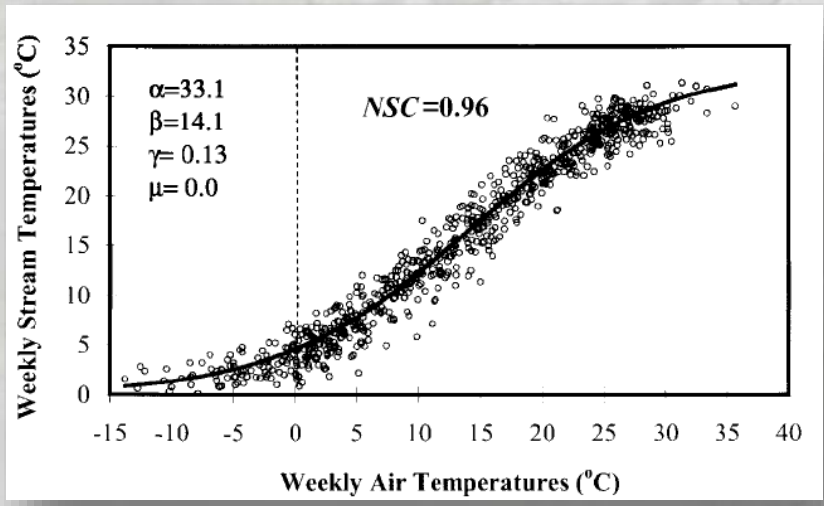
Mechanistic Models

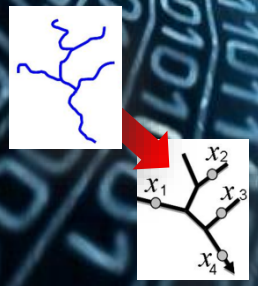


Statistical Models

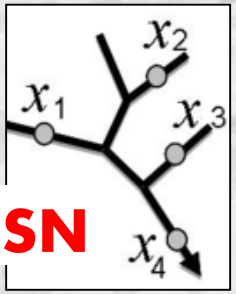
$$Y = b_o + b_1 x$$

- SSNs
- MaxEnt
- GLMM
- GLM
- Random forests





Our preference =

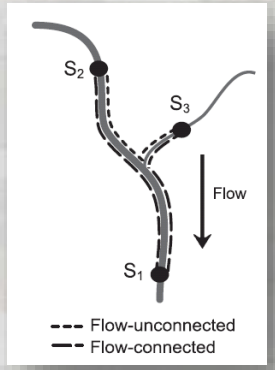


SSN

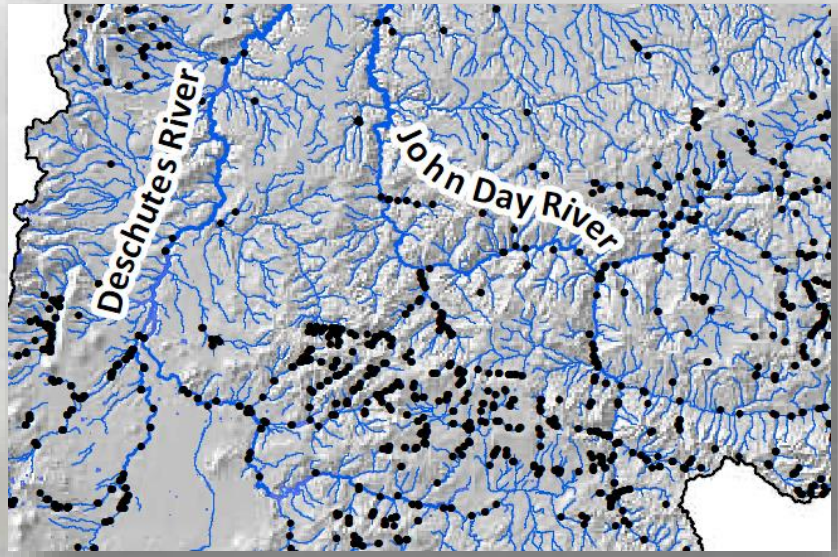
1) Versatility (binomial, Poisson, Gaussian)

- Water quality
- Discharge/temperature
- Species occurrence/abundance
- Habitat conditions

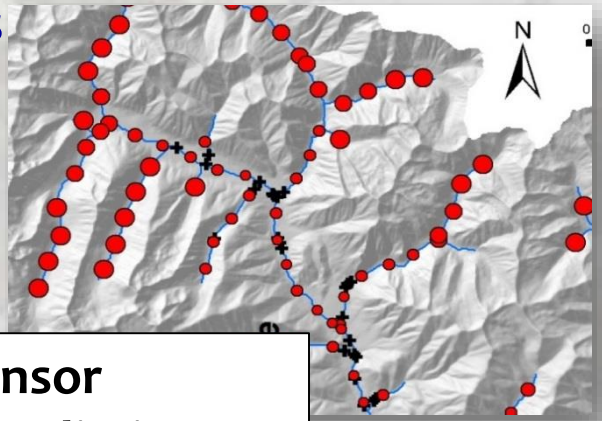
2) network topology recognition through covariance structure



4) Autocovariance functions enable applications with clustered datasets

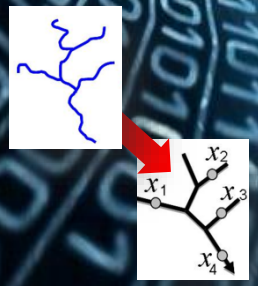


3) spatially explicit errors & maps



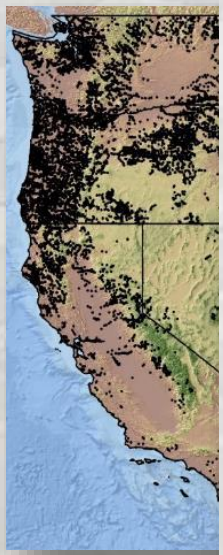
+ = Sensor

● = Prediction SE



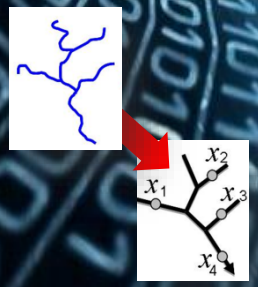
SSNs Facilitate BIG DATA Applications Relevant to Many Agencies

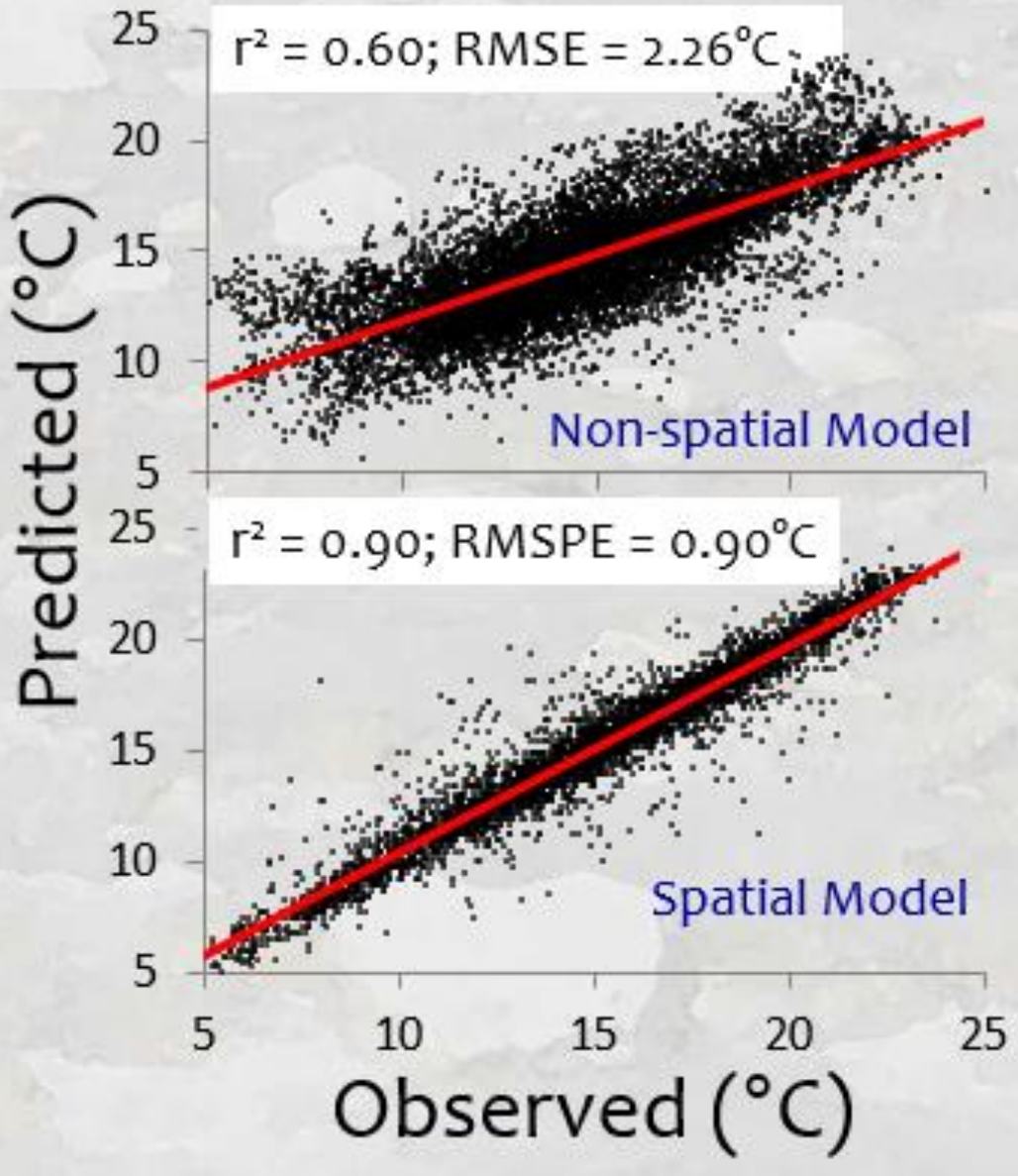
Aggregate Data



>23,000 uni

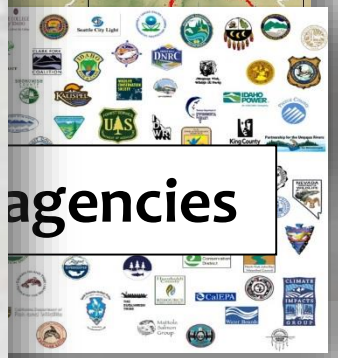
>220,000,0(





ature

os



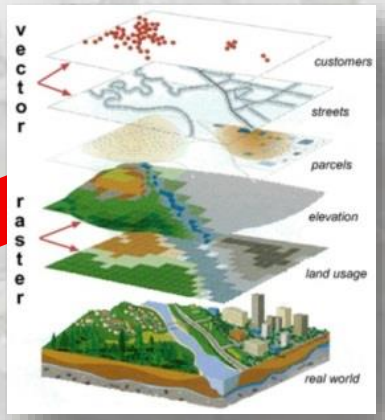
agencies

kilometers

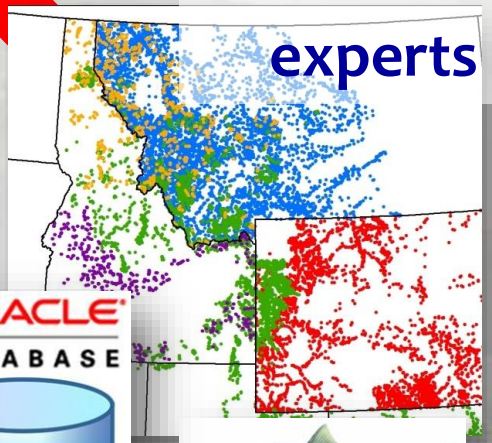
Challenge: Teams of People With Complementary Technical Skillsets are Needed

Managers

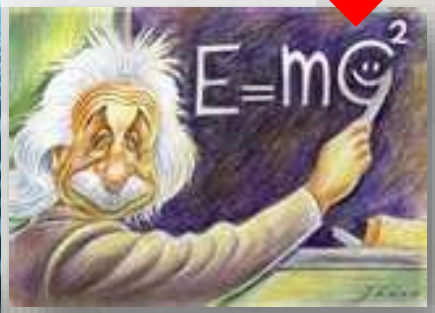
GIS analysts



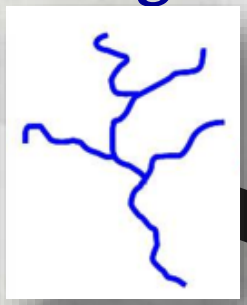
Database experts

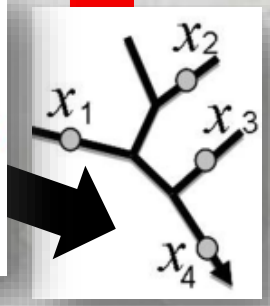


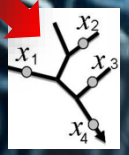
Scientists



Ecological Modelers







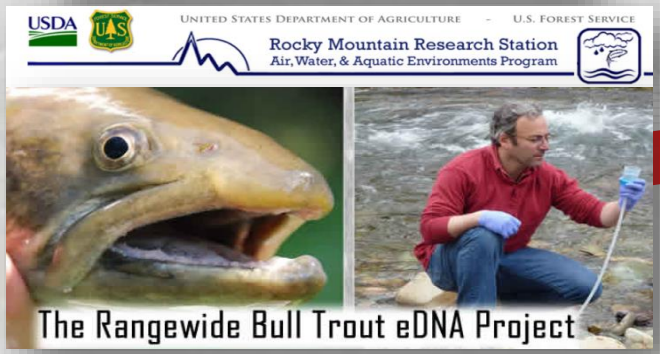
Component #5: Information Outputs & User-Community Engagement

Data & information must be:

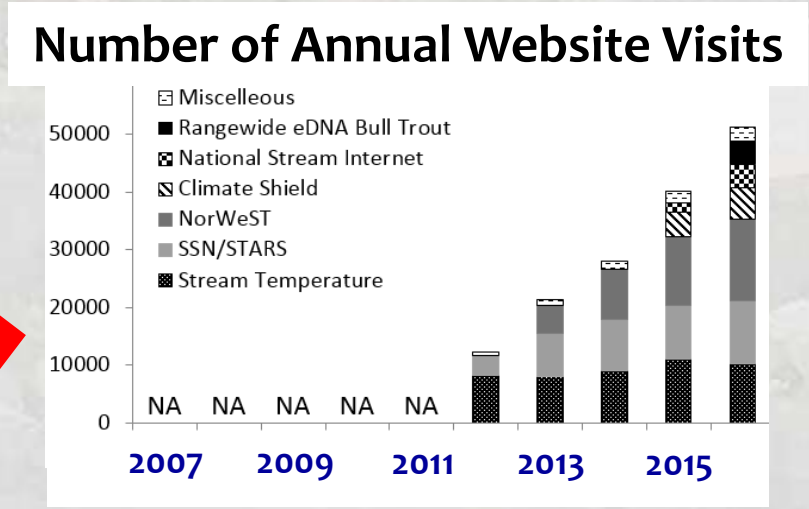
- Discoverable (Google-able)
- Understandable (thorough metadata)
- Usable (Software & User-Friendly Digital Formats)

ArcGIS ESRI | X | PDF

Custom websites



- 50,000 annual web-visits
- Hundreds of data products downloaded



As Databases & User Communities Grow, Things Become More Efficient

NHDPlus

DATABASE

NorWeST Stream Temp

SSN

Interpolated map scenarios

New research & models developed rapidly

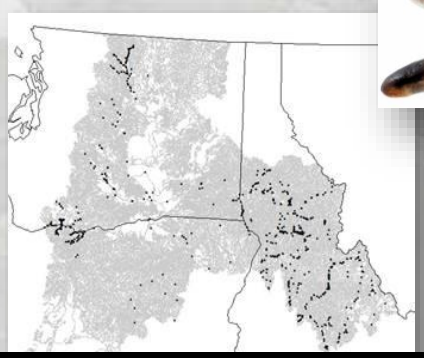
Interagency coordination of monitoring

Species distribution models

Recent Example: Pacific Lamprey Regional eDNA Sampling Campaign & Status Assessment

Obtain existing biological survey data (n = 988)

- OR
- WA
- ID



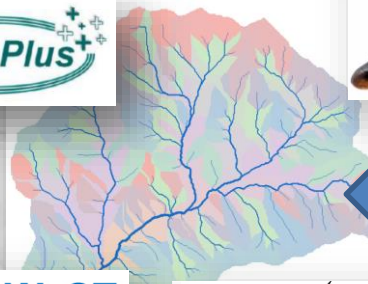
U.S. Fish & Wildlife Service

Pacific Lamprey Conservation Initiative

https://www.fws.gov/pacificlamprey/mainpage.cfm

Link data to NHD covariates & build preliminary model

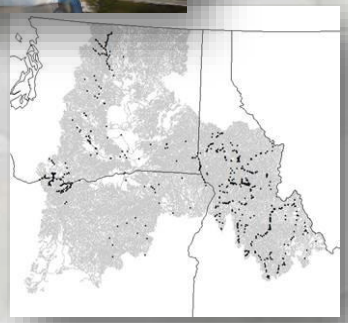
NHDPlus

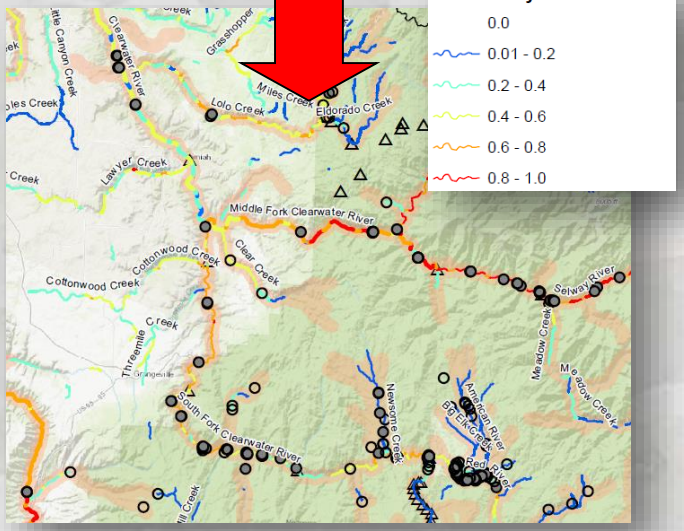


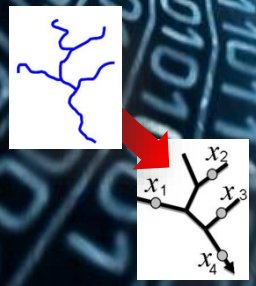
NorWeST Stream Temp

$$p = \frac{\exp(a + bx \ldots ny)}{(1 + \exp[a + bx \ldots ny])}$$

Refit model







Systematically sample potential habitat with eDNA

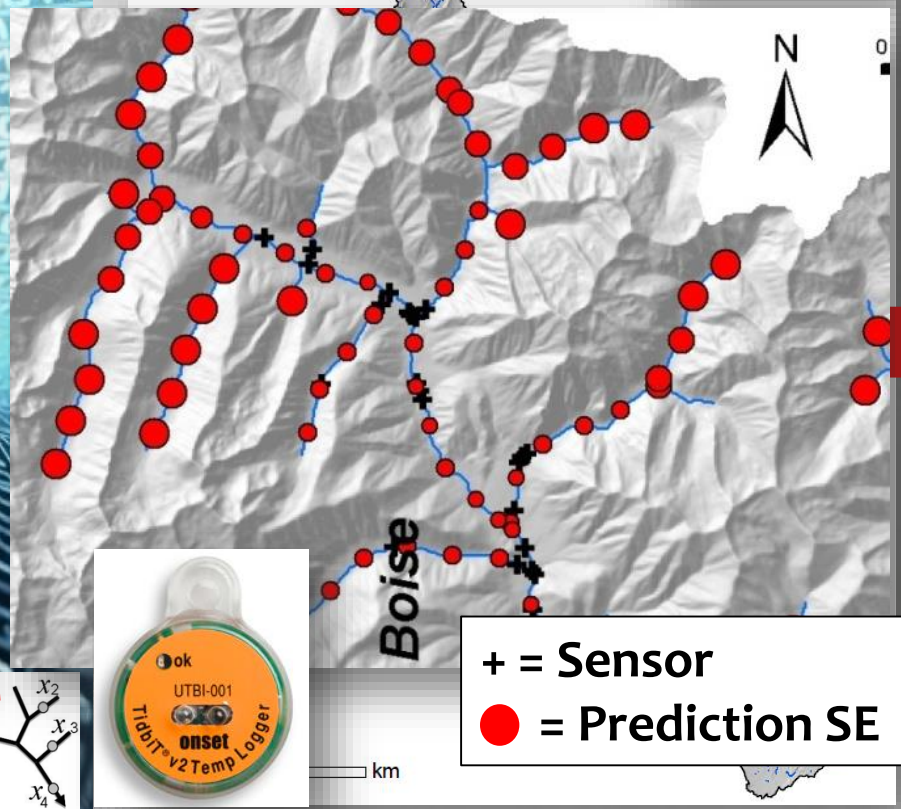
Use model to predict habitat suitability throughout study area network

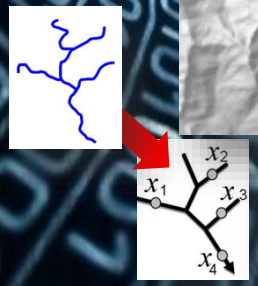
Recent Example: Supplemental Temperature Monitoring in Utah

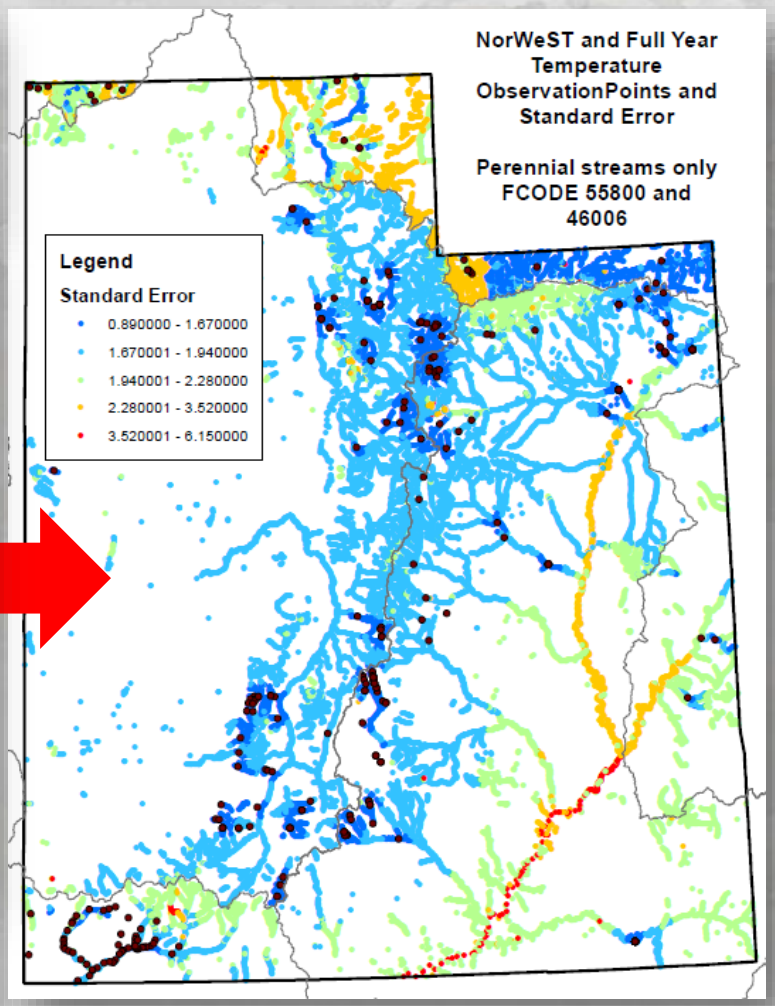
143 temperature sites originally
+ 100 new temperature sites this year

NorWeST Stream Temp

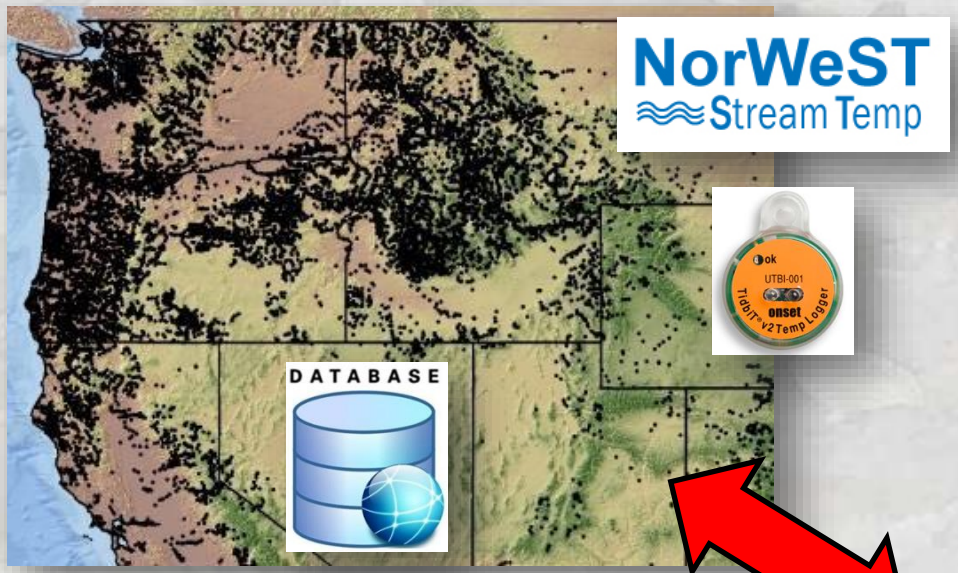
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

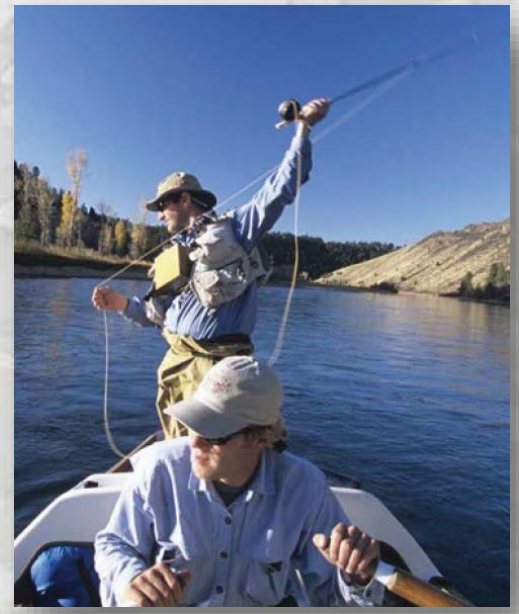






Recent Example: What are large river warming rates due to climate change?

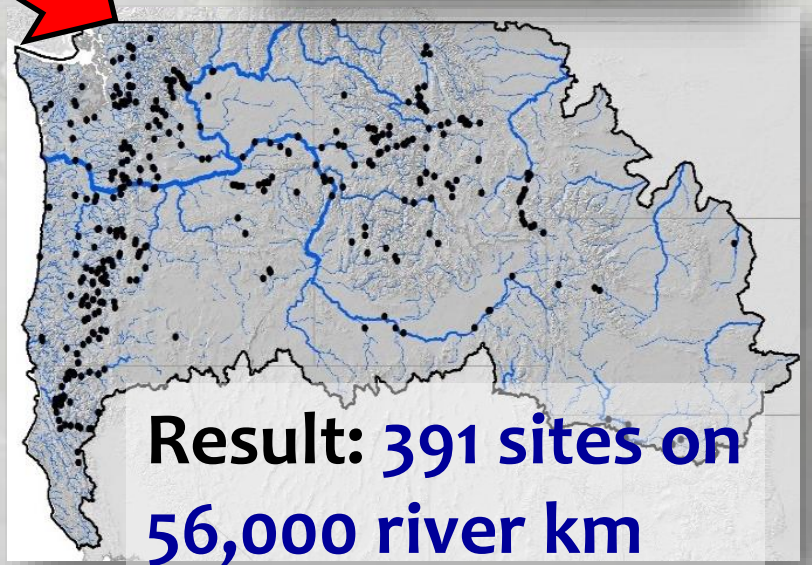




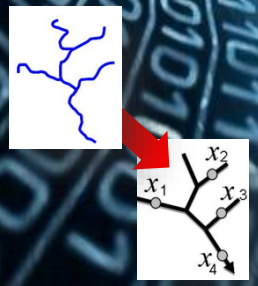
Database query:

1) Sites with >10 years of monitoring

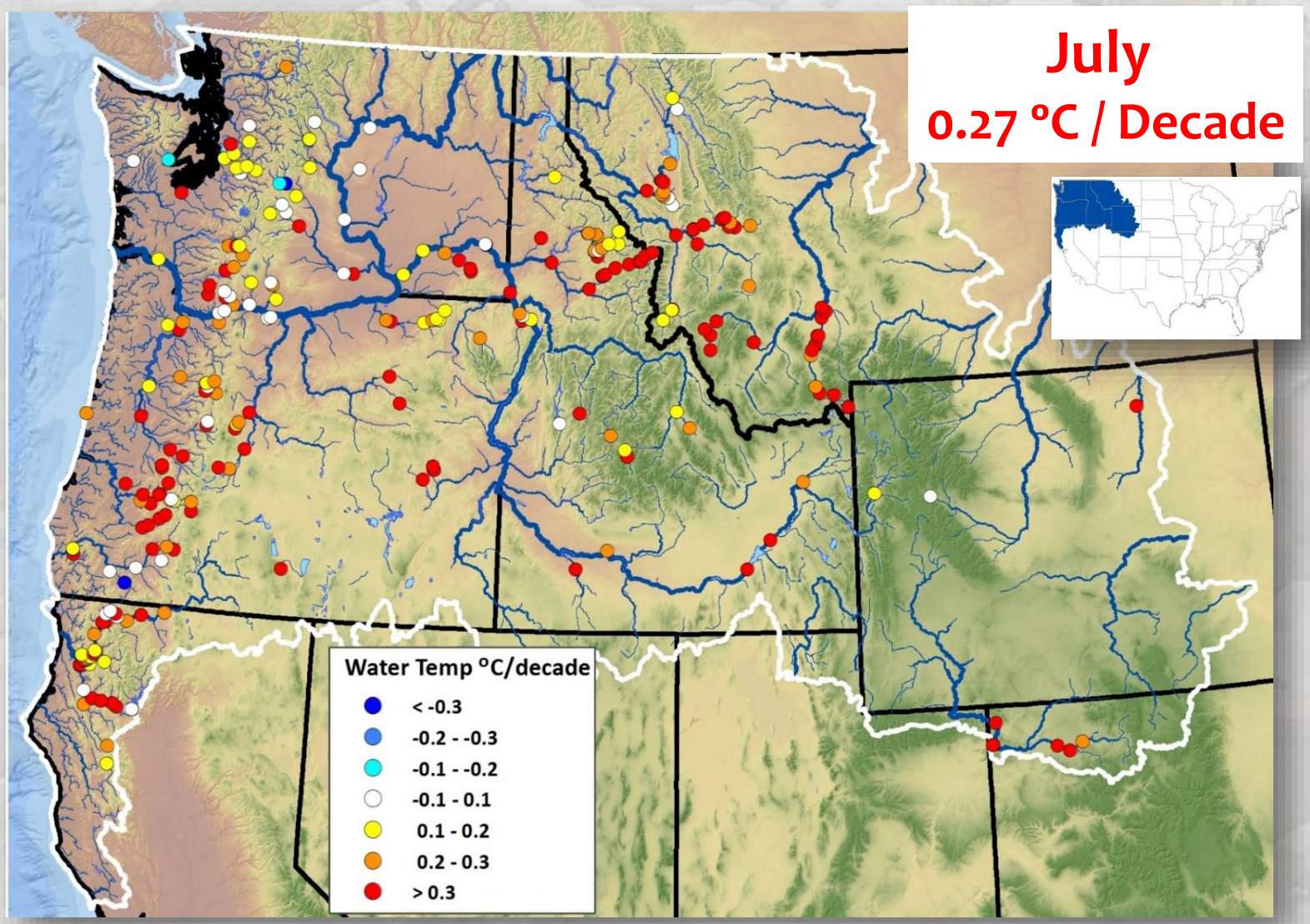
2) Sites that occur on rivers with >100 cfs flow



Result: 391 sites on 56,000 river km



River Temperature Trends for 1976–2015



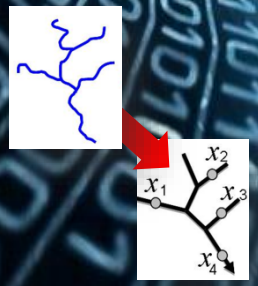
Isaak et al. 2018. Global warming of salmon and trout rivers: Road to ruin or path through purgatory? *Transactions of the American Fisheries Society.*

The Earth is Big

The Global Stream Internet will Take Time

But progress is ongoing (last 25 Years)…

- Field navigation from paper maps & compass to GPS to ?drones?
- Net seines & traps to eDNA sampling
- Small datasets (n = 10 to 100) to giant databases (n = 1,000 to 100,000,000)
- Limited spatial study components to ubiquitous GIS & digital stream networks & many covariates
- No stream statistical theory to SSNs
- Limited computing to virtually unlimited




The End