Informing “Make it or Break it” Decisions with High-Resolution Stream Geospatial Data & Climate Scenarios
Outline...

I. Invasible habitats, environmental context, & old fuzzy habitat definitions

II. Revolution #1: Quantity & quality of information mapped onto stream networks (GIS/spatial analysis/BIG DATA/sensor technology)

III. Revolution #2: Information access & portability (websites/smartphones/dynamic digital maps)

IV. Information overload & filtering the signal from the noise

V. Think globally, act locally with “Make it or Break it” decisions
Precise Local Information is Crucial for Tactical Decision Making

Debris flow susceptible channel
Thermally suitable - occupied
Thermally suitable - unoccupied
Projected habitat loss
Road culvert fish barrier

I’m going to break this stream...
make this one...
& leave this one alone
The Right Choices Depend on Context
Habitat & Climate & Biology Determine Invasibility

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Habitat & Climate & Biology Determine Invasibility


Distance to Nearest Valley Bottom

Do we have “actionable intelligence” that tells us where precisely throughout networks?
The Right Choices Depend on Context
Habitat & Climate & Biology Determine Invasibility

Invaders have warmer niches

Fall spawners more vulnerable


Do we have “actionable intelligence” that tells us where precisely throughout networks?
Brett Roper’s Contribution to Science
(When he’s not busy directly controlling invasive species)
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Describing habitat is subjective & imprecise

What is a Pool?  What is a Riffle?
We Don’t Know... We’re Not Fluvial Geomorphologists
Scary Climate Assessments Have Been Equally Imprecise

- Meisner 1988, 1990
- Eaton & Schaller 1996
- Keleher & Rahel 1996
- Rahel et al. 1996
- Mohseni et al. 2003
- Flebbe et al. 2006
- Rieman et al. 2007
- Kennedy et al. 2008
- Williams et al. 2009
- Wenger et al. 2011
- Almodovar et al. 2011
- Etc.
Fish Biologists Can Measure Fish & They’re Starting to Move...

National French Study

Survey sites (n = 3,500)

Difference in stream fish distributions (1980’s vs 2000’s)

32 species

Change in Elevation (m)

Bull Trout Distribution Shifts in Montana

- Resurveyed 77 Rich et al. (2003) sites 20 years later
- Modeled extirpations/colonizations accounting for detection efficiency

Bull Trout Distribution Shifts in Montana

Best predictors

- Standardized temperature
- Standardized elevation

Fire Severity
- None/low
- Moderate/high

Extirpation probability (95%CI)

Probability (95%CI)

Extirpations (15)
Colonizations (5)
Local Decisions also Need a Strategic Context

The 21\textsuperscript{st}-Century will Be a Transitional One

Pick these

Not these

Sorry Charlie
Revolution #1: Quantity & Quality of Information is Exploding

- Remote Sensing
- GIS / Computing Capacity
- Visualization
- Climate, weather, GCM data online
- Inexpensive sensors
- Spatial analyses
- Nationally Consistent Hydrology Databases (USGS NHD+)

- Elevation
- Slope
- Drainage Area
- Distance
The Era of BIG DATA is Here

>45,000,000 hourly records
>15,000 unique stream sites

20,000 fish surveys
BIG DATA presents big challenges
BIG DATA are often Autocorrelated

Spatial Statistical Network Models

Advantages:
- flexible & valid autocovariance structures that accommodate network topology & non-independence among observations
- improved predictive ability & parameter estimates relative to non-spatial models

Ver Hoef et al. 2006; Ver Hoef & Peterson 2010; Peterson & Ver Hoef 2013
Accurate, Unbiased Information from Aggregated Stream Databases

It’s the MOTHER LODE!
High Resolution Stream Thermalscape

1 kilometer resolution

1993-2011 Composite

The BLOB... it just keeps growing...

- 234,000 stream kilometers of thermal ooze
- 20,072 summers of data swallowed
High Resolution Stream Thermalscape

1 kilometer resolution

2040’s A1B

The BLOB... it just keeps growing...

- 234,000 stream kilometers of thermal ooze
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High Resolution Stream Thermalscape

1 kilometer resolution

2080’s A1B

The BLOB... it just keeps growing...

- 234,000 stream kilometers of thermal ooze
- 20,072 summers of data swallowed
VIC Streamflow Metrics & Scenarios

Winter flood frequency (95% event)

Historical

VIC Streamflow Metrics & Scenarios

Winter flood frequency (95% event)

2040s A1B

VIC Streamflow Metrics & Scenarios

Winter flood frequency (95% event)

Lots of Stream Habitat Descriptors
100’s are Available (NHDPlus, NLCD, DEMs...)

% Landuse

Precipitation

Drainage Area

Elevation

Slope

Better Information for Mainstem Rivers

Green Lidar flown to census Lemhi River last October

Precisely Quantify Fish Microhabitats

Hydrodynamic models simulate channel conditions

~1 m resolution DEMs for river bed & floodplain

McKean et al. 2008; McKean & Tonina 2013

Smolts

Walters et al. 2013

Redds

Link to fish population models
Synergies Emerge from Better Information
Regionally Consistent Thermal Criteria

Stream temperature maps
Regional fish survey databases (n ~ 20,000)

NorWeST
Stream Temp

Occurrence probability

Temperature (°C)

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

NorWeST Stream Temperature (S1)

Frequency of Occurrence

Cutthroat

Bull

Rainbow

Brook

~20,000 fish surveys

Wenger et al., In Preparation
Thermal Niche Nuances...

All Bull Trout

Competitive Interactions...

NorWeST Temperature

Frequency

NorWeST Temperature

Frequency
Salmon River Temperature Scenario
Historic (1993-2011 Average August)
Bull Trout Natal Habitats = Historic

11°C isotherm

Suitable

Unsuitable
Bull Trout Natal Habitats = +1°C

11°C isotherm

- **Suitable**
- **Unsuitable**
Bull Trout Natal Habitats = +2°C

11°C isotherm

- Suitable
- Unsuitable
Spatial Variation in Habitat Loss

Historical scenario

11°C isotherm

EFK. Salmon

White Clouds
Spatial Variation in Habitat Loss

+1°C Scenario

11°C isotherm

White Clouds

EFK. Salmon

White Clouds

EFK. Salmon
Difference Map ~ Invisible Habitats

11°C isotherm

White Clouds

EFK. Salmon

Break It?
Precise Predictions of Invasive Habitats & “Zombie” Populations

Where could invasions occur?

How much time is left on the clock?

x km upstream shift by 2050
Revolution #2: Information Access

Websites Distribute Geospatial Stream Data 24/7...

Google “NorWeST stream temp”

Google “Stream flow Metrics”

VIC Streamflow Scenarios
The BLOB is User-Friendly

Hmmm...where are all the streams <10°C that have slopes <3%?
Websurf the BLOB
Dynamic Online Map Viewer

See thermal patterns for all streams & data locations across all agencies from your desktop
Take the BLOB with You – Go Wireless

Real-time Access to Accurate Stream Data Anytime, Anywhere

ArcGIS app

Temperature Maps

Habitat Maps

Species distributions

VIC flows
Information Overload
How do We Filter it?
Filter #1: Amount of Habitat Needed to Support a Population

~2 - 20 stream kilometers
The Future will be Different...
NorWeST Predictions of Summer Stream Temperature Increases

CIG 10 GCM ensemble A1B trajectory

August Stream Increase (°C)

Salmon
Clearwater
SpoKoot
Missouri
SnakeBear
MidSnake

2040s
2080s
Climate Related Factors will Interact

- Warmer temperatures
- Reduced summer flows
- Fire & debris flows
- Winter flooding
- Non-native invasions

The Headwater Trout Vise
Bigger Floods, Fires, & Droughts are Coming…
So We’ll Need a Habitat Fudge Factor

Occurrence

Stream kilometers

~2 - 20 stream kilometers?
~4 - 40 stream kilometers?
Filter #2: Decision Support Tools Integrate Information from Multiple Sources

Structured Process & Transparent Logic

Problem A: Spatial prioritization among populations

Problem B: Barrier installation or removal

Habitats Color Coded by Size & Population Persistence Potential

Bull trout example in Boise River Basin

Historic
Habitats Color Coded by Size & Population Persistence Potential

Bull trout example in Boise River Basin

2080’s

Intermediate habitat = management critical!

Tiny habitat = lost cause?

Big habitat = OK?

Habitat Length  Occurrence Prob.
< 5 km  0-20%
5 - 10 km  20-40%
10 - 20 km  40-60%
20 - 40 km  60-80%
> 40 km  80-100%
Decision Tools Built From Regionally Consistent Geospatial Data to Enable Applications Anywhere

- Local Expertise
- BIG FISH Surveys
- VIC flows
- NHDPlus Hydrology Layer Variables
- Distance
- Slope

NorWeST
Stream Temp

Maps and data illustrating geospatial analysis tools and applications.
Think Globally, act Locally with “Make it or Break it” Decisions

More of this...

Less of this...

Largest habitats & nearest neighbors...
Think Globally, act Locally with “Make it or Break it” Decisions

Feature:
FISHERIES MANAGEMENT

Native Fish Conservation Areas: A Vision for Large-Scale Conservation of Native Fish Communities

Jack E. Williams, Richard N. Williams, Russell E. Thurow, Leah Elwell, David P. Philipp, Fred A. Harris, Jeffrey L. Kershner, Patrick J. Martinez, Dirk Miller, Gordon H. Reeves, Christopher A. Frissell, and James R. Sedell