The first statewide stream macroinvertebrate bioassessment in Washington State with a relative risk and attributable risk analysis for multiple stressors

Chad Larson
Environmental Assessment Program
Washington State Department of Ecology
Freshwater systems under threat

Vörösmarty et al. (2010) *Nature*

Freshwater systems comprise only a fraction of the total water found on the planet, yet supply nearly two-thirds of the water used in the world.
Biodiversity matters

Hooper et al. (2005) *Ecological Monographs*
Background

Clean Water Act – restore & maintain the chemical, physical and biological integrity of the nation’s waters

Prior to 2009, WA had no comprehensive stream biological monitoring program

Beginning in 2009, Watershed Health Monitoring Program implemented GRTS random sample survey design

50 sites in each of 7 Salmon Recovery Regions & 1 unlisted region
Measuring Chemical, Physical and Biological Parameters

11 major transects evaluated for substrate, riparian habitat and fish habitat

Physical, chemical and sediment parameters evaluated

262 habitat metrics generated with the data

8 randomly selected transects are sampled for invertebrates and periphyton
Standardized Sampling Protocol:

Composite sample from 8 randomly selected transects at a stream reach (8 ft²)

500 µm D-net kick-net sampler

30-second ‘kick’ sample at each transect

Minimum of 500 organisms subsampled and identified to ‘lowest practical level’ (i.e., typically genus & species)

10% of samples are recounted by different taxonomist and sorting efficiency, taxonomic precision, percent taxonomic disagreement, and percent difference in enumeration are calculated; all measures must be within acceptable industry criteria (e.g., Bray-Curtis index of at least 90%)

10% of sites are revisited within a given year
### Benthic Index of Biotic Integrity (B-IBI)

<table>
<thead>
<tr>
<th>Metric</th>
<th>Predicted response to stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxa richness</td>
<td>Decrease</td>
</tr>
<tr>
<td>Ephemeroptera richness</td>
<td>Decrease</td>
</tr>
<tr>
<td>Plecoptera richness</td>
<td>Decrease</td>
</tr>
<tr>
<td>Trichoptera richness</td>
<td>Decrease</td>
</tr>
<tr>
<td>Clinger richness</td>
<td>Decrease</td>
</tr>
<tr>
<td>Long-lived richness</td>
<td>Decrease</td>
</tr>
<tr>
<td>Intolerant richness</td>
<td>Decrease</td>
</tr>
<tr>
<td>Percent dominant</td>
<td>Increase</td>
</tr>
<tr>
<td>Predator percent</td>
<td>Decrease</td>
</tr>
<tr>
<td>Tolerant percent</td>
<td>Increase</td>
</tr>
</tbody>
</table>

B-IBI ranges from 0-100 with higher scores indicating greater biological health.
Status

- All Streams:
  - Good: 42.7%
  - Fair: 23.7%
  - Poor: 33.6%

- By Region:
  - Columbia Plateau:
    - Good: 37.8%
    - Fair: 16.7%
    - Poor: 45.6%
  - Eastern:
    - Good: 49.3%
    - Fair: 16.5%
    - Poor: 34.2%
  - Western:
    - Good: 42%
    - Fair: 26.3%
    - Poor: 31.7%
Status
Stressor Identification

![Graph showing stressor identification with Relative Risk and Attributable Risk (Proportion)]
Trends

A) Puget Sound

B) Coast Range

C) Lower Columbia

D) Mid Columbia

Wald statistic values for each region:

- Puget Sound: Wald = 3.54, p = 0.03
- Coast Range: Wald = 0.13, p = 0.88
- Lower Columbia: Wald = 4.55, p = 0.01
- Mid Columbia: Wald = 3.11, p = 0.049
Causal Analysis: Structural Equation Model

% Urbanization

% Forest Cover

% Sand/Fines

Water Temperature

Conductivity

Dissolved O$_2$

B-IBI

R$^2 = .481$

% Agriculture

$\beta = .481$

Correlations:

- $\beta = .176$
- $\beta = -.475$
- $\beta = .369$
- $\beta = .366$
- $\beta = .329$
- $\beta = -.385$
- $\beta = -.236$
- $\beta = .117$
- $\beta = -.255$
- $\beta = .117$
- $\beta = .255$
- $\beta = -.317$
- $\beta = .104$
- $\beta = -.334$
- $\beta = .182$
- $\beta = .124$
- $\beta = .111$
- $\beta = .095$
- $\beta = -.235$
Summary:

• In general, nearly 1/3 of stream kilometers assessed in WA in poor biological condition

• Regionally, Puget Sound and far eastern WA had highest proportion of stream kilometers in poor biological condition

• Poor substrate conditions prevalent across the state

• Poor B-IBI scores 4 times more likely when associated with elevated % sand/fines

• AR suggests that nearly 60% of streams now in poor biological condition could be improved with reduction of sand/fines

• Loss of sensitive taxa with impairment
CLIMATE CHANGE, WILDFIRE AND A MESSAGE OF RESILIENCE FROM THE “RIVER OF NO RETURN”

Colden Baxter
Stream Ecology Center, Department of Biological Sciences
Idaho State University
Climate Change

Atmospheric Temperature

Precipitation Regime

Stream Ecosystem State

Terrestrial Inputs:
- Light
- Hydrologic Run-off
- Nutrients
- Sediment
- Organic Matter
- Large Wood

Terrestrial Ecosystem Structure

Terrestrial Disturbance Regimes

Davis, Baxter, Rosi-Marshall, Pierce, & Crosby Ecosystems 2013
Study Location

Salmon River Basin
Frank Church
‘River of No Return’
Wilderness Area
Bastion of native biodiversity, complexity and connectivity

A landscape on fire

NASA MODIS image
August 12, 2007
Post-fire trajectories...changing?

Adapted from Minshall et al. 1989
Post-fire: Limited conifer regrowth?

Mortar Creek Fire, Burned 1979, Photo 2012
Dramatic changes in physical habitat...

(2000) pre-fire wetted edge

(2015) > 7m channel incision
Divergent Riparian Regrowth…
Divergent Riparian Regrowth...

Retaining relatively open canopy, or...

Rapidly regaining closed canopy
• Resistance & resilience
• Is the “mid-term” the new “long-term” state?
• Are changes reversible or no?
• We can’t tell without long term studies…

Gunderson & Holling 2001
Need for decadal-scale studies…
30-yr monitoring – started by G.W. Minshall
Time series - Periphyton & Invertebrates

Multi-trophic level responses mediated by riparian regrowth & light

Schenk et al. In prep.
2X terrestrial invert subsidy of salmonids under closed canopy

Schenk et al In prep.
...which may mediate “top-down” control

Schenk et al. In prep.
...paired stream findings corroborated by 12 stream, basin-wide comparison

Best models:
(for fish biomass)
- light
- nutrients
- invert biomass

Schenk et al In prep.
Responses “reverberate” between land and water
via emerging insects, responses extend to riparian wildlife.
Bird responses

High severity burn sites…
- Greater overall abundance & richness
- Greater incidence of riparian obligates (e.g., dippers) & fly-catchers

Low severity burn and unburned sites…
- Greater incidence of generalists (e.g., crows)
Network dynamics & the “fire pulse”

Export of habitat-forming sediment and wood

Export of insects from tributaries disturbed by fire & debris flows?

Network dynamics & the "fire pulse"
Unburned ($n = 5$)

Burned ($n = 5$)

Burned + debris flow ($n = 5$)

Unburned ($n = 5$)
Disturbance increases insect export from tributaries to mainstem.
Fish Use of Confluences

- Confluence habitat proportionally small
- Strong selection for confluences
- Preference for confluences with disturbed tribs

Harris, Baxter & Davis Aquat. Sci. 2018
Other signs of resilience...

Riparian veg responses mediated by wolf-ungulate interactions?
Summary & Discussion

• Post-severe wildfire “pulse” of productivity may extend more than a decade

• Trajectory of riparian regrowth and light regime mediate longer term patterns in post-fire productivity

• Effects reverberate between land & water and propagate through networks (e.g., debris flows)

• Some signs point to state changes, but what most would consider “positive” rather than “doomsday”

• Overall, message of resistance and resilience in face of dramatic disturbance

• “Time will tell…”
Management Discussion

• additional lines of evidence…

• warming of central Idaho headwater streams slow; role as “climate refugia” — Isaak et al. 2016. *PNAS*

• pulses of juv anadromous salmonids from these drainages post-fire — Copeland et al. 2017, pers. comm.

• low salmon returns driven by “out of basin” impacts; notably Snake River dams — Thurow et al. 2016; pers. comm.

*Slow climate velocities of mountain streams portend their role as refugia for cold-water biodiversity*

Daniel J. Isaak\textsuperscript{a,b}, Michael K. Young\textsuperscript{b}, Charles H. Luce\textsuperscript{a}, Steven W. Hostetler\textsuperscript{a}, Seth J. Wenger\textsuperscript{d}, Erin E. Peterson\textsuperscript{a}, Jay M. Ver Hoef\textsuperscript{c}, Matthew C. Groce\textsuperscript{a}, Dona L. Horan\textsuperscript{a}, and David E. Nagel\textsuperscript{b}
Management Discussion

• no need to “fortify” against natural effects of wildfire — especially in wilderness

• such actions (in name of “forest health”) may be misplaced and erroneously credited as restoration or mitigation

• could be diversions from addressing actual problems

• may even have unforeseen, undesired effects
Management Discussion

• “manage for the mess” – J. Sedell

• preserve dynamism, processes that create and maintain complexity in nature (habitat and organisms)

• these are keys to resilience and adaptive capacity in face of climate change
Acknowledgments

ISU Stream Ecology Center
• Dr. G. Wayne Minshall

Funding & Support
DeVlieg Foundation, National Science Foundation, US Forest Service, Idaho State University, James Morris Endowment, Taylor Wilderness Research Station
Submerged aquatic vegetation and its potential effect on salmonid cold-water refuges

Francine Mejia¹, Christian Torgersen¹, Eric Berntsen², and Joseph Maroney²,

¹USGS Forest and Rangeland Ecosystem Science Center, Cascadia Field Station, Seattle, Washington, USA
²Kalispel Tribe Natural Resources Department, Usk, Washington, USA
How does submerged aquatic vegetation (SAV) potentially influence fish habitat?

(Vilas et al. 2017)

SAV can influence many physicochemical aspects of the aquatic environment:

• Light penetration
• Water temperature
• Water velocity
• Fine sediments
• Phosphorus cycling
• Dissolved oxygen
What is a thermal refuge?

Areas that may be either cold or warm in relation to the surrounding water.

**Cold-water refuge** = a thermal refuge in the summer that is colder than the surrounding water.

Primer -- Torgersen et al 2012
How does submerged aquatic vegetation (SAV) potentially influence cold-water refuge?

Bull trout

Source: Raymond Ostlie

Westslope cutthroat trout

Source: Western native trout initiative

Trout needs
- High DO
- Cool temperatures
- Flowing water

SAV creates conditions with
- Lower DO
- Warm temperatures
- Slow moving water
Study Goal

Evaluate how removal of SAV influences water temperature and dissolved oxygen

Hypotheses:

1) Dense SAV areas exhibit **stronger vertical temperature gradients** and have **lower bottom dissolved oxygen** than areas without SAV (open).

2) Areas where SAV is removed exhibit **weaker vertical temperature gradients** and have **higher bottom dissolved oxygen** (more like open areas).
Study Area

Pend Oreille River
Aug 9 – Aug 12
Renshaw Creek rkm 65.9 (2017)
Renshaw Creek
(rkm 65.9)
8/26/17 - 8/30/17

**Dissolved oxygen (mg/l)**

- Bottom SAV
- Surface SAV
- Bottom Open
- Surface Open

**Temperature (°C)**

- Bottom SAV
- Surface SAV
- Bottom Open
- Surface Open
**Methods**

PME miniDOT logger dissolved oxygen/temperature
HOBO pendant® temperature/light data logger

Nitrogen & Phosphorus

Water velocity using an Acoustic Doppler Current Profiler (ACDP)
Water temperature (°C)

OPEN

REMOVAL

SAV

Bottom lower

Bottom/Surface

B = Bottom
S = Surface
Proximity and spatial arrangement of treatment types
Dissolved oxygen (mg/L)

DO minimum standard for fish

Bottom/Surface

OPEN

REMOVAL

SAV
Proximity and spatial arrangement of treatment types

USGS 12395500 PEND OREILLE RIVER AT NEWPORT WA

Discharge, cubic feet per second

00:00 12:00 00:00 12:00 00:00 12:00 00:00 12:00 00:00 12:00 00:00 12:00 00:00 12:00 00:00 12:00 00:00 12:00 00:00

Provisional Data Subject to Revision

△ Median daily statistic (08 years) — Discharge

Renshaw Creek

OPEN

SAV

SAV

OPEN
Placement of logger in the water column – proximity to sediment
Preliminary Conclusions

• Pilot study. Need to collect more data to tease out bottom DO dynamics.

• Work around logistical issues (e.g. vandalism, reservoir fluctuations).

• Enhancement of cold-water refuges likely need more than just removing SAV. Need to understand the existing preferential path as well.
Acknowledgements

Angel Klock University of Washington
Tyler Klock, Volunteer
Ken Merrill, Kalispel Natural Resources Department
Darren Reeves, Kalispel Natural Resources Department
Darren Lantzer, Tshimakain Creek Labs
Minimal differences in water temperature

2 YSI was located near Calispel Cr. confluence

2 DOT was about 1 km downstream of Calispel Cr. confluence

Potential temporal effect, data was not collected concurrently, but sequentially (8/2 to 9/5)
Dissolved oxygen gradient steepest at dense patches of SAV

O= Open
S= SAV
Brief overview of some of the technical efforts

Many, many people are working on this project
Project Background

- NMFS 2015 Jeopardy Biological Opinion on EPA’s Approval of Oregon’s Temperature Water Quality Standards

- Oregon Columbia & Lower Willamette River Temperature Criteria
  - 20C numeric criteria, plus
  - Cold Water Refugia (CWR) narrative criteria
    - “must have CWR that’s sufficiently distributed so as to allow salmon and steelhead migration without significant adverse effects from higher temperatures elsewhere in the water body”
    - “CWR means those portions of a water body where, or times during the diel cycle when, the water temperature is at least 2C colder than the daily maximum temperature of the adjacent well mixed flow of the water body”

- NMFS concluded CWR narrative criteria is not an effective criteria due to lack of implementation
  - Jeopardy for Steelhead (LCR, UWR, MCR, UCR, SRB); Chinook (LCR, UWR); Sockeye (SR); SR Killer Whales
  - Reasonable and Prudent Alternative (RPA) – EPA develop a Columbia River Cold Water Refuges Plan by November 2018
Background - EPA Columbia River CWR Plan

1. Map and characterize the CWR areas in the Lower Columbia River

2. Characterize the extent to which salmon and steelhead use CWR

3. Assess whether current CWR is sufficient to meet Oregon’s narrative criteria

4. Identify actions to protect, restore, or enhance CWR
EPA Columbia River CWR Plan

1. Map and characterize the CWR areas in the Lower Columbia River

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Predicted August Daily Average Stream Temperature (1993 – 2011) - NorWeST

Map and characterize the CWR areas in the Lower Columbia River
Map and characterize the CWR areas in the Lower Columbia River

Predicted August Daily Average Stream Temperature (1993 – 2011) - NorWeST

Mainstem and Tributary Stream Temperature Difference
- Tributary temperatures warmer than the mainstem
- Tributary temperatures between 0°C and 2°C cooler than the mainstem
- Tributary temperatures between 2°C and 4°C cooler than the mainstem
- Tributary temperatures >4°C cooler than the mainstem

Map and characterize the CWR areas in the Lower Columbia River
Map and characterize the CWR areas in the Lower Columbia River

Modeled Values

- Observed Columbia River Temperature (°C) [1993-2011 Average]
- Columbia River - Interpolated From Measured Temperatures
- Tributary temperatures >4°C cooler than the Columbia River
- Tributary temp. between 2°C to 4°C cooler than the Columbia River
- Tributary temp. between 0°C and 2°C cooler than the Columbia River
- Tributary temperatures warmer than the Columbia River
Map and characterize the CWR areas in the Lower Columbia River
### Table A-1. Observed Average Monthly Temperature Difference (°C) between the tributary and the Columbia River

<table>
<thead>
<tr>
<th>Site Name</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tributary #18 – Grays River</td>
<td>4.2</td>
<td>5.1</td>
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<td>Tributary #188 – Walla Walla River</td>
<td>-4.3</td>
<td>-6.0</td>
<td>-2.5</td>
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</tr>
</tbody>
</table>
Screening Criteria to Identify Potential CWR Tributaries

• August mean temperatures at least 2°C cooler than Columbia River and August mean flow greater than 10 cfs

• Added small cold tributaries (August mean of 16°C or cooler and August mean flow 7-10 cfs)

• Added larger rivers (Aug. mean flow 10 cfs or greater) that have periods of time at least 2°C cooler than Columbia River

• Removed tributaries that have limited or no access to the cold water plume
Map and characterize the CWR areas in the Lower Columbia River

Temperature Difference Between Columbia River and the 13 Primary Tributaries
- Tributary temperatures warmer than the Columbia
- Tributary temperatures between 0°C and 2°C cooler than the Columbia
- Tributary temperatures between 2°C and 4°C cooler than the Columbia
- Tributary temperatures > 4°C cooler than the Columbia

23 Tributaries Providing Cold Water Refuge in the Lower Columbia River
1. Map and characterize the CWR areas in the Lower Columbia River

2. Characterize the extent to which salmon and steelhead use CWR

3. Assess whether current CWR is sufficient to meet Oregon’s narrative criteria

4. Identify actions to protect, restore, or enhance CWR
EPA Columbia River CWR Plan

1. Map and characterize the CWR areas in the Lower Columbia River
2. Characterize the extent to which salmon and steelhead use CWR
3. Assess whether current CWR is **sufficient** to meet Oregon’s narrative criteria
4. Identify actions to protect, restore, or enhance CWR

*Sufficiency* is determined through the application of the HexSim model developed by EPA Corvallis ORD staff

Several HexSim model inputs were developed by EPA Regional staff:

- Potential CWR locations,
- Volume and temperature associated with these CWR areas
Assess whether current CWR is sufficient to meet Oregon’s narrative criteria

Results used in HexSim model development

Estimating CWR Plume Volume – CorMix Modeling

Deschutes River

Cowlitz River
Estimating CWR Plume Volume – Modeled from Field Data

Assess whether current CWR is sufficient to meet Oregon’s narrative criteria.
Assess whether current CWR is sufficient to meet Oregon’s narrative criteria

Results used in HexSim model development

Estimating CWR Plume Volume – Modeled from Field Data
Table 1. “Cold” water volume (m³), within specific temperature ranges, observed at the confluence zone between several sampled tributaries and Columbia River during the summers of 2016 and 2017

<table>
<thead>
<tr>
<th>River and Sample Date</th>
<th>Less than 16°C</th>
<th>Between 16°C and 18°C</th>
<th>Between 18°C and 20°C</th>
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<td>Elochoman Slough 8/18/2016</td>
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<tr>
<td>Washougal River 8/16/2016</td>
<td>0</td>
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<tr>
<td>Rock Creek 8/17/2016</td>
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<tr>
<td>Wind River 8/15/2016</td>
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<td>90,723</td>
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<td>1,267,874</td>
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<tr>
<td>Herman Creek 8/16/2017</td>
<td>30,499</td>
<td>36,558</td>
<td>68,583</td>
</tr>
</tbody>
</table>

Results used in HexSim model development

Assess whether current CWR is sufficient to meet Oregon’s narrative criteria
Estimating CWR Riverine Volume

*Tributary CWR Volume (m³)*

= Stream Length (SL) providing CWR habitat for Columbia River migratory salmonids (m) * Average Tributary Cross Sectional Area (\(\bar{A}\)) within this designated area (m²)

\[ \bar{A} = \frac{\text{Stream Discharge (m³/s)}}{\text{Stream Velocity (m/s)}} \]

<table>
<thead>
<tr>
<th>Tributary Code</th>
<th>Tributary Name</th>
<th>Stream Length Providing CWR Habitat (m)</th>
<th>Average August Stream Discharge (m³/s)</th>
<th>Average August Stream Velocity (m/s)</th>
<th>Potential Riverine CWR Volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Skamokawa Creek</td>
<td>317</td>
<td>0.57</td>
<td>0.17</td>
<td>1,053</td>
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<tr>
<td>38</td>
<td>Mill Creek</td>
<td>283</td>
<td>0.29</td>
<td>0.19</td>
<td>446</td>
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<tr>
<td>40</td>
<td>Abermethy Creek</td>
<td>337</td>
<td>0.29</td>
<td>0.12</td>
<td>806</td>
</tr>
<tr>
<td>41</td>
<td>Germany Creek</td>
<td>329</td>
<td>0.24</td>
<td>0.18</td>
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<tr>
<td>49</td>
<td>Cowitiz Creek</td>
<td>1,764</td>
<td>102.86</td>
<td>0.27</td>
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<td>52</td>
<td>Kalama River</td>
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<td>7.48</td>
<td>0.25</td>
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<td>63</td>
<td>Lewis River</td>
<td>2,543</td>
<td>40.12</td>
<td>0.21</td>
<td>493,455</td>
</tr>
<tr>
<td>77</td>
<td>Sandy River</td>
<td>1,763</td>
<td>13.29</td>
<td>0.18</td>
<td>129,272</td>
</tr>
</tbody>
</table>

Information used in HexSim model development

Assess whether current CWR is sufficient to meet Oregon’s narrative criteria
Assess whether current CWR is sufficient to meet Oregon's narrative criteria

### Information used in HexSim model development

<table>
<thead>
<tr>
<th>Tributary Name</th>
<th>River Mile</th>
<th>Mainstem Temp</th>
<th>Mainstem Temp</th>
<th>Tributary Temp</th>
<th>Temp Difference</th>
<th>Tributary Flow</th>
<th>Plume CWR Volume (&gt; 2°C Δ)</th>
<th>Stream CWR Volume (&gt; 2°C Δ)</th>
<th>Total CWR Volume (&gt; 2°C Δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skamokawa Creek</td>
<td>30.9</td>
<td>21.3</td>
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<td>Abernethy Creek</td>
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<td>Germany Creek</td>
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<tr>
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<td>870,000</td>
<td>684,230</td>
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<td>169</td>
<td>0</td>
<td>0</td>
<td>46,299</td>
<td>46,299</td>
</tr>
</tbody>
</table>
HexSim Modeling

Refuge use has many benefits, but also presents some risks.

Quantifying consequences of refuge use is difficult.

Evaluating impacts on the population level dynamics is even harder.

Constructed the HexSim mechanistic model to conduct virtual experiment that rank proposed management action on salmon and steelhead, for both individuals and populations.

Marcía Snyder, Nathan Schumaker (OSU), Joseph Ebersole, and Randy Comeleo

EPA ORD Corvalis

Assess whether current CWR is sufficient to meet Oregon’s narrative criteria
HexSim uses bioenergetics equations to keep track of the available energy for a fish. The equations take into account the fish weight and thermal exposure.

Assess whether current CWR is sufficient to meet Oregon’s narrative criteria.
HexSim is an individual based model used to model patchy landscapes

The individuals in HexSim move through a landscape of hexagons

Assess whether current CWR is sufficient to meet Oregon’s narrative criteria
HexSim Riverscape: temperature

Thermal regimes (and other simulation model inputs) can be characterized by tributaries, their plumes, and the Columbia River.

Assess whether current CWR is sufficient to meet Oregon’s narrative criteria.
HexSim-Fish Model Overview

Assess whether current CWR is sufficient to meet Oregon’s narrative criteria
Individual salmon and steelhead enter the model with associated characteristics.
HexSim Simulation Outcomes

Track individual exposure through space and time

- Measure cumulative exposure and impacts to multiple stresses
- Aggregate individual outcomes to the population scale

How do the costs and benefits of cold water refuges manifest at population and landscape scales?

Assess whether current CWR is sufficient to meet Oregon’s narrative criteria.
Temperature Time Series

**Observed**

**Modelled**

Temperature (°C)

- 24
- 20
- 16
- 12
- 8

Total time in system (hours)

- Jul
- Aug
- Sep
- Oct
- Nov

Graphs A, B, C, and D show the temperature time series over the months from July to November.
Effect of Density

Total individuals per refuge through time for steelhead and chinook combined.

Effective density per refuge through time for steelhead and chinook combined.
Energy Use

Assess whether current CWR is sufficient to meet Oregon’s narrative criteria.
Fish Fitness Model Outcomes
EPA Columbia River CWR Plan

1. Map and characterize the CWR areas in the Lower Columbia River

2. Characterize the extent to which salmon and steelhead use CWR

3. Assess whether current CWR is sufficient to meet Oregon’s narrative criteria

4. Identify actions to protect, restore, or enhance CWR
Calculate Stream Temperature using the SSN Model (NorWeST)

NorWeST Spatial Covariates
1) Air Temperature
2) Stream Discharge
3) Elevation
4) Latitude
5) Canopy %
6) Cumulative drainage area
7) Stream Slope %
8) Mean annual precipitation
9) Base Flow index (BFI)
10) Glacier %
11) Lake %
12) Tailwater (Y/N)

Identify actions to protect, restore, or enhance CWR
Calculate Stream Temperature using the SSN Model (NorWeST)

NorWeST Spatial Covariates

1) Air Temperature
2) Stream Discharge
3) Elevation
4) Latitude
5) Canopy %
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7) Stream Slope %
8) Mean annual precipitation
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10) Glacier %
11) Lake %
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Identify actions to protect, restore, or enhance CWR
Calculate Stream Temperature using the SSN Model (NorWeST)

NorWeST Spatial Covariates

1) Air Temperature
2) Stream Discharge
3) Elevation
4) Latitude
5) Canopy %
6) Cumulative drainage area
7) Stream Slope %
8) Mean annual precipitation
9) Base Flow index (BFI)
10) Glacier %
11) Lake %
12) Tailwater (Y/N)

Predicted Stream Temperature (C)
- 6.7 - 11.3
- 11.4 - 12.3
- 12.4 - 13.0
- 13.1 - 13.4
- 13.5 - 14.1
- 14.2 - 14.8
- 14.9 - 15.3
- 15.4 - 15.9
- 16.0 - 16.7
- 16.8 - 20.6

Identify actions to protect, restore, or enhance CWR
Shade Maps:

Topographic Shading

Identify actions to protect, restore, or enhance CWR
Temp Change by Shade

How does altering riparian shade affect stream temperature?

Topographic Shade and Present Climate

Matthew Fuller, and Naomi Detenbeck (EPA ORD Narraganset), and Dan Isaak (USFS)

Identify actions to protect, restore, or enhance CWR
Temp Change by Climate

How will future climate shifts affect stream temperature?

Present Veg. Shade and Present Climate

Matthew Fuller, and Naomi Detenbeck (EPA ORD Narraganset), and Dan Isaak (USFS)
Calculate Stream Temperature using the SSN Model (NorWeST)

All tributaries (198)

**LOWER-COLUMBIA**
- n=116
- Largest: Willamette

**MID-COLUMBIA**
- n=82
- Largest: Deschutes

Potential Input into the HexSim Model

Identify actions to protect, restore, or enhance CWR
Individual Tributary Management

Present climate tributary outflow temperatures
13 focal tributaries

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2040</td>
<td>2040/Topo</td>
<td>2040/Pot.</td>
<td>2040/Pot.</td>
</tr>
<tr>
<td>2080</td>
<td>2080/Topo</td>
<td>2080/Pot.</td>
<td>2080/Pot.</td>
</tr>
</tbody>
</table>

Predicted mean August stream temperature (°C)

Shade symbols: topographic (circles), current vegetation (diamonds), and restored vegetation (triangles)

Potential Input into the HexSim Model

Identify actions to protect, restore, or enhance CWR
Currently we are starting the “what if” runs with the HexSim Model

Thank You
Extra Slides
Big Cold  Small Cold RARE Project

Identify actions to protect, restore, or enhance CWR
Identify actions to protect, restore, or enhance CWR

Calculate Effective Shade using Methods Presented at 2016 NWMod meeting
Identify actions to protect, restore, or enhance CWR

Calculate Effective Shade using Methods Presented at 2016 NWMod meeting
Calculate Stream Temperature using the SSN Model (NorWeST)

Stream Temperature (°C)
- Less than 12
- 12.1 - 13.0
- 13.1 - 14.0
- 14.1 - 15.0
- 15.1 - 16.0
- 16.1 - 17.0
- 17.1 - 18.0
- 18.1 - 19.0
- 19.1 - 20.0
- Greater than 20

Identify actions to protect, restore, or enhance CWR
Calculate Stream Temperature using the SSN Model (NorWeST)

Identify actions to protect, restore, or enhance CWR
CITY OF BOISE 316(A) DEMONSTRATION PROJECT FOR IDAHO POLLUTANT DISCHARGE ELIMINATION SYSTEM (IPDES) PERMITS

Dorene MacCoy, Water Quality Environmental Coordinator, Public Works Department
Darcy Sharp, Environmental Data Analyst, Public Works Department
AGENDA

- Area overview
  - Receiving water – Lower Boise River
  - Water Renewal Facilities – Lander Street and West Boise
  - Temperature discharge limits
  - Need for thermal variance

- 316(a) thermal variance
- Temperature data
- Temperature modeling
- Biological data
- Demonstration results
• North Fork
• Middle Fork
• South Fork
• Reservoirs/irrigation
  • Diversion Dam/NY Canal - 1909
  • Arrowrock - 1915
  • Anderson Ranch – 1950
  • Lucky Peak - 1955
MULTIPLE USES
LOWER BOISE RIVER
Water Renewal Facilities

Lander Street Water Renewal Facility

West Boise Water Renewal Facility
DISCHARGE PERMIT LIMITS

Idaho water quality standards (Integrated impairment status report)
- Beneficial use support
- Cold Water Criteria – max 22°C, max daily average 19°C

Antidegradation policy and Total Maximum Daily Load (TMDL)
- Temperature impaired – Veterans Bridge to mouth (4 segments)
- Protect existing uses

Discharge mixing zone criteria
- Plume – 2 seconds from discharge max 32°C, >5% of cross-section >25°C, >25% of cross-section >21°C
- Plume in spawning areas – max weekly max 13°C, during spawning no increase >0.3°C
## DISCHARGE PERMIT LIMITS CONT.

### Lander Street

Existing thermal limits (°C)
To be met by Aug 2022 (10 years after permit issuance)

<table>
<thead>
<tr>
<th>Date</th>
<th>Max Wkly Max</th>
<th>Ave Daily limit</th>
<th>Max limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov – April 30</td>
<td>15.8</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>May</td>
<td>16.4</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>July 16 – Sept 30</td>
<td>NA</td>
<td>19.0</td>
<td>22.0</td>
</tr>
<tr>
<td>October</td>
<td>NA</td>
<td>22.2</td>
<td>27.3</td>
</tr>
</tbody>
</table>

### West Boise

Existing thermal limits (°C)
To be met by Aug 2022 (10 years after permit issuance)

<table>
<thead>
<tr>
<th>Date</th>
<th>Max Wkly Max</th>
<th>Ave Daily limit</th>
<th>Max limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov 1 – March 31</td>
<td>13.5</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>April</td>
<td>13.3</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>May</td>
<td>13.5</td>
<td>NA</td>
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</tr>
<tr>
<td>June 1 – July 15</td>
<td>NA</td>
<td>22.6</td>
<td>26.1</td>
</tr>
<tr>
<td>July 16 – Sept 30</td>
<td>NA</td>
<td>19.0</td>
<td>22.0</td>
</tr>
<tr>
<td>October</td>
<td>NA</td>
<td>20.3</td>
<td>24.2</td>
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</table>

These limits proved to be more restrictive than necessary.
WHY THERMAL VARIANCE?
**ALTERNATIVE THERMAL LIMITS**

Requested (using current and predicted air temperature and instream temperatures upstream and downstream of the water renewal facilities)

<table>
<thead>
<tr>
<th>Date</th>
<th>Lander daily max °C</th>
<th>West Boise daily max °C</th>
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<tbody>
<tr>
<td>Jan - March</td>
<td>23.3</td>
<td>18.8</td>
</tr>
<tr>
<td>April - June</td>
<td>25.8</td>
<td>24.5</td>
</tr>
<tr>
<td>July - Sept</td>
<td>25.1</td>
<td>25.4</td>
</tr>
<tr>
<td>Oct - Dec</td>
<td>26.0</td>
<td>23.3</td>
</tr>
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</table>
Alternative thermal effluent limits (ATEL) must be protective

- Protect Balanced Indigenous Community (BIC)
- Demonstration 1 – no prior appreciable harm to BIC
- Demonstration 2 – proposed ATELs will be protective of BIC and representative important species (RIS) in the future
HEAT LOAD

River and Effluent Heat Loads
2014 Water Year

Heat Load Comparisons
2014 Water Year

Proportion of Lander Heat Load to River Downstream of Lander
Proportion of West Boise Heat Load to River Downstream of West Boise
TEMPERATURE MODELING

- CORMIX plume model
  - Meets mixing zone criteria
- StreamTemp river model
  - No exceedances of Representative Important Species
  - 95th percentile low flow year—CWAL average exceedances with or without effluent
ENVIRONMENTAL HEAT SOURCES

- Air Temperature
- Channel Morphology
- Shade
- Diffuse Sources
  - Groundwater
  - Overland Runoff
RIVER DISCHARGE
BIOLOGICAL DATA

Sampling reaches

- Boise River below Eckert Road (Eckert)
- Boise River above Glenwood Bridge (Glenwood)
- Boise River near Middleton (Middleton)
- Boise River at Caldwell (Caldwell)
- Boise River at the Mouth (Mouth)
MACROINVERTEBRATE DATA

Overview

316a Framework

Temperature data

Temperature modeling

Biological data

Results

Low flow years

Introduction of New Zealand Mudsnail

Least disturbed streams in Idaho
(Maret and others, 2001; Tetra Tech 2011)
Least disturbed rivers in Idaho
(Maret and others 2001; Tetra Tech, 2011)
Representative Important Species

Native cold-water fish

Low flow years (2001 – 2004)
RESULTS

- Flow alteration and habitat loss affect biological communities
- Alternative thermal effluent limits (ATELs) are protective
- Balanced Indigenous Community (BIC) is protected
- Demonstration 1 – no prior appreciable harm to BIC
- Demonstration 2 – proposed ATELs will be protective of BIC and representative important species (RIS) in the future
NEXT STEPS

- Continuous temperature monitoring
- Biological Community assessment – 3 to 5 year interval
- Habitat assessment – 3 to 5 year interval
- Continue to investigate WRF temperature reduction
- Discharge reduction and water reuse
THANK YOU

Dorene MacCoy
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Darcy Sharp
Environmental Data Analyst
City of Boise Public Works Department
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That Lower Priest River’s so hot right now: Describing thermal heterogeneity in a dam-influenced river

Eric Berntsen and Todd Andersen
Kalispel Tribe Natural Resources Department

Francine Mejia and Christian Torgersen
U.S. Geological Survey
Objective

To describe the spatial and temporal thermal heterogeneity in the lower Priest River
Mechanisms that induce thermal diversity

B. L. KURYLYK et al.
Kalispel Adjudicated Lands

From spokesman.com
Study area
Near confluence with Pend Oreille River
Temperature decreases downstream (from Berger et al. 2014)
Binarch Creek

Unnamed tributary near Lost Landing area

East River
Methods - Temperature loggers (June 26 - Sep 3, 2018)

n = 36

10 km
Thermal profiling – August 21, 2018

From Vaccaro and Maloy 2006
Thermal profiling – August 21, 2018
Hottest day sampled - August 10, 2018
(Maximum air temperature 40°C)

Water temperature (°C)
- 18-20
- 20-22
- 22-24
- 24-26
- No data

n = 36
Seepage?

Cold tributary, pool?

Tributary input, seepage?

Seepage?

278 min / 8.5 km

Water temperature (°C)

Time/Distance
Notes indicate that volunteers passed 100+ fish off rock bank!

<table>
<thead>
<tr>
<th>Water temperature (°C)</th>
<th>Time/Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>278 min / 8.5 km</td>
</tr>
<tr>
<td>18</td>
<td>Team 7</td>
</tr>
<tr>
<td>16</td>
<td>Pool!</td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>
Implications

• Helps inform efforts to preserve, augment, and/or create thermal heterogeneity

• Provides information for developing a Temperature Total Maximum Daily Load for the Lower Priest River
Acknowledgments

Trout Unlimited
Panhandle Chapter
Sean Stash, IPNF
Idaho Master Naturalists
Angel Klock and Zach Johnson, University of Washington
David Bluff, Darren Reeves, Jim LeMieux, Mike Lithgow, Kalispel Tribe Department Natural Resources
A Biological Condition Gradient (BCG) Model for Benthic Macroinvertebrate Assemblages in Puget Lowland & Willamette Valley Streams

Presented by:
Robert Plotnikoff, Snohomish County Public Works
Chad Larson, Washington Department of Ecology

Pacific Northwest Chapter – Society for Freshwater Science
Wednesday, November 7th, 2018
Ketchum, ID
Acknowledgements

Construction and Calibration of the Puget Lowlands and Willamette Valley BCG Model

Thank You - A Team Effort!

Tetra Tech
Jen Stamp
Jeroen Gerritsen
Erik Leppo

US EPA
Susan Jackson
Gretchen Hayslip (ret)
Britta Bierwagen

<table>
<thead>
<tr>
<th>Organization</th>
<th>Expert Panelist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oregon Department of Environmental Quality</td>
<td>Shannon Hubler</td>
</tr>
<tr>
<td>Washington Department of Ecology</td>
<td>Chad Larson</td>
</tr>
<tr>
<td>King County</td>
<td>Kate Macneale</td>
</tr>
<tr>
<td>Snohomish County</td>
<td>Rob Plotnikoff</td>
</tr>
<tr>
<td>Rhithron Associates, Inc.</td>
<td>Sean Sullivan</td>
</tr>
<tr>
<td>EcoAnalysts, Inc.</td>
<td>John Pfeiffer</td>
</tr>
<tr>
<td>Aquatic Biology Associates</td>
<td>Bob Wisseman</td>
</tr>
<tr>
<td>Cole Ecological, Inc.</td>
<td>Mike Cole</td>
</tr>
<tr>
<td>Apolysis, LLC</td>
<td>Rick Hafele</td>
</tr>
<tr>
<td>US Geological Survey</td>
<td>Ian Waite</td>
</tr>
<tr>
<td>US Environmental Protection Agency (USEPA) Office of Research and Development (ORD)</td>
<td>Dave Peck</td>
</tr>
<tr>
<td></td>
<td>Ryan Hill</td>
</tr>
<tr>
<td>Oregon State University</td>
<td>Alan Herlihy</td>
</tr>
<tr>
<td>Portland State University</td>
<td>Patrick Edwards</td>
</tr>
</tbody>
</table>
Outline

1. BCG Overview
2. Calibration and Development
3. Historical Conditions
4. Practical Uses for State and Local Governments
5. Future Work and Expansion of the PS & WL BCG
6. R Tool Development
OVERVIEW

Natural structure and function of biotic community maintained

Minimal changes in structure and function

Evident changes in structure and minimal changes in function

Moderate changes in structure and minimal changes in function

Major changes in structure and moderate changes in function

Severe changes in structure and function

Effects of human disturbance
The Biological Condition Gradient (BCG)

A scientific framework for identifying biological response to anthropogenic stress.

**The Building Blocks of the BCG**

- Longstanding, accepted science
- Measurable and predictable
- Based on bioassessments
- Generalized scale
- Fixed anchor to minimize shifting baseline
- Biologically meaningful and robust thresholds
- Expert ecological judgement
Key Concepts

The BCG has **two key concepts**

1) **Attributes**
   *measurable components of a biological system* (Karr and Chu 1999)
   Examples → Organism condition, pollution tolerance

2) **Levels**
   Levels are the discrete levels of biological condition across a stressor-response gradient

*Example:*
Level 1 = undisturbed, pristine;
Level 6 = severely degraded
## BCG Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Historically documented, sensitive, long-lived, or regionally endemic taxa</td>
</tr>
<tr>
<td>II</td>
<td>Highly sensitive taxa</td>
</tr>
<tr>
<td>III</td>
<td>Intermediate sensitive taxa</td>
</tr>
<tr>
<td>IV</td>
<td>Intermediate tolerant taxa</td>
</tr>
<tr>
<td>V</td>
<td>Tolerant taxa</td>
</tr>
<tr>
<td>VI</td>
<td>Non-native or intentionally introduced species</td>
</tr>
<tr>
<td>VII</td>
<td>Organism condition</td>
</tr>
<tr>
<td>VIII</td>
<td>Ecosystem function</td>
</tr>
<tr>
<td>IX</td>
<td>Spatial and temporal extent of detrimental effects</td>
</tr>
<tr>
<td>X</td>
<td>Ecosystem connectance</td>
</tr>
</tbody>
</table>
BCG Levels

1. **Natural** structural, functional and taxonomic integrity

2. Structure and function **similar to natural community** with some additional taxa and biomass or the first detectable shifts in expected composition. Ecosystem level functions fully maintained.

3. **Evident changes in community structure** with loss of some highly sensitive native taxa & shifts in relative abundance. Ecosystem level functions fully maintained.

4. Ecosystem functions **largely** maintained, but some sensitive ubiquitous taxa replaced by more tolerant taxa.

5. **Reduced** ecosystem function, with diminished sensitive taxa, unbalanced distribution of major taxonomic groups and organisms showing signs of physiological stress

6. **Extreme** changes in structure and ecosystem function with wholesale changes in taxonomic composition and poor organism condition
The BCG: biological response to increasing stress

Levels of Biological Condition

1. Natural structural, functional, and taxonomic integrity is preserved.
2. Structure & function similar to natural community with some additional taxa & biomass; ecosystem level functions are fully maintained.
3. Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance; ecosystem level functions fully maintained.
4. Moderate changes in structure due to replacement of some sensitive ubiquitous taxa by more tolerant taxa; ecosystem functions largely maintained.
5. Sensitive taxa markedly diminished; conspicuously unbalanced distribution of major taxonomic groups; ecosystem function shows reduced complexity & redundancy.
6. Extreme changes in structure and ecosystem function; wholesale changes in taxonomic composition; extreme alterations from normal densities.

Watershed, habitat, flow regime and water chemistry as naturally occurs.

Chemistry, habitat, and/or flow regime severely altered from natural conditions.
The BCG Process

1. Identify participants and expert panel
2. Compile data
3. Assign BCG attributes to taxa
   • Perform analyses to help inform assignments
4. Assign BCG levels to samples
5. Develop & refine BCG rules
6. Assess BCG model performance
   • Calibration
   • Confirmation
7. Automated BCG model (with narrative decision rules) that assigns BCG levels to samples

Iterative – These steps are revisited throughout the process
BCG CALIBRATION AND DEVELOPMENT

Narrative Levels and Attributes → Ecoregional Numeric Decision Rules
Describe why you make an assignment, in BCG terms – e.g., what is missing or present?

<table>
<thead>
<tr>
<th>Participant</th>
<th>Score</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jason</td>
<td>4-</td>
<td>Doesn’t seem as nice as the other greenbrier site (421) its bigger but not much more diversity and seem less balanced</td>
</tr>
<tr>
<td>Royce</td>
<td>6+</td>
<td>Very elevated counts… possible nutrient enrichment?</td>
</tr>
<tr>
<td>Rick</td>
<td>4</td>
<td>Presence of introduced taxa lowered my rank.</td>
</tr>
<tr>
<td>Brett</td>
<td>5+</td>
<td>Short taxa list for catchment area. Expect more species of darters, sculpins, and madtoms.</td>
</tr>
<tr>
<td>Mark</td>
<td>4</td>
<td>Over half of individuals are att. 5 or 6 taxa, but relatively balanced community</td>
</tr>
<tr>
<td>Ryan</td>
<td>5+</td>
<td>Number of fish suggest a possible nutrient loading/human disturbance nearby, lots of stonerollers</td>
</tr>
</tbody>
</table>
Timeline of BCG Model Development

September - December 2016
- Held calls with Steering Committee
- Obtained data and prepared sample worksheets for the BCG workshop
- Held pre-workshop webinars (Dec 8 & 15) to introduce the group to the BCG

January 10-12, 2017
- Conducted expert workshop in Portland, OR.

February-September 2017
- Refined taxa attributes, develop decision rules, rated samples.
- Held four webinars to refine decision rules
- Sent out confirmation samples (June 28)
- Compiled confirmation results, assessed model performance

October 2017
- Status update webinar (Thurs Oct 12)
- BCG report
- Climate pilot webinar (Monday Oct 16)

November 2017
- PNW-SFS meeting (Nov 7-9); presentation only (no BCG workshop)
- Begin next phase of work with Britta and David (restoration potential, improving resiliency)

March 20-22, 2018
- Second expert panel meeting (Olympia, WA)

Summer/fall 2018
- Finalize deliverables (Version 1 of the BCG model, report, R tool)
Calibration Dataset

- Puget Lowlands & Willamette Valley Ecoregions
- Streams from Watershed Areas of 1 to 100 mi²
- Low and high gradient
- 500-count target
- Lowest practical taxonomic resolution
  (with some exceptions from early on)
- At least 8 ft² sampling area
  (with some exceptions from earlier years)
- ODEQ, WA ECY and Puget Sound Stream Benthos sampling methods
  - WA ECY method is multi-habitat (random)
  - Other Organizations target riffle/run habitat

### Level 3 ecoregion

<table>
<thead>
<tr>
<th>Entity</th>
<th># Samples in full calibration dataset</th>
<th># Samples assessed by experts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puget Lowland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>King County - DNRP</td>
<td>212</td>
<td>35</td>
</tr>
<tr>
<td>Snohomish County</td>
<td>107</td>
<td>7</td>
</tr>
<tr>
<td>Kitsap County</td>
<td>105</td>
<td>2</td>
</tr>
<tr>
<td>WA ECY</td>
<td>91</td>
<td>18</td>
</tr>
<tr>
<td>City of Seattle</td>
<td>64</td>
<td>1</td>
</tr>
<tr>
<td>City of Everett</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>City of Redmond</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>City of Kirkland</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Snoqualmie Tribe</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>City of Bellevue</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>City of Issaquah</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Willamette Valley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ODEQ</td>
<td>35</td>
<td>21</td>
</tr>
<tr>
<td>Yamhill Basin Council</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>678</strong></td>
<td><strong>85</strong></td>
</tr>
</tbody>
</table>
Characteristics of the Calibration Dataset

Slope < 1%
252 out of 678 samples (37%)

Drainage area 1 to 10 mi²
484 out of 678 samples (71.4%)
Drainage Area versus # Total Taxa

- Surprisingly high number of taxa at very small sites!
- Based on plots like this, we did not see reason to adjust expectations based on stream size
Two Stream Types (Gradient)

- Low (<1% NHDPlus slope)
  - Previously referred to as ‘depositional’
- High (≥ 1% slope)
  - Previously referred to as ‘transitional/erosional’
Spatial Distribution of Calibration Dataset

Assessed samples (85)
# Calibration Dataset

Tally of assessed samples (Low & High Gradient Streams)

<table>
<thead>
<tr>
<th>BCG level</th>
<th>Puget Lowlands</th>
<th>Willamette Valley</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Totals</td>
<td>20</td>
<td>43</td>
</tr>
</tbody>
</table>

### Calibration Dataset by:

**Ecoregion**
- Puget Lowlands - 63
- Willamette Valley - 22

**Stream Type**
- Low gradient - 33
- High gradient - 52

### Calibration Sites in each BCG Level
- Level 2 – 14%
- Level 3 – 35%
- Level 4 – 21%
- Level 5 – 20%
- Level 6 – 9%
### Calibrated BCG Level 2 Rules

**BCG level 2:** Minimal changes in structure of the biotic community and minimal changes in ecosystem function - virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability.

<table>
<thead>
<tr>
<th>Narrative Descriptions</th>
<th>Metric</th>
<th>Numeric Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Diverse assemblage with moderate to high numbers of total taxa</td>
<td>Number of total taxa</td>
<td>≥ 30 (25-35)</td>
</tr>
<tr>
<td>A fair number of highly sensitive species are present</td>
<td>Number of Attribute I+II taxa</td>
<td>&gt; 5 (3-8)</td>
</tr>
<tr>
<td>A third or more of total taxa belong to one of the three sensitive groups, with slightly higher proportions expected in higher gradient streams</td>
<td>% Attribute I+II+III % taxa</td>
<td>≥ 35% (30-40)</td>
</tr>
<tr>
<td>Sensitive taxa comprise a almost a quarter of the organisms</td>
<td>% Attribute I+II+III % individuals</td>
<td>≥ 20% (15-25)</td>
</tr>
<tr>
<td>Tolerant and non-native taxa make up a very small fraction of the organisms (or are absent)</td>
<td>% Attribute V+VI taxa</td>
<td>≤ 5% (3-7)</td>
</tr>
<tr>
<td>% Attribute V+VI individuals</td>
<td>≤ 5% (3-7)</td>
<td></td>
</tr>
<tr>
<td>Sensitive EPT species are present in high numbers</td>
<td>Number of Attribute I+II+III EPT taxa</td>
<td>≥ 15 (10-20)</td>
</tr>
<tr>
<td>Tolerant non-insect taxa comprise a small percentage of the individuals (or are absent). Juga and Rissooidea are excluded from consideration for reasons described below</td>
<td>% Attribute IV+V+VI non-insect(^1), individuals, excluding Juga and Rissooidea(^2)</td>
<td>≤ 15% (10-20)</td>
</tr>
</tbody>
</table>
**Calibrated BCG Level 5 Rules**

**BCG level 5**: Major changes in structure of the biotic community and moderate changes in ecosystem function - Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials

<table>
<thead>
<tr>
<th>Narrative Descriptions</th>
<th>Metric</th>
<th>Numeric Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total richness ranges widely; at a minimum, at least thirteen total taxa are present</td>
<td>Number of total taxa</td>
<td>≥ 13 (8-18)</td>
</tr>
<tr>
<td>At least -20% of the subsampling target is achieved (in our calibration dataset, the</td>
<td>Number of total individuals</td>
<td>≥ 400 (390-410)</td>
</tr>
<tr>
<td>target is achieved (in our calibration dataset, the target is 500 organisms; if the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>target was 300, the rule would be ≥ 240 total organisms)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At least one EPT taxon is present</td>
<td>Number of EPT taxa</td>
<td>&gt; 0 (0-1)</td>
</tr>
<tr>
<td>Up to a third of total taxa may be tolerant or non-native</td>
<td>% Attribute V+VI taxa</td>
<td>≤ 35% (30-40)</td>
</tr>
<tr>
<td>Tolerant non-insect individuals comprise up to three-quarters of organisms.</td>
<td>% Attribute IV+V+VI non-insect¹</td>
<td>≤ 75% (70-80)</td>
</tr>
</tbody>
</table>

¹: Non-insect individuals include crustaceans, molluscs, oligochaetes, and earthworms.
Model Performance: Predictive Capacity

Compared panelist consensus calls to BCG level outputs (automated in Excel, and now R).

- **Calibration** – 97.4% accurate within ± 0.5 BCG Level
- **Confirmation** – 100% accurate within ± 0.5 BCG Level

<table>
<thead>
<tr>
<th>Stream Type (Gradient)</th>
<th>Dataset</th>
<th>Unit</th>
<th>Model 1 level better</th>
<th>Model 1/2 level better</th>
<th>Exact match</th>
<th>Model 1/2 level worse</th>
<th>Model 1 level worse</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low</strong></td>
<td>Calibrate</td>
<td>Number</td>
<td>1</td>
<td>29</td>
<td>3.3%</td>
<td>96.7%</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percent</td>
<td>3.3%</td>
<td>96.7%</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Confirm</td>
<td>Number</td>
<td>3</td>
<td></td>
<td>100%</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percent</td>
<td>3.3%</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td><strong>High</strong></td>
<td>Calibrate</td>
<td>Number</td>
<td>1</td>
<td>1</td>
<td>2.1%</td>
<td>87.2%</td>
<td>6.4%</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percent</td>
<td>2.1%</td>
<td>87.2%</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Confirm</td>
<td>Number</td>
<td>4</td>
<td>1</td>
<td>80.0%</td>
<td>20%</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percent</td>
<td>8.0%</td>
<td>20%</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>Calibrate</td>
<td>Number</td>
<td>1</td>
<td>2</td>
<td>70</td>
<td>3</td>
<td>1</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percent</td>
<td>1.3%</td>
<td>2.6%</td>
<td>90.9%</td>
<td>3.9%</td>
<td>1.3%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Confirm</td>
<td>Number</td>
<td>7</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Percent</td>
<td>87.5%</td>
<td>12.5%</td>
<td></td>
<td></td>
<td></td>
<td>100.0%</td>
</tr>
</tbody>
</table>
Historical Conditions
What do we know about BCG Level 1?
Quantification of Habitat Loss from Historical Conditions

Magnitude of Change from Reference

- Majority of streams have lost more than 20% of habitat historically accessible (Haring 2002);
- Majority of streams have lost more than 66% of wetted area (Haring 2002);
- Loss of large woody debris (Haring 2002);
- Loss of pool habitat (Haring 2002);
- Degradation or loss of riparian habitat (Haring 2002); and
- Less than 60% of watershed with forest stands aged 25 years or more (Haring 2002)
Changes in Stream Condition from 1895:

- > 25 times return spawners
- > 2.5 times intact area
- < 0.5m/sec average water velocity
- > 3 times the tributary wetted area
- > 1.25 times more useable habitat
- > 3m tributary stream width
Computer simulation of the upper Willamette River and floodplain between Harrisburg and Eugene-Springfield, ca. 1850 and ca. 1990. (From USEPA 2002b).
Summary of Changes in Willamette Basin Conditions from 1850 to current (1990 or 2005)

- Beaver: Nearly eliminated by 1835

- (Lowlands) % Ag: 0% → 41.6%
- (Lowlands) % Develop: 0% → 10.3%
- (Lowlands) % Nat. Grass: 16.8% → 1.0%
- (Lowlands) % Hudr: 24.7% → 9.9%
- (Lowlands) % Conif For: 25.4% → 9.6%
- (Lowlands) % Wetlands: 14.2% → 1.1%
- (Lowlands) % Mixed For: 0.3% → 36.6%
- (Lowlands) % Conif For: 98.2% → 52.1%
- Water Quality Index (WRB): 100 → < 25 → 85
- Temperature Ag (% Mi Impaired) 0% → 90%
- Temperature For (% Mi Impaired) 0% → 65%
- BCG Level 1 Lowlands 25% → 0%
- BCG Level 2 Lowlands 50% → 0%
- BCG Level 3 Lowlands 15% → 10%
- BCG Level > 4 Lowlands 10% → 90%
- BCG Level 1 Uplands 25% → 0%
- BCG Level 2 Uplands 50% → 50%
- BCG Level 3 Uplands 15% → 30%
- BCG Level > 4 Uplands 10% → 20%

From: Willamette Basin Planning Atlas
Percent within 120 meter riparian area
From: DEQ Willamette Rivers & Streams Assessment
Historical Condition Narrative for BCG Level 1

Streams with high habitat complexity; natural disturbance regimes to refresh micro-habitats; year-round flow without anthropogenic impacts to hydrology, temperature, or water quality; water often dominated by cool-cold water flow from springs, groundwater accretion, and/or natural runoff; high resilience to disturbance including drought and flood extremes; exemplary biological diversity with high taxa richness of rheophilic, lotic-depositional, and micro-habitat specialist macroinvertebrates; non-native invasive species absent; biotic community supports all ecosystem functions.
<table>
<thead>
<tr>
<th>Fundamental Characteristics</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stream channel</strong></td>
<td>Channel connected to hyporheos and flood plain including wetlands, beaver ponds, etc.; diverse habitats present (e.g. braided channels, side channels, debris jams, mixture of steps and pools consistent with stream gradient); wood debris typically present and may be abundant; quality habitat and refugia persists during periods of both low and high stream-flows.</td>
</tr>
<tr>
<td><strong>Riparian &amp; watershed</strong></td>
<td>Riparian zone supports intact community of overstory, understory and groundcover plants (including a mixture of mature conifer and hardwood trees with a diverse age structure in forested watersheds); upper watershed vegetation intact, supporting delivery of water of high chemical and thermal quality to lower reaches.</td>
</tr>
<tr>
<td><strong>Hydrologic regime</strong></td>
<td>Hydrologic regime natural, without alteration from dams and/or irrigation withdrawals or return flow; cool-cold water common from springs, groundwater accretion, and/or natural runoff; perennial surface or subsurface flow. Re-charge in the watershed sustains flow, especially during years of extreme drought. Perennial surface water in some portion of watersheds maintain endemic taxa that serve as recolonization sources sustaining high biodiversity at select locations. These locations promote resiliency in stream reaches that are periodically de-watered.</td>
</tr>
<tr>
<td><strong>Disturbance regime and resilience</strong></td>
<td>Natural seasonal range of high and low stream-flows present, which enhances and maintains channel and habitat complexity. Natural sediment transport based on local geology, soils and stream gradient. High resilience (ability to recover from disturbance) to natural and anthropogenic watershed stressors (Flotemersch et al. 2016). Watershed integrity maintains disturbance levels within ranges tolerable by endemic taxa and promotes connectivity for purpose of recolonization.</td>
</tr>
<tr>
<td><strong>Biodiversity</strong></td>
<td>Benthic macroinvertebrate community typically with high taxa richness, including many micro-habitat specialist taxa and species sensitive to human disturbance. Habitat complexity results in diversity of both rheophilic and lotic-depositional taxa. Non-native, invasive species not present.</td>
</tr>
<tr>
<td><strong>Ecosystem function</strong></td>
<td>Watershed supports full range of ecological processes and functions essential to maintaining high biodiversity provided by a minimally disturbed ecosystem. Food web, nutrient and energy flow linkages between aquatic and terrestrial environments fully supported.</td>
</tr>
</tbody>
</table>
State and Local Government Applications
**Applications**

- **State**
  - compare and corroborate with existing B-IBI, RIVPACS tools
  - consider including BCG in 305(b)/303(d) assessment toolbox
  - stressor ID, environmental tolerances, and TMDL studies
  - ID as reporting item in regional studies (e.g., stormwater action monitoring)
- **Local**
  - Restoration Project Placement
  - Coordination of Capital Improvement Projects within a drainage
  - Identification of local stressors with CADDIS model
  - Effectiveness Monitoring of Salmon Habitat Recovery Projects
Future BCG Work

Ryan Hill (2018)

Probability of Good Condition (NRSA-Design NHD Streams)
Pilot projects

- Addressing climate change by examining strategies for adapting to changing thermal & hydrologic conditions
  - Thermal Impact Checklist
  - Thermal Prediction Models and Taxa Tolerances

- BCG Refinements
  - Integration of ICI and IWI metric suites to populate disturbance gradient
  - Prediction of BCG for unmonitored sites

- Possible extension to other regions:
  - NW Pacific Maritime Region Model
BCG applications

- Puget Lowlands/Willamette Valley
- Columbia Estuary
- Casco Bay
- Narrangansett Bay
- Northern Piedmont, MD & VA
- Central Appalachians, WV & VA
- Mobile Bay
- Tampa Bay
- Fish & coral reefs in the Caribbean & Puerto Rico
R Tool
(BCGcalc Package)

https://github.com/leppott/BCGcalc
How does the quantitative model and R Tool work?

Like a cascade…

The BCG model evaluates metric membership values for all the metrics included in the rules for a given BCG level.

We automate the model in Excel.
Core Functions

• metric.values()
  - Calculate MMI and BCG metrics.

• BCG.Metric.Membership()
  - Generate membership for each metric. Requires a table of values.

• BCG.Level.Membership()
  - Uses metric membership and table of values to classify each site’s membership for Levels 1 to 6.

• BCG.Level.Assignment()
  - Assign 1\textsuperscript{st} and 2\textsuperscript{nd} Levels by Level membership
Steps for running the BCG R tool

1. Prepare your data input file (save as .csv)
   • SampleID, TaxonID, Count, Excluded, and master taxa attributes (phylogenetic and autecological)

2. Use the BCG R tool to
   • Calculate suite of metrics
   • Calculate metric membership values for each BCG level
   • Calculate overall BCG membership values

3. Save output as .csv or Excel file
**Calibrated BCG Level 4 Rules**

**BCG level 4:** Moderate changes in structure of the biotic community and minimal changes in ecosystem function - Moderate changes in structure due to replacement of some intermediate sensitive taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes.

<table>
<thead>
<tr>
<th>Narrative Descriptions</th>
<th>Metric</th>
<th>Numeric Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate numbers of total taxa</td>
<td>Number of total taxa</td>
<td>≥ 20 (15-25)</td>
</tr>
<tr>
<td>Sensitive taxa occur in reduced numbers but still comprise at least a tenth of the taxa</td>
<td>% Attribute II+II+III % taxa</td>
<td>≥ 10% (5-15)</td>
</tr>
<tr>
<td>Tolerant and non-native taxa comprise up to a quarter of the organisms. Slightly higher proportions occur in low gradient streams.</td>
<td>% Attribute V+VI taxa</td>
<td>≤ 20% (15-25)</td>
</tr>
<tr>
<td></td>
<td>% Attribute V+VI individuals</td>
<td>≤ 25% (20-30)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤ 20% (15-25)</td>
</tr>
<tr>
<td>At least one sensitive EPT taxon is present</td>
<td>Number of Attribute II+II+III EPT taxa</td>
<td>&gt; 1 (0-3)</td>
</tr>
<tr>
<td>Tolerant non-insect taxa become more prevalent, and may comprise up to a third of the assemblage.</td>
<td>% Attribute IV+V+VI non-insect taxa</td>
<td>≤ 30% (25-35)</td>
</tr>
<tr>
<td>Tolerant non-insect taxa comprise up to half the individuals in low gradient streams and up to a third of the individuals in high gradient streams. Juga and Rissoidea are excluded from consideration for reasons described above</td>
<td>% Attribute IV+V+VI non-insect1, individuals, excluding Juga and Rissoidea2</td>
<td>≤ 50% (45-55)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤ 35% (30-40)</td>
</tr>
</tbody>
</table>

1. Excluding Juga and Rissoidea.
2. Including Juga and Rissoidea.

Source: [Metcalf et al. (2013)](http://www.example.com/metcalf2013)
Metric membership calculations – example

Example – the BCG level 4 rule for total taxa richness is \( \geq 20 \) (15-25) (the lower bound is 15 and the upper bound is 25).

- If there are 15 or fewer total taxa in the sample, the metric membership value is 0.
- If there are 25 or more total taxa in the sample, the metric membership value is 1.
- If the number of total taxa falls within the lower and upper bounds, the metric membership value will range from 0 to 1 (e.g., if there are 20 total taxa, the membership value will be 0.5; if there are 17 total taxa, the membership value will be 0.2; if there are 23 total taxa, the membership value will be 0.8).
Overall BCG level membership

May include membership of a sample in

• A single level only
  - e.g., probability of membership in BCG level 3 = 1.0

• Two levels (tie)
  - e.g., probability of membership in BCG level 3 = 0.5 and BCG level 4 = 0.5

• Varying memberships among two or more levels
  - e.g., probability of membership in BCG level 3 = 0.8 and probability of membership in BCG level 4 = 0.2.

The level with the highest membership value is taken as the primary level.
Thank You!

QUESTIONS?
Additional Slides
Calibrated BCG Level 3 Rules

**BCG level 3**: Evident changes in structure of the biotic community and minimal changes in ecosystem function - Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but intermediate sensitive taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system.

<table>
<thead>
<tr>
<th>Narrative rules and comments</th>
<th>Metric</th>
<th>Numeric Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate to high numbers of total taxa</td>
<td>Number of total taxa</td>
<td>≥ 25 (20-30)</td>
</tr>
<tr>
<td>At least a quarter of the total taxa belong to one of the three sensitive groups</td>
<td>% Attribute li+II+III taxa</td>
<td>≥ 25% (20-30)</td>
</tr>
<tr>
<td>Sensitive taxa comprise at least a tenth of the individuals</td>
<td>% Attribute V+VI individuals</td>
<td>≥ 10% (5-15)</td>
</tr>
<tr>
<td>Tolerant and non-native taxa make up a small fraction of the organisms</td>
<td>% Attribute V+VI taxa</td>
<td>≤ 10% (5-15)</td>
</tr>
<tr>
<td>Sensitive EPT species are present in moderate to high numbers</td>
<td>Number of Attribute li+II+III EPT taxa</td>
<td>≥ 9 (6-12)</td>
</tr>
<tr>
<td>Tolerant non-insect taxa comprise a less than a quarter of the assemblage. Slightly higher proportions of non-insect individuals are expected in low versus high gradient streams. Juga and Rissoidea are excluded from consideration for reasons described above</td>
<td>% Attribute IV+V+VI non-insect(^1), individuals, excluding Juga and Rissoidea(^2)</td>
<td>≤ 30% (25-35)</td>
</tr>
</tbody>
</table>
Habitat Characteristics Based on Modeling Results of Steelhead Parr Survival (1895 Conditions)

- Average tributary channel width available for maximum parr production = 3m
- Where tributary meets mainstem: ≤ 0.5m depth & ≤ 0.5m/sec water velocity
- Open canopy and primary productivity enhances BMI response → food for fingerlings/juv.
  - Parr survival = increased spawners
  - Increased spawners = increased redds
  - Buried eggs are the primary source of marine-derived nutrients benefiting BMI

Capacity of the Available Habitat and Loss from Historic Conditions

Direct Effects on Stream Biota
- loss of suitable habitat (Structural Attributes; e.g., Density, No. of Species)

Indirect Effects on Stream Biota
- conditions that affect population productivity (e.g., Density, Spatial Distribution)
Historical Condition for BCG Level 1

**Work in Progress: Signal Checklist**

- Identify
  - best quality sites that remain
  - provide measure of BCG 1 elements at a site
  - degree to which site conditions reflect Level 1
- Metrics (current exploration)
  - Ecologic
    - # attribute li, II taxa, # sensitive EPT, # cold water taxa, # (Heptageniidae, Ephemerellidae, Nemouridae, Perlidae and Rhyacophilidae), habitat specialist (e.g., in low gradient valley streams, high dytiscid diversity)
  - Physical Habitat, Watershed Condition
    - Index of Catchment Integrity, Index of Watershed Integrity
Preliminary comparison of B-IBI with BCG for sites in Puget Lowlands
Effects of macrophyte growth and senescence on sediment dynamics in a regulated, low-gradient river

Rob Van Kirk
Melissa Muradian
Zach Kuzniar
Ben Ortman

Henry’s Fork Foundation
Ashton, Idaho
Study Motivation and Questions

Harriman State Park Reach of Henry’s Fork
- World-renowned wild Rainbow Trout fishery
- Famous for prolific aquatic insect hatches
- Wide, shallow channel
- Low-gradient: 0.10%
- Embedded gravel substrate
- Minimal riparian vegetation
- Seasonal growth and senescence of macrophytes
- 5 miles downstream of large irrigation reservoir

1. How do macrophytes and irrigation management affect fine sediment transport and deposition?
2. Can we relate invertebrate assemblage to sediment?
Study Reach

• 15 miles of river downstream of Island Park Dam
• 4th-order reach; mean annual flow 650 cfs
• Drainage basin area: 500 mi²
• Unregulated hydrology dominated by groundwater
• Reservoir stores 1/3 of annual basin yield
Monitoring Sites in Study Reach

▲ Water-quality
  - YSI sondes, continuous
    ▪ Turbidity
    ▪ Temp., DO, etc.
  - Weekly samples
    ▪ Nutrients
    ▪ Turbidity
    ▪ Suspended sediment

★ Macroinvertebrates
  - Sample in March
  - Quantitative Hess
  - 3-6 samples/location
  - Data back to 1992 at upstream site
Previous Results from Study Reach

Macrophytes:
- Grow Jun-Sep
- Slow water velocity
- Increase depth
- Trap sediment
- Senesce Dec-Mar
- Determine fish habitat characteristics

Sediment Analysis

• Turbidity-SSC relationship from samples
• Daily SSC from sonde turbidity data
• Streamflow: Island Park Dam and Buffalo River
• Streamflow at reach bottom ≈ sum of these
• Load = SSC concentration × streamflow
• Net reach transport = load at bottom – load at top
• Effect of reservoir operation on SSC and turbidity
• Effect of reservoir operation on invertebrates
Results: Reservoir operations and SSC

- **SSC vs. Flow**
  - $R^2(\text{log}) = 0.35$

- **SSC vs. Reservoir Volume**
  - $R^2(\text{log}) = 0.35$
Results: Reservoir operations and turbidity

Turbidity and SSC at dam:
• High when reservoir outflow is high and volume is low
• High in late summer of years when irrigation demand is high
• Low when outflow is low and reservoir is full
• Low in late winter
Results: Net reach sediment transport

Arrows show invertebrate sampling dates
Results: Net reach sediment transport: 2016-2017

![Graph showing sediment load and IP Dam outflow over time from 2016 to 2017. The graph also highlights an invertebrate sampling date.](image-url)
Sediment Transport: Context Matters

Yellowstone River near Livingston, MT

Henry’s Fork in study reach
Macrophytes and sediment dynamics

- Macrophytes trap fine sediment delivered during irrigation season
- Sediment transported out of reach highest when macrophyte biomass lowest

September

April
Sediment dynamics and invertebrates

- Is net sediment deposition/scour between summer invertebrate reproduction and March sampling a function of streamflow?
- Ratio of winter (December-March) flow to irrigation-season flow (July-September): higher values should result in less deposition/more scour.

Some evidence that higher flow ratios lead to better invertebrate metrics.
Sediment dynamics over long term

- 50,000 – 100,000 tons released from reservoir in 1992 (complete drawdown)
- Since 2014, net transport out of reach ≈ 2,000 tons/year but not uniform!
- 1992 sediment moved out of reach in 25-50 years?
Possible explanation for invertebrate trend?
Conclusions and management implications

• Sediment dynamics in Henry’s Fork differ from usual model of mobilization on ascending limb of runoff and deposition on descending limb.
• Reservoir sediment transport highest in July-September (irrigation season), out of phase with natural runoff timing.
• Macrophytes trap fine sediment during irrigation season.
• Sediment transport out of reach highest in late winter/early spring.
• Trends in invertebrate assemblage show some correlation with short- and long-term sediment dynamics.
• High winter flows and low irrigation-season flows lead to net transport of sediment out of Harriman reach, among other benefits to fishery.
Growing Our Understanding Through Communication

Brian Reese
Water Quality Standards Analyst.

Chase Cusack
Watershed Manager

Idaho Department of Environmental Quality
Bloom Coverage (%)

- 0
- 0.001-0.079
- 0.080-0.487
- 0.488-2.218
- 2.219-68.666
Why do we care?
Hypoxia
Taste and odors
Aesthetics
Cyanotoxins
Idaho Cyanobacteria
1. Aphanizomenon sp.
2. Dolichospermum
3. Gloeotrichia
4. Lyngbya
5. Microcystis
6. Planktothrix
7. Woronichinia
Hepatotoxins

Disrupt proteins that keep the liver functioning, may act slowly

- **Microcystins** (fast death factor) : 240+ variants, known tumor promotor.
- **Nodularin**
- **Cylindrospermopsin**

Potentially produced by:
1. *Aphanizomenon*
2. *Dolichospermum*
3. *Gloeotrichia*
4. *Lyngbya*
5. *Microcystis*
6. *Oscillatoria*
7. *Woronichinia*
Microcystin exposure: response

- Uptake by bile acid transporter
- Inhibit protein phosphatases 1 and 2A
- Affects cytoskeleton, cell cycle, general metabolism, apoptosis

**Hepatotoxicity**

MICROFILAMENTS (red threads in micrographs), structural components of cells, are usually quite long, as in the rat hepatocyte at the left. But after exposure to microcystsins (right), microfilaments collapse toward the nucleus (blue). (This cell, like many healthy hepatocytes, happens to have two nuclei.) Such collapse helps to shrink hepatocytes—which normally touch one another and touch sinusoidal capillaries (left drawing). Then the shrunken cells separate from one another and from the sinusoids (right drawing). The cells of the sinusoids separate as well, causing blood to spill into liver tissue. This bleeding can lead swiftly to death.

NORMAL LIVER

BILE DUCT

SINUSOIDAL CAPILLARY

HEPATOCYTES

LIVER AFTER TOXINS ACT

DAMAGED CAPILLARY

BLOOD SEEPING INTO LIVER TISSUE

Blatantly borrowed from Barry Rosen, USGS
Neurotoxins

Neurological toxicity  loss of coordination, muscle spasms, convulsions and rapid paralysis of skeletal and respiratory muscles (minutes)

- Anatoxin -a (Very Fast Death Factor)
- Anatoxin –a (s)
- Saxitoxin
- Neosaxitoxin

Potentially produced by:
1. Aphanizomenon
2. Dolichospermum
3. Gloeotrichia
4. Lyngbya
5. Microcystis
6. Oscillatoria
7. Woronichinia

Idaho Department of Environmental Quality
Dermatotoxins

Produce rashes and other skin reactions, usually within a day (hours)

- Lyngbyatoxin

Potentially produced by:
1. *Aphanizomenon*
2. *Dolichospermum*
3. *Gloeotrichia*
4. *Lyngbya*
5. *Microcystis*
6. *Oscillatoria*
7. *Woronichinia*
b-N-methylamino-L-alanine
BMAA

Neurological, linked to ALS and AD

Potentially produced by:
1. Aphanizomenon
2. Dolichospermum
3. Gloeotrichia
4. Lyngbya
5. Microcystis
6. Oscillatoria
7. Woronichinia
Cyanotoxins are highly potent

### Compounds & $LD_{50}$ (µg/kg)

<table>
<thead>
<tr>
<th>Compound</th>
<th>LD$_{50}$ (µg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saxitoxin</td>
<td>9</td>
</tr>
<tr>
<td>Microcystin</td>
<td>20</td>
</tr>
<tr>
<td>Anatoxin – a(s)</td>
<td>50</td>
</tr>
<tr>
<td>Anatoxin – a</td>
<td>200 – 250</td>
</tr>
<tr>
<td>Nodularin</td>
<td>50</td>
</tr>
<tr>
<td>Cylindrospermopsins</td>
<td>200</td>
</tr>
<tr>
<td>Ricin</td>
<td>0.02</td>
</tr>
<tr>
<td>Cobra toxin</td>
<td>20</td>
</tr>
<tr>
<td>Curare</td>
<td>500</td>
</tr>
<tr>
<td>Strychnine</td>
<td>2000</td>
</tr>
</tbody>
</table>

Blatantly borrowed from Barry Rosen, USGS

Idaho Department of Environmental Quality
Cyanotoxins are highly potent

Compounds & LD$_{50}$ (µg/kg)

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</tr>
<tr>
<td>Cylindrospermopsins</td>
<td>200</td>
</tr>
<tr>
<td>Ricin</td>
<td>0.02</td>
</tr>
<tr>
<td>Saxitoxin</td>
<td><strong>0.00000002g</strong></td>
</tr>
</tbody>
</table>
Cyanotoxins are highly potent

**Microcystin**
4 ppb =

- Saxitoxin
- Microcystin
- Anatoxin–α
- Anatoxin–β
- Nodularin
- Cylindrospermopsins
- Ricin
- Cobra toxin
- Curare
- Strychnine

*Microcystin in 4 ppb is equivalent to Saxitoxin in 20 ppb, or Microcystin in 500 ppb, or Anatoxin–α in 2000 ppb.*

---

Idaho Department of Environmental Quality
Cyanotoxins are highly potent compounds.

- Saxitoxin
- Microcystin
- Anatoxin-α
- Anatoxin-β
- Nodularin
- Cylindrospermopsins
- Ricin
- Cobra toxin
- Curare
- Strychnine

**Microcystin**

8 ppb =

---

Idaho Department of Environmental Quality
Observed Cyanobacteria and known toxins

**Cyanobacteria & Known Toxins Chart. Version 1.0 2/08/2017**

<table>
<thead>
<tr>
<th>Cyanobacteria Genus</th>
<th>CYL</th>
<th>MC</th>
<th>NOD</th>
<th>ATX</th>
<th>SAX</th>
<th>NEO</th>
<th>LYN</th>
<th>BMAA</th>
<th>DAT</th>
<th>APL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphanizomenon</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cylindrospermum</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dolichospermum</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Gloeotrichia</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Lyngbya</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Microcystis</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Oscillatoria (Planktothrix)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Woronichinia</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tbody>
</table>

**CYL** = cylindrospermopsin  **MC** = microcystin  **NOD** = nodularin  **ATX** = anatoxin-a  **SAX** = saxitoxin  **NEO** = neosaxitoxins  **BMAA** = β-N-methylamino-L-alanine  **LYN** = lyngbyatoxin-a  **DAT** = debromoaiplysatoxin  **APL** = aiplysatoxin

Blatently adapted from the SWAMP - HAB Field Guide - Cyanobacteria & Known Toxins Chart. Version 1.0 2/09/2017

Toxins tested for
Genetics tested for

Idaho Department of Environmental Quality
What are we missing?
Communication
Communication
With the Public
Salem area water advisory remains in effect, cyanotoxin levels decline

Florida's toxic algae crisis: Are Gulf and seafood safe to eat?

Annabelle Tometich and Ed Killer, Fort Myers News-Press
Published 7:00 a.m. ET Aug. 10, 2018

Aerial view news-press

WARNINGS
Don't drink water
Don't let children bathe
Boiling water increases toxins

Toledo residents warned against toxins in wat...
Vet: Toxic algae near Rupert kills dogs, horses

LAURIE WELCH | lwelch@magicvalley.com | Nov 22, 2016

Esther Simplot Pond reopens after algae bloom

Idaho Department of Environmental Quality
1. Avondale Lake
2. Black Lake
3. Fernan Lake
4. Hayden Lake
5. Cocolalla Lake
6. Chatcolet Res.
7. Dworshak Res.
8. Brownlee Res.
10. Oxbow Res.
11. Horsethief Res.
12. Cascade Res.
13. NF Payette River
14. Lake Lowell
15. Blacks Creek Res.
16. Little Camas Res.
17. Mountain Home Res.
18. Salmon Falls Creek Res.
19. Long Tom Res.
20. C.J. Strike Res.
21. Snake River (mult)
22. Private property (mult)
23. Murtaugh Lake
25. Island Park Res.
26. Henry’s Lake
27. Henry’s Fork
29. Mormon Res.
30. Chesterfield Res.
31. Fish Creek Res.
32. Blackfoot Res.
33. Lost Valley Res.
34. Eagle Island State Park
35. Anderson Ranch

2016 – 2018
Public reports, observations, photos
1. Avondale Lake
2. Black Lake
3. Fernan Lake
4. Hayden Lake
5. Cocolalla Lake
6. Chatcolet Res.
7. Dworshak Res.
8. Brownlee Res.
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29. Mormon Res.
30. Chesterfield Res.
31. Fish Creek Res.
32. Blackfoot Res.
33. Lost Valley Res.
34. Eagle Island State Park
35. Anderson Ranch
Idaho Department of Environmental Quality

We presented our Pollution Prevention Champion award to Esterline/Advanced Input Systems for its successful efforts to retrofit its factory floor lighting in its Coeur d'Alene fabrication facility. This is the third time the company has been recognized as a pollution prevention champion. Learn more about our pollution prevention recognition here: https://go.usa.gov/xP2sq
Boise Parks & Rec @boiseparks · Jul 20

Esther Simplot Park Pond No. 1 remains closed due to the discovery of blue-green algae. This type of algae *may produce toxins under the right conditions. Measures have been taken to eliminate the bloom. We'll update the public as we get new info.
Harmful Algal Blooms in Idaho

What does a harmful algal bloom look like and how can you report one? We explain what to look for and how to contact DEQ if you suspect a bloom is in an Idaho water body. When in doubt, stay out! Check our map for current recreation water quality health advisories and learn how to report a harmful algal bloom here: https://go.usa.gov/xRnSj.
Central District Health Department has issued a health advisory for Lake Cascade due to the presence of a cyanobacteria harmful algal bloom. Check our map for current recreation water quality health advisories and learn how to report a harmful algal bloom here: https://go.usa.gov/xRnSj

News release: http://www.cchd.idaho.gov/.../09-07-18-lake-cascade-bg-algae...
Communication Between Agencies
Idaho Harmful algal Bloom Response Partners
Idaho Harmful algal Bloom Response Partners

Idaho Department of Environmental Quality
Idaho Harmful algal Bloom Response Partners
Idaho Fish and Game Magic Valley

September 27 - 🌐

Attention Anglers: A salvage order has been issued on Little Camas Reservoir. The Health Advisory on Little Camas related to bluegreen algae toxins was recently lifted, but that does not mean its "all clear". We encouraged folks visiting Little Camas Reservoir to still take precautions and avoid swimming, keep dogs away from the water, and prepare fish meals in the same manner recommended when advisories are in place. Please fillet the fish, remove the skin, trim fat, and only eat the meat of the fish.
Idaho Department of Environmental Quality

Satellite Imagery for monitoring…
Sentinel 2-MSI
(Aug 30, 2018)
Cascade Reservoir

9/2 / 8/30

Population Density Estimate (cells/mL)
Cyanobacteria Monitoring Collaborative

cyanos.org

Three coordinated monitoring projects to locate and understand harmful cyanobacteria.
Technology & Citizen Science

BloomWatch App - Cyanobacteria Monitoring Collaborative
What’s ahead?

Questions to consider...
Impacts of Cyanotoxins on Drinking Water Systems

Increasingly, water systems are monitoring for and addressing cyanotoxins and the algal growth that can cause their formation. Some cyanotoxins are on EPA’s list of drinking water contaminants of concern. In 2016, EPA published “Health Advisories” for two cyanotoxins.
<table>
<thead>
<tr>
<th>Sample Description</th>
<th>Date</th>
<th>Time</th>
<th>Taxa ID and Enumeration (cells/mL)</th>
<th>Microcystin (ppb)</th>
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</thead>
<tbody>
<tr>
<td>NF Payette</td>
<td>9/11/2018</td>
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<td>Dolichospermum sp.:14,200</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td>Sample Description</td>
<td>Date</td>
<td>Time</td>
<td>Taxa ID and Enumeration (cells/mL)</td>
<td>Microcystin (ppb)</td>
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<td>NF Payette</td>
<td>9/11/2018</td>
<td></td>
<td>Dolichospermum sp.: 14,200</td>
<td>&lt;0.15</td>
</tr>
</tbody>
</table>
Questions?

Brian.Reese@deq.idaho.gov
Chase.Cusack@deq.idaho.gov
Algae@deq.idaho.gov
Harmful Algal Blooms

A story of Cyanobacteria, Satellites, Source Water and the Senate

SFS - PNW Meeting
Ketchum, ID
8 Nov, 2018

Matt Schult, Aaron Borisenko | Oregon Dept. Environmental Quality
HABs SURVEILLANCE PROGRAM

OHA: Advisories
DEQ: Responsible to investigate causes
  - Identify source of pollution
  - Write pollution reduction plan
  - Sample and analyze recreational waters and drinking water
  - Clean Water Act
    - 303(d) listed water bodies

**Meter status—Monitoring.** Drinking water remains safe for all Salem residents and water customers. Based on current test results from sampling of water within Detroit Reservoir, cyanotoxins have been detected in Salem’s drinking water source, but have **not** been detected within the drinking water distribution system.
CYANOBACTERIA 101

• Prokaryotes
• Earliest: - life forms on earth
  - fossils
  - photosynthesizers
• Simple organisms?......not that simple
CYANOBACTERIA 101

- Gas vesicles – buoyancy regulation
- Phycobilins – low light photosynthesis
- Akinetes – resting cell or “spore”
- Heterocysts – dedicated to fix N
- Toxins – defense, competition
IDENTIFY CAUSES

• Waterbody specific and may involve any of these factors:
  • Increasing nutrient input
  • Warming water temperatures
  • Reduced mixing/circulation
  • Invasive species, particularly fish and filter feeders

Upper Klamath Lake, OR
https://sentinel.esa.int
DEVELOP STRATEGIES

“The success of water management strategies to combat harmful cyanobacteria hinges on a proper identification of the cyanobacterial species involved and the ecosystem processes that govern their population dynamics.”

(Huisman et al., 2005)
DEVELOP STRATEGIES

• Strategies are waterbody specific
  • Reduce nutrient inputs from:
    • Point sources of wastewater
    • Leaky septic systems
    • Agricultural runoff
    • Urban stormwater
    • Forest lands
  • Restore vegetation to provide cooling
  • Promote water movement
  • Invasive species control/prevention
## MICROCYSTINS

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<thead>
<tr>
<th>Animal/Source</th>
<th>Specimen</th>
<th>Specimen Type</th>
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<td>ppb</td>
<td>10</td>
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</tbody>
</table>

Report 4.34-CAHFS Standard Report - 05/31/2017
HEALTH ADVISORY

AVOID WATER CONTACT

Due to high levels of blue-green algae that can produce harmful toxins.

Do not use this water for drinking or cooking.

Children and pets are at greatest risk.

For more information about water quality and monitoring contact:
Department of Environmental Quality at 503-693-5723
For information about harmful algae blooms, symptoms of exposure or to report a human or pet illness, contact the Oregon Health Authority at 971-673-0400 or visit www.healthyoregon.org/HAB
## Ross Island Lagoon

**Advisory by cell count:**

Cumulative toxigenic species ≥100,000 cells/mL?

<table>
<thead>
<tr>
<th>Location</th>
<th>Cells/mL</th>
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<tbody>
<tr>
<td>Inner Lagoon</td>
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<tr>
<td>Lagoon Mouth</td>
<td>1,099,313</td>
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<tr>
<td>Willamette R</td>
<td>629,112</td>
</tr>
<tr>
<td>Ross Isl. Channel</td>
<td>5,246</td>
</tr>
</tbody>
</table>
Future of blue-green algae in Willamette River still uncertain; users frustrated

By Courtney</p><p>PORTLAND—The rowing community that was excited for the first weekend of rowing competition this season was instead disappointed to hear the news that blue-green algae has returned to the Willamette River.</p><p>"It was too much to hope for," said Tim, a member of the local rowing club. "We had planned to start our season with a big regatta, but now we're奋斗目标 needs to be scaled back."</p><p>Volunteers for the Oregon Health Authority have put up warning signs in Willamette, Sellwood, Waterfront, and Eastbank Esplanade parks. These signs caution users against drinking or cooking with the water due to blue-green algae bloom scum that can produce harmful toxins. (Arianna Rodriguez)
The location of the European Space Agency Sentinel 3A at 9:59 am on Thursday July 18, 2018
Ocean and Land Color Instrument (OLCI)

- 1,270 km swath width
- 300m² spatial resolution
- Global coverage (2 days)
RESOURCES

- SeaDAS Software
- ArcGIS Tool Box
- Android Mobile App (EPA’s CyAN)

Clark et al. (2017) *Ecological Indicators* 80:94-95
EPA’s Cyanobacteria Assessment Network (CyAN)
SALEM, Ore. - The Oregon Health Authority said Wednesday it has updated a recreational use health advisory issued June 22 for part of Lake Billy Chinook to cover all three arms of the lake, based on the latest test results.

The original advisory, extended from the area at Upper South Cove around
Health Advisory Issued For Upper Klamath Lake Due To Algae Bloom

EPA - June 17, 2018 - 3pm (Pacific, Or)

Blue-green algae have spread to another lake. State officials have issued a health advisory for Upper Klamath Lake. It's in southern Oregon, west of Klamath Falls.

Toxins from blue-green algae can be harmful to humans and animals.

In the affected areas of Klamath Lake, visitors should avoid swimming and boating. The toxins are not absorbed through the skin, but people with skin sensitivities may experience a puffy red rash at the affected area.

Drinking water that contains the algae is especially dangerous. The toxins cannot be removed by boiling, filtering, or treating water with campsite

Oregon health officials say that if you choose to eat fish from the affected water, you should remove all fat, skin and organs before cooking. Fishers should also be rinsed with clear water. Transfers of wet freshwater clams from Upper Klamath Lake.

More News
545,941 cells/mL since previous data
(Max: 812,830, Valid: 6)

Location Detroit Reservoir 2
19 of 43
Overview Imagery Chart

DETROIT RESERVOIR
26 MAY, 2018
City of Salem issues drinking water advisory

May 29, 2018

Late this afternoon, the city of Salem issued the following press release regarding a "Do Not Drink" notice for tap water in the cities of Salem, Turner, Suburban East Salem Water District, and Orchard Heights Water Association. The city is recommending that vulnerable people including infants, children under six, people with compromised immune systems, people receiving dialysis treatment, people with pre-existing liver conditions, pets, pregnant women or nursing mothers, or other sensitive populations should follow this advisory.

Everyone may use tap water for showering, bathing, washing hands, washing dishes, flushing toilets, cleaning and doing laundry.

Please see the full press release below for more information or visit cityofsalem.net.

DRINKING WATER ADVISORY

City of Salem: MAY 29, 2018,
CYANOTOXINS PRESENT IN DRINKING WATER DO NOT DRINK THE TAP WATER -- INFANTS, YOUNG CHILDREN AND OTHER VULNERABLE INDIVIDUALS

Applies to City of Salem, City of Turner, Suburban East Salem Water District, and Orchard Heights Water Association

WHY IS THERE AN ADVISORY? Low levels of cylindrospermopsin and microcystin (cyanotoxins) have been found in treated drinking water. These toxins are created by algal blooms in the source of City of Salem drinking water, Detroit Reservoir. To ensure the greatest quality of drinking water, City of Salem voluntarily samples for such toxins during algal events. Samples were collected on May 23, 2018, and May 25, 2018.
June 13, 2018

Director Richard Whitman
Department of Environmental Quality
700 NE Multnomah Street, Suite 600
Portland, OR 97232

Dear Director Whitman,

Over the last few weeks Oregonians have learned about the dangers of cyanotoxins in drinking water. Even low levels of exposure to these toxins can be harmful to children, older adults and those with specific pre-existing health conditions.

I have heard from the City of Salem and several other local water utilities that the lack of in-state testing is a problem. The process of shipping samples to out-of-state labs is cumbersome and slow for the water officials and the public.

It is my understanding that the department has the equipment and expertise to conduct the testing in-state, but lacks the needed personnel. I am requesting today that the Oregon Department of Environmental Quality move quickly to use existing staff to conduct testing for cyanotoxins in drinking water and if necessary submit a budgetary request to the Legislative Emergency Board to be considered when the board meets in September.

Throughout our history, Oregon has prided itself on its clean air and water. Algal blooms and the resulting toxins in our drinking water systems are now threatening public confidence in a resource we have long considered pure. This is exactly why the Emergency Board exists. Oregon is facing a crisis and we have the means to aid in our response.

I believe that timely in-state testing can provide water systems with the information they need to react and help restore Oregonians’ faith in this essential element of our daily lives.

Thank you,

Respectfully,

Peter Courtney
President of the Oregon Senate
EPA Method 546: ELISA for *Mycrocystin* and *Nodularin* in drinking water & ambient water
DRINKING WATER TESTING

• Approximately 100 facilities that provide drinking water
• Sampling period July - November
DRINKING WATER TESTING

**SOURCE:** Biweekly testing

**YES:** Test **FINISH** water

**NO?**
Test **SOURCE** water weekly (until 2 non-detects)

**YES?**
Test **FINISH** water daily (until 2 non-detects)

**NO?**
Test **SOURCE** water daily (until 2 non-detects)
<table>
<thead>
<tr>
<th>FACILITY</th>
<th>SAMPLE DESCRIPTION</th>
<th>ANALYTE</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
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</tr>
</tbody>
</table>
• Continue in-state testing
• Expand Lab capacity (ELISA, LC/MS) for advisory notices
• Vision for recreational posting with State-wide partnerships
THANKS!
• This slide intentionally left blank.............
RESOURCES

• CyAN (Sept-2017) : https://drive.google.com/open?id=0B6EtCnMZhZ28dTRqUThSTkZPX00

• CyAN Fact Sheet: https://www.epa.gov/sites/production/files/2016-10/documents/cyanfactsheet.pdf

• OHA Current Advisories: https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/RECREATION/HARMFULALGAEBLOOMS/Pages/Blue-GreenAlgaeAdvisories.aspx
CyAN Limitations

• Ice can potentially register as high cyanobacteria concentrations

• The land mask may cover dry lakes, and may exclude other lakes

• Caution should be used where mixed pixels may occur at land/water interface

• Land mask does not have an accurate representation of Rhode Island’s coastline

• Undetected thin clouds can potentially register as high cyanobacteria concentrations

• Retrievals are considered more robust for lakes ≥ 900 m, or 3 x 3-pixel array; smaller water bodies and rivers are not masked and may be erroneous

• Satellite data processing does not account for changes in water levels due to cycles, such as drought and flood
ESTHER SIMPLOT POND HARMFUL ALGAL BLOOMS

Dorene MacCoy, Water Quality Environmental Coordinator, Public Works Department
Paul Faulkner, Senior Water Quality Environmental Specialist, Public Works Department
LOCATION
PARK USE

- Swimming
- Boating
- Picnic and recreation
- Fishing
- Greenbelt access
- Wildlife viewing – wetland

https://vimeo.com/190813627
PARK TOXIC TIMELINE

- Nov ‘16 - ESP Grand opening
- June ’17 - ESP and Quinns closed high E. coli criteria (storm water and runoff)
- Aug ‘17 – ESP HABs (Planktotherix, Dolichospermum, Microcystis), park closed
- April ‘18 park open
- June ‘18 ESP and Quinns high E. coli, several treatments
- July’18 ESP HABs (Oscillatoria) closed, treated, and reopened
- Sept ‘18 ESP HABs (Aphanizomenon, Dolichospermum) park closed

Quinn’s Pond (Quinns) 39 acres
Esther Simplot Pond (ESP) 16.5 acres
2018 MONITORING

- E. Coli – weekly e. coli
- Nutrients (TP, TN, ammonia, dissolved reactive phosphorus, nitrate/nitrite)
- Temperature and DO - continuous profiles
- July 2018 cyanobacteria bloom
  - Oscillatoria – microcystin 0.26 ppb (µg/L)
- August 2 - 27 2018 ESP Pond experiment
  - Circulation pumps and wetland use
  - E.coli reduction and reduced stratification
- September 2018 cyanobacteria bloom
  - Aphanizomenon – microcystin 0.42 ppb
  - Dolichospermum – microcystin 0.30 ppb
Table 1. Draft EPA Recommended Values for Recreational Criteria and Swimming Advisories for Cyanotoxins

<table>
<thead>
<tr>
<th></th>
<th>Microcystins</th>
<th>Cylindrospermopsis</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 µg/L</td>
<td>8 µg/L</td>
<td></td>
</tr>
</tbody>
</table>

a) Swimming Advisory: not to be exceeded on any day
b) Recreational Criteria for Waterbody Impairment: not exceeded more than 10 percent of days per recreational season up to one calendar year.

Table 2. WHO (2003) Recreational Guidance/Action Levels for Cyanobacteria, Chlorophyll a, and Microcystin

<table>
<thead>
<tr>
<th>Relative Probability of Acute Health Effects</th>
<th>Cyanobacteria (cells/mL)</th>
<th>Chlorophyll a (µg/L)</th>
<th>Estimated Microcystin Levels (µg/L)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt; 20,000</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Moderate</td>
<td>20,000–100,000</td>
<td>10–50</td>
<td>10–20</td>
</tr>
<tr>
<td>High</td>
<td>&gt;100,000–10,000,000</td>
<td>50–5,000</td>
<td>20–2,000</td>
</tr>
<tr>
<td>Very High</td>
<td>&gt; 10,000,000</td>
<td>&gt; 5,000</td>
<td>&gt; 2,000</td>
</tr>
</tbody>
</table>

*WHO (2003) derived the microcystin concentrations from the cyanobacterial cell density levels.
### Cyanobacteria Found in Esther Simplot Ponds 2017 and 2018

<table>
<thead>
<tr>
<th>Cyanobacteria Genus</th>
<th>CYL</th>
<th>MC</th>
<th>NOD</th>
<th>ATX</th>
<th>SAX</th>
<th>NEO</th>
<th>LYN</th>
<th>BMAA</th>
<th>APL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphanizomenon</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dolichospermum</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Microcystis</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Oscillatoria (Planktothrix)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**CYL** = cylindrospermopsin  **MC** = microcystin  **NOD** = nodularin  **ATX** = anatoxin-a  **SAX** = saxitoxin  **NEO** = neosaxitoxins  **BMAA** = β-N-methylamino-L-alanine  **LYN** = lyngbyatoxin-a  **DAT** = debromoaplysiatoxin  **APL** = aplysiatoxin

Adapted from IDEQ and SWAMP - HAB Field Guide

**Toxins found**
# NUTRIENTS AND BLOOMS

Preliminary data – note low nutrient concentrations

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>E. Coli</th>
<th>HABs</th>
<th>cell/mL</th>
<th>Orthophosphate, as P (mg/L)</th>
<th>Total Phosphorus as P (μg/L)</th>
<th>Ammonia as N (μg/L)</th>
<th>Nitrite-Nitrate as N (mg/L)</th>
<th>TKN (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP1</td>
<td>7/2/2018</td>
<td>50</td>
<td></td>
<td></td>
<td>0.00321</td>
<td>17.0</td>
<td>&lt;35.0</td>
<td>&lt;0.02</td>
<td>0.405</td>
</tr>
<tr>
<td>ESP2</td>
<td>7/2/2018</td>
<td>4</td>
<td></td>
<td></td>
<td>0.002</td>
<td>16.5</td>
<td>&lt;35.0</td>
<td>&lt;0.020</td>
<td>0.358</td>
</tr>
<tr>
<td>ESP3</td>
<td>7/2/2018</td>
<td>17</td>
<td></td>
<td></td>
<td>0.002</td>
<td>17.9</td>
<td>&lt;35.0</td>
<td>&lt;0.020</td>
<td>0.37</td>
</tr>
<tr>
<td>ESP1</td>
<td>7/16/2018</td>
<td>&lt;1</td>
<td>Oscillatoria</td>
<td>1,425,000</td>
<td>0.0091</td>
<td>27.2</td>
<td>127</td>
<td>0.053</td>
<td>0.446</td>
</tr>
<tr>
<td>ESP2</td>
<td>7/16/2018</td>
<td>1</td>
<td>Oscillatoria</td>
<td>1,292,000</td>
<td>0.00687</td>
<td>25.7</td>
<td>125</td>
<td>0.0448</td>
<td>0.582</td>
</tr>
<tr>
<td>ESP3</td>
<td>7/16/2018</td>
<td>1</td>
<td></td>
<td></td>
<td>0.00604</td>
<td>27.1</td>
<td>376</td>
<td>0.0236</td>
<td>0.667</td>
</tr>
</tbody>
</table>
TEST STRIPS?

- Unsure where to take sample
- Issues with interpretation
TEST STRIP READER

Reader negative for Anatoxin-a and Mycrocystin
Or there was an invalid control
TEST READER

When strips are not read right away
False positives or false negatives
NEXT STEPS

- Public education
- Monitoring Plan
- Aeration/circulation/treatment
- Phytoremediation
NEED YOUR FEEDBACK

New to the City of Boise – Swim Beaches and HABs

Dorene MacCoy
Water Quality Environmental Coordinator
City of Boise Public Works Department
dmaccoy@cityofboise.org
208-608-7515

Paul Faulkner
Water Quality Environmental Specialist
City of Boise Public Works Department
pfaulkner@cityofboise.org
208-608-7507
A New Master Sample

Washington Statewide Stream Biological Monitoring
Our talk

• What we’ve been using
  • Requirements for build
  • Features
  • Issues

• What we are making
  • Requirements for build
  • The process
  • Issues
Background

https://ecology.wa.gov

https://tinyurl.com/WatershedHealth
**Multi-scale**

- Statewide (Dept. Ecology)
- Broad Regions (Depth Ecology)
- Watersheds, etc. (local interests)

---

**Quality Assurance Monitoring Plan**

- Monitoring Forum (Exec order 04-03)
- Stakeholder Workshops
Two federal mandates and state responses

CWA

...to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.

WA State of the Salmon Report

305(b): status of waters of the state

ESA

...de-listing requires analysis of the physical & chemical conditions that affect the species’ continued existence.

PCS Ralph: Annual Reports to Congress

Reporting on salmon and habitat in Washington
Required features of 1st WA Master Sample

• **1:24,000** - stakeholder request
• **Statewide** - not necessarily beyond
• **1 km spacing** - stakeholder request
• **Strahler*** – represent *all* size rivers/streams (in EPA fashion)

* Not available at 1:24k in 2008
Scale issues from National Surveys

- Coarse hydro 1:100k*
- Skewed to Mountains
- Sparse: About 50 sites

* Largest issue for local adoption

EMAP-West 2000-2003

=Federal or Tribal Land
Washington Master Sample

Metadata also available as

**Metadata:**

- Identification Information
- Spatial Data Organization Information
- Spatial Reference Information
- Entity and Attribute Information
- Distribution Information
- Metadata Reference Information

---

**Identification Information:**

**Citation Information:**

*Originator:* USEPA NHEERL Western Ecology Division, Anthony (Tony) R. Olsen  
*Publication Date:* 20081124  
*Title:* Washington Master Sample  
*Geospatial Data Presentation Form:* map

**Description:**

*Abstract:*  

*Purpose:*  
To provide a common set of probabilistic sites for sharing efforts in monitoring rivers and streams.

---

https://ecology.wa.gov/Research-Data/Data-resources/Geographic-Information-Systems-GIS/Data#m
Technical issues with Frame for our first Washington Master Sample

• **Non-standard** hydrography
  • Variable density
  • Coverage gap
  • Requires confirming NHD membership for Db inclusion
  • Dated – now 13 years old

• **No Strahler** attribute in frame
  • Required manual evaluation vs NHD+ (1:100k)

• “**Perennial**” attribute unknown, not in Master Sample

• **Confined** to Washington
Variable Density of WA DNR (2005)

A timber management agency
• Extra lines near timber sales
• Lines inconsistently updated
Counties (West)       Gap       Watersheds (East)
Must compare DNR frame with 2 other hydrographies...

NHD (state standard)  

NHDPlus (has Strahler)
Effects of using multiple hydro layers

• Inferences based on hundreds NOT tens of thousands
• Time & effort
• Lack of clarity when discussing
• Location errors (see the Puyallup River example)
Master Sample Ends at Washington’s Boundaries

Our interests do not
Inferences based on spatially-balanced random sample

Obtain unbiased estimates of:

• Status
• Extent
• Stressor Identification
• Trends
Status

![Graph showing stream length assessed (km) for different statuses and regions.](image)

**All Streams**
- Good: 42.7%
- Fair: 23.7%
- Poor: 33.6%

**Stream length assessed (km)**

**Western**
- Good: 49.3%
- Fair: 26.3%
- Poor: 31.7%

**Eastern**
- Good: 37.8%
- Fair: 16.5%
- Poor: 45.6%

**Columbia Plateau**
- Good: 42%
- Fair: 26.3%
- Poor: 31.7%
Extent of poor condition for various environmental parameters:

- LRBS
- % Sand/Fines
- Total Nitrogen
- DO
- DgmLog10
- Embeddedness
- B-IBI
- LWDSiteVolume
- Temperature
- PPNCanopy
- Total Phosphorus
- Slope
- TSS
- pH-low
- Conductivity
- Sinuosity
- Turbidity
- Chloride
- pH-high
- Copper
- Lead
Stressor Identification

![Graph showing Stressor Identification](image)
Trends

A) Puget Sound
Wald $\chi^2 = 3.54, p = 0.03$

B) Coast Range
Wald $\chi^2 = 0.13, p = 0.88$

C) Lower Columbia
Wald $\chi^2 = 4.55, p = 0.01$

D) Mid Columbia
Wald $\chi^2 = 3.11, p = 0.049$
The New Master Sample

Rebuilding from the stream up

- NHD 1:24000
- Stream/River & Artificial Path
- Points directly on the NHD flowline, so NHD attributes available
Region 1711

21 HUC 8 regions
<table>
<thead>
<tr>
<th>FCODE</th>
<th>Feature Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>46000</td>
<td>No Attributes</td>
</tr>
<tr>
<td>46003</td>
<td>Intermittent</td>
</tr>
<tr>
<td>46006</td>
<td>Perennial</td>
</tr>
<tr>
<td>46007</td>
<td>Ephemeral</td>
</tr>
<tr>
<td>55800</td>
<td>No Attributes</td>
</tr>
</tbody>
</table>
4,808 stream kilometers = 4,808 points
3,096 stream kilometers = 3,096 points
21 HUC 8 regions

114,482 points

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Canada</th>
<th>WA</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Attributes</td>
<td>15,132</td>
<td>132</td>
</tr>
<tr>
<td>Intermittent</td>
<td>0</td>
<td>57,481</td>
</tr>
<tr>
<td>Perennial</td>
<td>9</td>
<td>35,768</td>
</tr>
<tr>
<td>Ephemeral</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Artificial Path</td>
<td>952</td>
<td>5007</td>
</tr>
<tr>
<td>Total</td>
<td>16,093</td>
<td>98,389</td>
</tr>
</tbody>
</table>
The New Master Sample

Points joined with additional information so as to be able to select/subset as needed:

- NHDplus information
- Ecoregions
- County
- HUC02-HUC12
- Stream order
- Urban Growth Boundaries
- StreamCat (ICI & IWI)
- Etc.
Other Monitoring groups using:
- Storm Water Action Monitoring (SAM)
- City of Bothell, WA
- We anticipate others will also be interested
The New Master Sample

Benefits
• Less time with desktop site verification
• More efficient calculation of adjusted spatial weights
• Easier to explain
• More recent framework

Challenges/questions
• May sometimes be challenging to compare old vs new points
• Frame attributes not intuitively named (e.g. “Artificial path”)
Final thoughts

• Collaboration across borders? Just add HUCs as needed.

• WA Master Sample can contribute to CWA accounting
  1. A State 305(b) report to objectively describe status and trends of state waters, and
  2. The EPA’s Report to Congress about national waters

• WA Master Sample contributes to ESA accounting
  1. The Governor’s State-of-the-Salmon Report, to describe status and trends of salmon/steelhead and bull trout limiting factors.
  2. Hopefully to NOAA’s Report to Congress about results from PCSRF (ESA accounting).
• Site-specific trends information reduced

1. New master sample means sites from original surveys won’t be re-sampled

2. New study design means replacement rate will be lower than 50%
Glenn Merritt and Chad Larson
Washington State Department of Ecology
Environmental Assessment Program
tinyurl.com/WHMHomePage
WHY DO WE SNORKEL?
WHY DO WE SNORKEL?

Electrofishing
- Hands on
- More efficient for higher densities
- More labor intensive in larger rivers
- Requires a lot of gear
- Need conductive water

Snorkeling
- Observational only
- More efficient for lower densities
- Less labor/gear intensive in larger rivers
- Need good visibility
- Requires more training
WHY DO WE SNORKEL?

- Granitic soils of Idaho Batholith result in low nutrients
  - Anadromous life history
WHY DO WE SNORKEL?

• Granitic soils of Idaho Batholith result in low nutrients
  – Anadromous life history

• Undammed rivers in the Batholith have
  – very low conductivity
  – High visibility
  – Low fish densities
WHY DO WE SNORKEL?

- Granitic soils of Idaho Batholith result in low nutrients
  - Anadromous life history
- Undammed rivers in the Batholith have
  - Very low conductivity
  - High visibility
  - Low fish densities
- Regional waters we routinely snorkel include the NF and MF Boise, and SF Payette rivers
NFBR BACKGROUND

• The NFBR originates on west side of Sawtooths and flows SW for 80 km before joining the MFBR
NFBR BACKGROUND

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• The NFBR loses roughly 1,000 m in elevation (about 13 m/km)
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• The NFBR loses roughly 1,000 m in elevation (about 13 m/km)

• Classic Idaho Batholith River
The NFBR originates on west side of Sawtooths and flows SW for 80 km before joining the MFBR.

The NFBR loses roughly 1,000 m in elevation (about 13 m/km).

Classic Idaho Batholith River

Shallow granitic soil susceptible to high rates of erosion, especially following wildfires

- Rabbit Creek Fire 1994
- McNutt Fire 2009
NFBR BACKGROUND

• Native gamefish in the NFBR include Redband Trout (RBT), Bull Trout, and Mountain Whitefish
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RBT are native to all major rivers in SW ID below Shoshone Falls:
- Desert populations petitioned for ESA listing in 1997
- Rangewide assessment conducted in 2012 (Muhlfeld)
- Conservation strategy developed in 2016 (for states of CA, ID, MT, NV, OR, and WA)
Native gamefish in the NFBR include Redband Trout (RBT), Bull Trout, and Mountain Whitefish.

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- Desert populations petitioned for ESA listing in 1997
- Rangewide assessment conducted in 2012 (Muhlfeld)
- Conservation strategy developed in 2016 (for states of CA, ID, MT, NV, OR, and WA)

IDFG continues to monitor population trends within RBT distribution as part of the conservation strategy.
METHODS

• 15 historic trend sites
  – Surveys started in 1980s

• Describe distribution, abundance, and species composition

• Compare current pop trends to historical estimates
LOWER CANYON SECTION

- Rabbit Creek
- Short Creek
- 01 Sucker Hole
- X1
- X2
- French Creek
- 96 Sucker Hole

Images of people kayaking in a river with rapids.
MIDDLE ROADED SECTION
METHODS

• All sites surveyed in both 2017 and 2018
  – Sites ranged from 30 to 80 meters long
METHODS

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  – Some sights were deep pools that were snorkeled downriver
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METHODS

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  – Sites ranged from 30 to 80 meters long

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  – Some sights were deep pools that were snorkeled downriver

• Recorded species and size (nearest inch) of all observed fish

• Lengths and widths of each site measured
NORTH FORK BOISE RIVER
BEWARE OF DEER-BO

THE ACTION-PACKED SEQUEL:
DEER-BO II
WITH
DEER-BO "BUCK" NORRIS - GOLDIE FAWN

YOU'LL LAFF, YOU'LL CRY, YOU'LL KISS SOME BUCKS
GOODBYE...
RESULTS - 2017

Graph showing fish density (fish/100m²) over different sample periods (years 88-89 to 2017). Legend includes:
- Wild Rainbow
- Bull Trout
- Mountain Whitefish
- Sucker (var. spp)
RESULTS - 2017
RESULTS - 2017

Copeland and Meyer (2011)

Stream flow 3 & 4 years previous to sampling most important bioclimatic condition influencing Brook and Bull Trout densities in Idaho rivers
RESULTS - 2017

Fish densities fluctuate with river flow
Redband density $\uparrow$ with 3 years of higher flow and $\downarrow$ with 3 years of lower flow

- **NF Boise River**: $y = 0.001x + 0.555$, $R^2 = 0.9563$
- **MF Boise River**: $y = 0.0028x - 2.2204$, $R^2 = 0.7989$
RESULTS - 2018

The graph illustrates the fish density (fish/100m²) over different sample periods (years) for various fish species:

- **Wild Rainbow** indicated by yellow squares.
- **Bull Trout** indicated by black diamonds.
- **Mountain Whitefish** indicated by purple diamonds.
- **Sucker (var. spp)** indicated by orange circles.

The x-axis represents the sample period (years) ranging from 1988-1989 to 2018. The y-axis represents the fish density ranging from 0.0 to 4.5.
SF PAYETTE RIVER

Fish density (fish/100m²)

- **Wild Rainbow**
- **Mountain Whitefish**

Sample period (years)

- 1996
- 1997
- 2003
- 2004
- 2016
- Rain on snow in 1999
  - Several thousand years of sediment in 1 d
- Poor growth and productivity
- Sediment from recent fires
- Reduced minimum summer flow
- Flow shifts (Clark 2010)
  - During last 40 years,
    - 25 percentile has shifted 23 d
    - Min daily has declined by 24%
SF PAYETTE RIVER

Sample period (years)

Fish density (fish/100m²)

- Wild Rainbow
- Mountain Whitefish

Flow (ave. cfs three years prior to sampling)

Redband Trout density (fish/100m²)

y = 0.0016x - 0.784
R² = 0.6628
CONCLUSIONS

• Long term fish density trend data is an important population monitoring tool
  – Snorkeling remains most effective way to survey low conductivity rivers of Idaho Batholith
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  – Snorkeling remains most effective way to survey low conductivity rivers of Idaho Batholith

• Fish densities are influenced by flow patterns
  – “snapshot” sampling infrequently over time may not tell the whole story
  – Sampling in blocks across successive years is more adequate
CONCLUSIONS

• Long term fish density trend data is an important population monitoring tool
  – Snorkeling remains most effective way to survey low conductivity rivers of Idaho Batholith

• Fish densities are influenced by flow patterns
  – “snapshot” sampling infrequently over time may not tell the whole story
  – Sampling in blocks across successive years is more adequate

• Wild Redband populations in the NFBR appear stable
  – Will sample again in 2019