Big Data Compilations to Engage Conservation Communities and Assess Climate Change Effects On Aquatic Environments

Dan Isaak, US Forest Service
With idiosyncratic local effects

Global Phenomenon...

Adaptation requires understanding local nuance

I’m going to invest here... instead of here
Precise & Consistent Information Needed Across Broad Areas & Multiple Jurisdictions

~3,500,000 km²

Western U.S.
Downscaling is improving but precision is lacking.

Topoclimate models (e.g., WorldClim, PRISM, DayMet)

Covariates: Elevation, Slope, Aspect, Etc...

Sparse empirical support

n = 191 weather stations

Dense Datasets Exist If Viewed Collectively

>23,000 stream temperature sites   >20,000 fish sample sites

>100 agencies
Dense Datasets Exist If Viewed Collectively
Many Groups Collect Similar Types of Data with Standard Protocols & Sensors...

- Tissue Samples & DNA barcoding
- Water Chemistry
- Water Temperature
- Species distribution & abundance
- Stream discharge

A Watershed-Scale Monitoring Protocol for Bull Trout

A Simple Protocol Using Underwater Epoxy to Install Annual Temperature Monitoring Sites in Rivers and Streams
Data ≠ Database

Data Aggregation

QA/QC Data Cleaning

Metadata & Digitally Archiving

Data Summaries & Georeferencing

Mean

Minimum

Maximum

DATABASE

ESRI ArcGIS™
Creating & Maintaining Big Databases is a Full-Time Job for Technical Experts

Geospatial databases

Relational databases

Statistical analysis & summaries
Big Data Requires Expanding the Traditional Aquatic Science Model

Modelers

Scientists

Webdesigner

GIS analysts

Database experts
Custom Websites Make Data Available to User-Communities & Engages Them

GIS shapefiles of stream temperature scenarios

Regional Database and Modeled Stream Temperatures

Temperature data summaries

>100 agencies

40-50 visits/day
12,000 visits/year
Comprehensive, Open-Access Databases Create Synergies

- Species distribution models
- Coordinated Interagency monitoring
- Data access accelerates temperature research

High Resolution Scenarios
Question: At What Rate is Climate Change Warming Rivers in the Western US?

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

December 0.07 °C / Decade

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

July
0.27 °C / Decade

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

August
0.14 °C / Decade

Isaak et al. In Review. Global warming of salmon and trout rivers: Road to ruin or path through purgatory? Transactions of the American Fisheries Society.
**Need: High-Resolution Climate Scenarios**

Global climate model
Resolution: 1000’s of kilometers

Regional climate model
Resolution: 100’s of km

River network: 10’s of km

Stream reaches: 1’s of km
Database Query: Dataset for Modeling

n = 63,461  August Temperature Observations

Covariate Predictors
1. Elevation (m)
2. Canopy (%)
3. Stream slope (%)
4. Ave Precipitation (mm)
5. Latitude (km)
6. Lakes upstream (%)
7. Glaciers upstream (%)
8. Baseflow Index
9. Watershed size (km²)
10. Discharge (m³/s)
11. Air Temperature (°C)

\[ y = X\beta + L\gamma + R\eta + z_{TU} + z_{TD} + z_{EUC} + \varepsilon, \]

\[ r^2 = 0.91 \]
\[ \text{RMSPE} = 1.10°C \]
\[ \text{MAPE} = 0.72°C \]
High-Resolution Stream Climate Scenarios

1-km resolution
400,000 km of rivers & streams

Combining Big Databases Creates Synergy

Realized Thermal Niches

Frequency of Occurrence

NorWeST Stream Temperature

Precise Species Distribution Models to Highlight Climate Refugia

Additional Covariates
1. Elevation (m)
2. Stream slope (%)
3. Lakes upstream (%)
4. Baseflow Index
5. Watershed size (km²)

Predictive Logistic Regression Models

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

Occurrence probability maps

Bull Trout Probability Map

2000s

Stream population scale predictions

5,332 >0.1 habitats
1,325 >0.5 habitats
348 >0.9 habitats
Bull Trout Probability Map

3,304 >0.1 habitats
641 >0.5 habitats
130 >0.9 habitats
Bull Trout Probability Map

2,712 >0.1 habitats
460 >0.5 habitats
62 >0.9 habitats

North Cascades
Walla Walla
Flathead
Metolius
Central Idaho

2080s
Extreme scenario! +5°C
Extinction not Likely

2,712 >0.1 habitats
460 >0.5 habitats
62 >0.9 habitats
Website Provides Information in User-Friendly Digital Formats

Just Google “Climate shield trout”

File formats:
• ArcGIS files
• pdf files

15 Scenarios:
• 3 climate periods
• 5 Brook invasion levels

Digital Maps & ArcGIS Shapefiles

Presentations & Publications

Fish Data Sources

Distribution Monitoring
Precise Information Across Broad Scales

Empowers local decision makers & facilitates efficient coordination

Highest priority conservation investment!
Goal: Big Data & Precise Models for all Species in all Streams, Rivers, Lakes, Ponds, etc.

I'm going to invest here...
Aquatic eDNA Revolution: Water Samples Contain the DNA of All Species

Comprehensive Biodiversity Archive
One Person Can Sample Many Sites Rapidly

• 20 minutes to collect a sample
• All sampling equipment is carried in a daypack

Bull trout eDNA survey
St. Joe River (266 sites)

- Detection
- No detection
eDNAAtlas Database for the Western U.S.
Online this winter with 10,000 samples
Update database with thousands of new samples annually

Partner Agencies

- BLM
- Bureau of Reclamation
- Chehalis Tribe
- Clark Fork Coalition
- Coeur d'Alene Tribes
- Great Northern LCC
- Idaho Conservation League
- Idaho DEQ
- Idaho Fish and Game
- Idaho Power Company
- Kalispel Tribes
- Montana Dept. Natural Resources Conservation
- Montana Fish, Wildlife & Parks
- National Fish & Wildlife Foundation
- The Nature Conservancy
- National Park Service
- Oregon Dept. Fish & Wildlife
- Shoshone-Bannock Tribes
- Trout Unlimited
- University of Washington
- U.S. Fish and Wildlife Service
- Washington Dept. Fish & Wildlife
- Yakama Nation
Open-Access Big Databases are Cost-Effective & Engage Everyone

Many stakeholders

“Boots-on-the-Ground”

Research develops databases & relevant information

Standard data protocols
Better Information Enables Better Adaptation, Conservation & Management...

Urbanization & Population Growth

Habitat degradation

Climate Change