December 5, 2023

MEMORANDUM

TO: Council Members

FROM: Mark Fritsch

SUBJECT: Update on technical service contract Project #2017-002-00, Analysis of Spatial Stream Networks for Salmonids

BACKGROUND:

Presenter: Jody Lando - Research, Monitoring and Evaluation Lead for Bonneville Power Administration; and Dan Isaak, Research Fish Biologist for Rocky Mountain Research Station, U.S. Forest Service

Summary: Dan will provide a summary of work completed under contract with Bonneville, associated with Project #2017-002-00, Analysis of Spatial Stream Networks (SSN) for Salmonids (“FDAT”) a technical services contract¹ to develop linear networks for salmon densities using spatial statistics and GIS stream networks. This work was conducted by the US Forest Service Rocky Mountain Research division(s) NorthWest Stream Temperature (NorWeST) team with NOAA and Queensland University. The products from this exploratory effort intended to support tributary habitat restoration planning and support a proposed action commitment to monitoring temperature.

¹ Technical service contracts (TSC) are categorized as Bonneville Program Support (i.e., provide expertise and/or capacity to Bonneville staff) – A project that supports the (direct) Program but is not included in a Council recommendation or ISRP review.
Relevance: This work was designed to test novel methods of incorporating fish distribution monitoring data into updated fish distribution maps.

Workplan: 2023 Fish and Wildlife Division Work Plan; Program Planning and Coordination.

Background: This effort was developed in three phases.

- **Phase 1, 2018:** Develop linear networks and related web-tools for modeling salmonid density (carrying capacity) and habitat relationships relative to temperature, flow, and other covariates using Spatial Stream Networks (SSN) models and the National Hydrography Dataset Network. Working with United States Forest Services Rocky Mountain Research Center in partnership with Queensland University of Technology and the NOAA-NMFS Alaska Fisheries Science Center, Bonneville explored opportunities to aggregate and format fish monitoring data in an efficient interface, with tools to inform tributary habitat prioritization efforts, life cycle models, and fish trends information limited to the Grande Ronde River.

- **Phase 2, 2019:** Support Phase 2 development of the Fish Data Analysis Tools (FDAT) linear networks for salmon and steelhead. This phase included an expanded geographic scope (John Day, Salmon and Clearwater basins) and ODFW and IDFG sources of data with the goal of improving estimate precision.
  
  - **NorWeST Phase 2: FY 2021-22:** BPA funded a NorWeST temperature dataset update along with USFWS cost share to ensure Bonneville funded M&E was added to a stream temperature network update. The work provided estimates of winter lows and updated the existing data set from 2013 to include more recent data.

- **Phase 3, 2022-23:** additional FDAT development for salmon and steelhead, using a proposed exchange standard to support NOAA’s 2020 Biological Opinion terms and conditions to provide carrying capacity products to the Tributary Habitat Steering Committee to inform restoration planning and prioritization for Chinook salmon.

The result of this exploratory effort appears to be reliable and as such, could provide valuable data input to support tributary habitat restoration planning as well as a proposed action commitment to monitor stream temperature. For the future there may be opportunities to explore development of exchange processes to automate update of the FDAT and potentially coordinated with StreamNet. If this initiative is to be supported...
through the direct fish and wildlife program, staff recommends prioritization, and a project review and recommendation, as typical for a project like this.

More Info:

- [NorWest Stream Temperature- Regional Database and Model](#): This website hosts a comprehensive interagency stream temperature database and high resolution climate scenarios for the Northwest U.S.
NorWeST Stream Temperature Project
Updates & Applications With the Fish Density Analysis Tool (FDAT)

Dan Isaak, Erin Peterson, Jay VerHoef, Dave Nagel, Gwynne Chandler, Sharon Parkes, Sherry Wollrab, Dona Horan, and Will Dubois

Recent Funding:
December 13, 2023

Original Funding:
NorWeST’s Motivation: **Temperature is Destiny for Cold-Water Fish Species**

**Thermal controls on:**
- Metabolic rates & stress responses
- Foraging & migratory behaviors
- Distributions & abundance
- Phenology
- Life history expression
- Evolutionary trajectories

**Accurate, high-resolution information needed for project-level planning**

**Commonly used stream temp surrogates were imprecise**

![Graph showing correlation between stream temperature and other variables](image)

**I’m going to invest here...**

**...instead of here**
Miniature Sensors Made Stream Temperature Data Collection Easy 30 Years ago...

- >23,000 unique monitoring sites
- Dozens of agencies monitor stream temperatures in the West
Data ≠ Database, hence...

Data Aggregation

QA/QC Data Cleaning

Metadata & Digitally Archiving

Data Summaries & Georeferencing

Mean

Minimum

Maximum
NorWeST Database Enables Many Types of Stream Temperature Models for Multiple Purposes

Mechanistic models

Spatial-Statistical Network (SSN) Models: Ideal for large, spatially clustered datasets on stream networks

Statistical models

\[ Y_i = \beta_0 + \beta_1 X_i + \epsilon_i \]

Spatial statistical models that use flow and stream distance

Jay M. Ver Hoef · Erin Peterson · David Theobald

2006
High-Resolution Stream Temperature Scenarios

44 Historical & Future Scenarios


$r^2 = 0.91$

RMSPE = 1.10°C

MAPE = 0.72°C

1-km resolution
1,600,000 km of rivers & streams
NorWeST Website Distributes Temperature Datasets & Model Prediction Scenarios

Prediction scenario maps for NHD streamlines

NorWeST Website Distributes Temperature Datasets & Model Prediction Scenarios

Temperature data summaries

• ArcGIS shapefiles
• .pdf maps
• Excel file spreadsheets
• Dynamic mapping tools

Google “NorWeST stream temp” or https://www.fs.usda.gov/rm/boise/AWAE/projects/NorWeSTST.html

>300,000,000 hourly records
>23,000 unique stream sites
NorWeST Application: Determining Rates at Which PNW Rivers are Warming

Bonneville Dam Temperature Record

- n = 345 long-term river sites
- 1976–2015 trend: ~0.15–0.3 °C/decade
- Most warming: summer & fall

NorWeST Application:

Columbia River Coldwater Refuges Plan

NorWeST Application: Modeling Prespawn Mortality Rates in Chinook

NorWeST Application: Delineating Long-Term Climate Refugia for Native Trout Populations

Large trout occurrence datasets + NorWeST Application: Delineating Long-Term Climate Refugia for Native Trout Populations

Additional Covariates
1. Temperature (°C)
2. Patch slope (%)
3. Patch size (km)
4. Brook trout prevalence

Predictive Model
Response Curves

Streams with highest potential for population persistence

NorWeST 1.0 Had Some Limitations

- Database included temperature records only through 2011/2013 for PNW streams
- Most data were from summer rather than annual monitoring
- Modeled scenarios predicted only summer temperature metrics
NorWeST 2.0 Funded by BPA & USFS

Focus: Interior Columbia Basin areas accessible to anadromous fish

Objectives:
1) Aggregate, organize, & integrate new data into NorWeST database & post to website for public access

   ~75% of cost share

2) Analysis to create annual monthly scenarios for past & future climate conditions

   ~25% of cost share

Upper Columbia River Unit: Annual Thermal Cycle

New Scenarios Consist of:

- Predictions maps for 14 thermal metrics (12 months plus annual maximum & minimum)
- 44 different historical & future scenarios for each metric
- 1-km spatial resolution
- Available as ArcGIS shapefiles from website
NorWeST Datasets Have Facilitated Additional Modeling & Scenario Development Efforts

1) Annual monthly temperature scenarios for Pacific coast


2) Daily PNW stream temperature scenarios for 1990-2020

NorWeST Datasets Could Help Inform More Efficient Sampling Strategies

Simple awareness of when & where data exist

August monitoring sites

Interagency coordination

Formal sampling design strategies

PLOS ONE

SSNdesign—an R package for pseudo-Bayesian optimal and adaptive sampling designs on stream networks

Alan R. Pearse, James M. McGreg, Nicholas A. Som, Catherine Leight, Paul Maxwell, Jay M. Ver Hoef, Erin E. Peterson

Spatial sampling on streams: principles for inference on aquatic networks

Nicholas A. Som, Pascal Monestiez, Jay M. Ver Hoef, Dale L. Zimmerman and Erin E. Peterson
The Future of PNW Stream Temperature Monitoring

• It’s going to continue in significant ways

• Motivated by: climate change, need to understand the effects of habitat restoration, and unknowns regarding species’ thermal ecology

We could be more strategic & efficient

• Better coordination of monitoring efforts within & among agencies

• More timely aggregation & usage of data with customized webtools, semi-automated analyses, & a dedicated database team

• Default alternative: *ad hoc* approach characterized by periodic, opportunistic updates
SSN Models Applicable to More than Stream Temperature Data...

Distribution & abundance

Response Metrics
- Gaussian
- Poisson
- Binomial

eDNA/Genetic Attributes

Water Quality Parameters

Stream Temperature
Large Amounts of Fish Density & Occurrence Data Exist in PNW

Mims et al. 2018

eDNAAtlas ~30,000 sample results

Young et al. 2018

Quantifying biophysical relationships from reach-scale observations & extrapolating to networks requires models

~200,000 kilometers of fish-bearing streams in PNW

Fish Data Analysis Tool (FDAT) Capitalizes on These Datasets
**FDAT Example: Modeling Juvenile Chinook Salmon & Steelhead Densities**

**Data contributors (2000–2018)**

<table>
<thead>
<tr>
<th>Species</th>
<th>Data source</th>
<th>Unique stream sites</th>
<th>Site-years of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook salmon</td>
<td>ODFW</td>
<td>56</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>FDAT Phase 1 (CRITFC and ODFW)</td>
<td>131</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>IDFG</td>
<td>1594</td>
<td>5,556</td>
</tr>
<tr>
<td></td>
<td>IDFG - ISEMP</td>
<td>469</td>
<td>682</td>
</tr>
<tr>
<td></td>
<td>BioMark Kevin See</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>U.S. Forest Service(^a)</td>
<td>51</td>
<td>66</td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
<td></td>
<td><strong>2,307</strong></td>
<td><strong>6,757</strong></td>
</tr>
</tbody>
</table>

| Steelhead        | ODFW                                             | 161                 | 270                |
|                  | FDAT Phase 1 (CRITFC and ODFW)                   | 148                 | 366                |
|                  | IDFG                                             | 1,727               | 5,744              |
|                  | IDFG – ISEMP                                     | 657                 | 937                |
|                  | BioMark Kevin See                                | 21                  | 23                 |
|                  | U.S. Forest Service\(^a\)                        | 81                  | 96                 |
| **Totals:**      |                                                  | **2,797**           | **7,436**          |

\(^a\) Additional data from other sources not listed.
Juvenile Chinook Salmon & Steelhead Density Datasets

$n = 6,757$ surveys at 2,307 sites

$n = 7,436$ surveys at 2,797 sites
Potential Habitat Network Extent Delineation

1. StreamNet species reach layers matched to NHD+ reaches
2. Reaches extended upstream if fish data indicated upstream occurrence
3. CRITFC modifications within Grande Ronde basin

- **9,064 km potential habitat network (381 km not in StreamNet)**
- **18,064 km potential habitat network (580 km not in StreamNet)**
FDAT Project Modeling Steps for Juvenile Chinook and Steelhead Trout


Additional Covariates
1. Watershed condition
2. Stream flow (cfs)
3. Reach slope (%)
4. Riparian conifer (%)
5. Baseflow Index
6. Brook trout (%)

Juvenile density scenario maps

n ~ 7,000 density surveys

Density Model Response Curves
Predictive Accuracy of SSN Models for Juvenile Densities

$r^2 = 0.48$

$r^2 = 0.57$
Juvenile Chinook Salmon Density Map Scenario
(Scenario 1: Average densities for 2000–2018)
24 historical & future scenarios created
FDAT Application: Climate Sensitivity Analysis

S23 densities (+2°C)

Change in Density from Historical Period

# of Juvenile Chinook/100m

- < -15
- -5 to -15
- -5 to 5
- 5 to 15
- > 15

Chinook density (fish/100 m)

August stream temperature (°C)
FDAT Application: Population estimates & future trends by geographic areas

- 9,064 km network
- 35 population areas

Table 7. Population estimates and average densities of juvenile Chinook salmon by designated population areas for the baseline scenario (Scenario 1) and a future scenario representing a 2 °C increase in August stream temperatures (Scenario 23).

<table>
<thead>
<tr>
<th>Population area name</th>
<th>Habitat network length (km)</th>
<th>Scenario 1 average density (fish / 100 m)</th>
<th>Scenario 1 population estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asotin Creek</td>
<td>57.8</td>
<td>1.33</td>
<td>771</td>
</tr>
<tr>
<td>Bear Valley Creek</td>
<td>149</td>
<td>30.15</td>
<td>44,838</td>
</tr>
<tr>
<td>Big Creek</td>
<td>186</td>
<td>24.62</td>
<td>45,827</td>
</tr>
<tr>
<td>Big Sheep Creek</td>
<td>79.2</td>
<td>7.29</td>
<td>5,773</td>
</tr>
<tr>
<td>Camas Creek</td>
<td>138</td>
<td>3.54</td>
<td>4,896</td>
</tr>
<tr>
<td>Catherine Creek</td>
<td>214</td>
<td>36.72</td>
<td>78,441</td>
</tr>
<tr>
<td>Chamberlain Creek</td>
<td>241</td>
<td>25.68</td>
<td>61,788</td>
</tr>
<tr>
<td>East Fork Salmon River</td>
<td>151</td>
<td>9.37</td>
<td>14,136</td>
</tr>
<tr>
<td>East Fork South Fork Salmon River</td>
<td>174</td>
<td>25.87</td>
<td>44,929</td>
</tr>
</tbody>
</table>
FDAT Application: Comparison of FDAT Predicted Densities with Intrinsic Habitat Potential

Where are the differences greatest?
FDAT Datasets & Statistical Code are Available

- Density scenarios (24) at 250-m resolution available as ArcGIS shapefiles @ the StreamNet data store (https://app.streamnet.org/datastore_search_classic.cfm?id=775&keywords=fish%20data%20analysis%20tools)

- Observed juvenile steelhead & Chinook salmon densities at survey sites (ArcGIS shapefiles)

- Digital stream networks of potential habitat/observed occurrences for updating StreamNet species distributions (ArcGIS shapefiles)

- R code & SSN files to replicate analyses

- BPA report describing methods, results, & datasets with a peer-reviewed publication in development for 2024
Next FDAT Phase: Regional Expansion is Underway

**Major Objectives:**

1. Expand FDAT datasets & prediction scenarios for consistency throughout PNW anadromous streams
2. Develop pilot application with bull trout
3. Develop a consistent data exchange standard for reporting density information
FDAT Architecture Adaptable to Many Species Using Legacy Datasets or Recent eDNA Survey Results

**eDNAtlas ~30,000 sample results (& growing)**

**Guidance for refined field sampling campaigns**

**Many agencies**

**n = 3,143 Pacific lamprey results**

**Guidance for habitat restoration locations**

**Species distribution models and scenarios**

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

**Young et al. 2018**
Ultimate Goal: Better Information to Guide Restoration & Conservation Investments

Many options:
1) Improve riparian function & shade
2) Increase summer flow volumes
3) Restore channel complexity & floodplain connections
4) Minimize habitat fragmentation
5) Control invasive species

Where to do them?
How to maximize bang for the

Strategic Investing is Key
The End

Questions?
Applications Continue Growing...

Website bibliography listed 30 projects as of 2022

NorWeST data applications

Climate-shield cold-water refuges for native trout website: https://www.fs.fed.us/rm/boise/AWAE/projects/ClimateShield2019.html

The rangewide bull trout eDNA project website: https://www.fs.fed.us/rm/boise/rm/boise/AWAE/projects/BullTrout_eDNA.html


EcoAdapt. 2014. A climate change vulnerability assessment for resources of Nez-Percé Clearwater National Forests. Version 3.0. EcoAdapt, Bainbridge Island, WA.


