Let The River Run: Insights into Understanding the Klamath Basin

37th Annual Salmonid Restoration Conference

April 26, 2019

9:00am - 12:15pm

Session Coordinators:

Mike Belchik, Yurok Tribe
Cynthia Le Doux-Bloom, Hoopa Valley Tribe

The session will feature a range of insightful topics, including: (1). Klamath Estuary; (2). Baseline Data Analyses; (3). Application of Tribal Ecological Knowledge; (4). Effectiveness of Restoration Projects; and (5). Pre-dam removal through post-dam removal monitoring.

Presenters will include tribal, agency, and consultant biologists, academics conducting studies in the Klamath Basin, and member of the Klamath River Renewal Corporation.

Let The River Run: Insights into Understanding the Klamath Basin

Klamath River Renewal

Project Overview

Restoring the natural vitality of the Klamath River

KLAMATH RIVER RENEWAL CORPORATION

Presentation Overview

1. Background and KRRC Overview
2. Update on Progress of Dam Removal
   - Regulatory Schedule
   - Technical Studies
   - Procurement Process
3. Restoration Strategies
4. Next Steps
5. Questions

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1 – Background and KRRC Overview

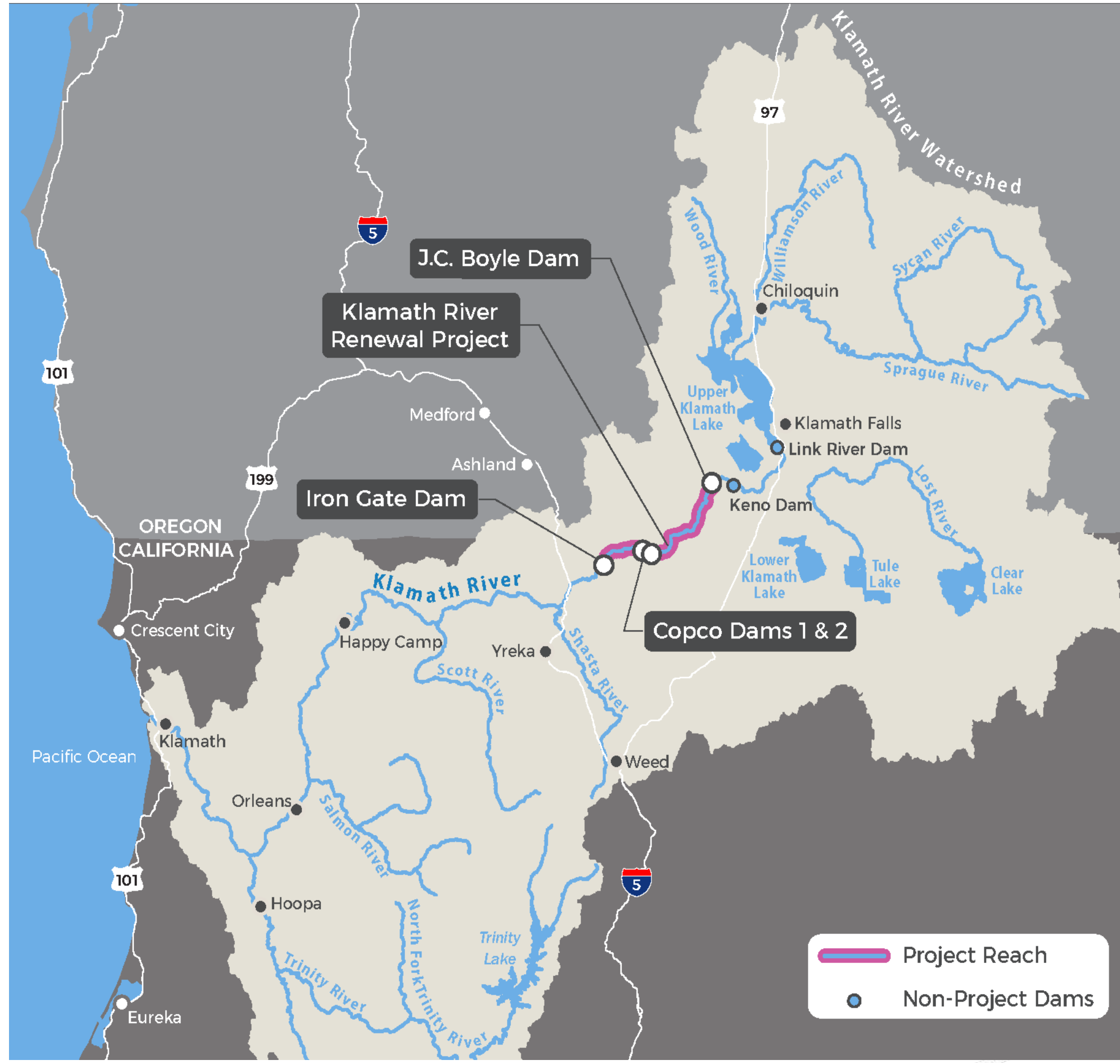
KLAMATH
RIVER RENEWAL
CORPORATION

Klamath River Renewal Corporation

JC Boyle, OR

Copco No. 1 & 2, CA

Iron Gate, CA



Klamath River Basin

Project Funds Available

- **PacifiCorp customer funds via PUC funding agreements**
  - **Oregon: $184M**
  - **California: $16M**

- **California Prop. 1 Bond Funds**
  - **Up to $250M**

Klamath River between JC Boyle Dam and Powerhouse



2 – Update on Progress of Dam Removal

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Regulatory Schedule

Milestone	Status klamathrenewal.org/regulatory
KRRC applications to FERC and States	• Submitted September 2016
FERC Transfer Application	• FERC's March 15, 2018 order split license and deferred decision on transfer • Responded to FERC's information requests • Convened Board of Consultants to provide peer review • Decision on transfer pending
FERC Surrender Application	• National Environmental Policy Act (NEPA): FERC has not yet initiated review • Decision on surrender pending

FERC/Board of Consultants Process	• July 29 Submittal to FERC
	    • Revisions to Definite Plan
	    • Updated Cost Estimate
	    • KRRC Fiscal Capacity - $450M+$1
	    • Risk Management Approach
	    • Insurance/Liability Transfer

CA Water Board & ODEQ Water Quality Certifications	• OR final certification released on Sept. 7, 2018 • CA draft certification released on June 7, 2018
KRRC Definite Plan sent to FERC	• Filed June 29, 2018
EIR under CEQA	• CA Water Board draft EIR released December 2018 • KRRC comments submitted February 26, 2019

Endangered Species Act (ESA) Consultation

- ESA Section 7 Consultation on Project Effects to ESA Species
- KRRC Technical Team leading Biological Assessment (BA) development
  - KRRC is in regular consultation with co-lead agencies
    - National Oceanic and Atmospheric Administration (NOAA) Fisheries
    - US Fish & Wildlife Service (USFWS)
  - BA expected in 2019
- NOAA and USFWS will issue a Biological Opinion (BO) on project effects and mitigation after NEPA process is complete

Tribal Consultations

Formal Consultations - AB 52

- CA Water Board leading the AB52 tribal consultation process as part of CEQA process
  - Agreed to tribal cultural resources mitigation under CA law

FERC/Yurok Consultation

Informal Consultation - Sec 106

- FERC designated KRRC and PacifiCorp as nonfederal representative
  - AECOM facilitating on their behalf
- Pursuant to Section 106 of the NHPA and Advisory Council regulations
- Conducting regular Tribal Caucus and Cultural Resources Working Group (CRWG) Meetings with federal and state agencies and eight Native American tribes
- Goals include definition of the Area of Potential Effects (APE) and preparation of cultural resources plans and agreement documents

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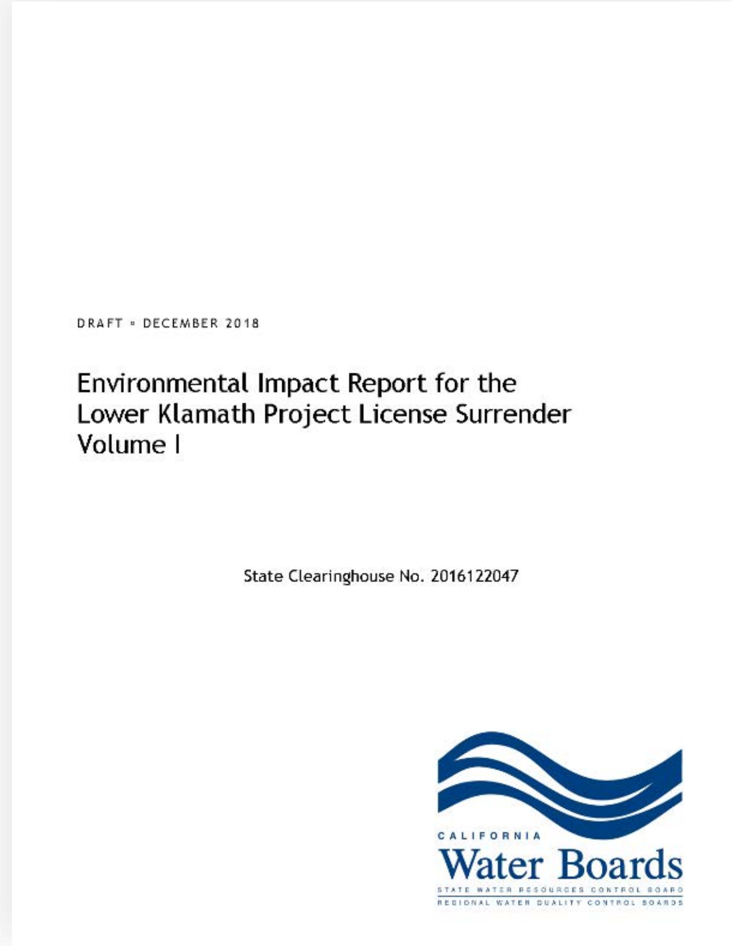
Technical Studies

- Draft Environmental Impact Report released Dec 2018; KRRC comments submitted Feb 2019
- Upcoming:
  - Continue field studies and technical assessments
  - Risk management: insurance and liability protections



DRAFT ▪ DECEMBER 2018

Environmental Impact Report for the
Lower Klamath Project License Surrender
Volume I

State Clearinghouse No. 2016122047

CALIFORNIA
Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

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Procurement Status

- ✓ **Definite Plan**
  - – Completed Definite Plan as basis for regulatory approvals and design-build contract
  - – Detailed methods for implementation, including deconstruction, mitigation, and risk management
- ✓ **Engagement of Progressive Design-Build (PDB) contractor**
  - – Issued Request for Qualifications (RFQ) for PDB contractor for dam removal
  - – Issued Request for Proposals (RFP) to three finalists
  - – Selected Dam Removal contractor
- ✓ **Insurance**
  - – Developed comprehensive insurance approach to dam removal project
  - – Identified new indemnification options to optimize use of Liability Transfer Corporation (LTC)
  - – Anticipate selecting LTC in 2019
- ✓ **Preparation for mitigation after dam removal**
  - – Selected contractor for native seed collection – Pacific Coast Seed and Mid Klamath Watershed Council
  - – Selected contractor for construction of vegetation test plots - Hanford ARC
  - – Selected contractor for native seed propagation – Benson Farms and S&S Seeds

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3 – Restoration Strategies

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Primary Work Components/Categories

Related to Aquatic Resources

1. City of Yreka Intake and Pipeline Replacement
2. Temporary Construction Access Improvements
3. Permanent Road and Bridge Improvements
4. Downstream Flood Control Improvements
5. **Hatchery Modifications**
6. **Dam Modifications**
7. **Dam and Hydropower Facility Removal**
8. **Reservoir Restoration**
9. **Recreation Plan and Restoration**

General Construction Progression

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5. Hatchery Modifications

Iron Gate Hatchery

- Will continue operations for Chinook smolt
- Riparian water right on Bogus Creek will be registered
- Bogus Creek water diversion will be evaluated under CEQA and in consultation with NMFS and CDFW
- Water supply modifications would occur on the current hatchery footprint

Fall Creek Hatchery

- Will reopen for Coho and Chinook yearling production
- New circular tanks in the current hatchery footprint
- New settling pond and discharge point for Fall Creek is being evaluated

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6. Dam Modification

Modify dam infrastructure to allow for full reservoir drawdown

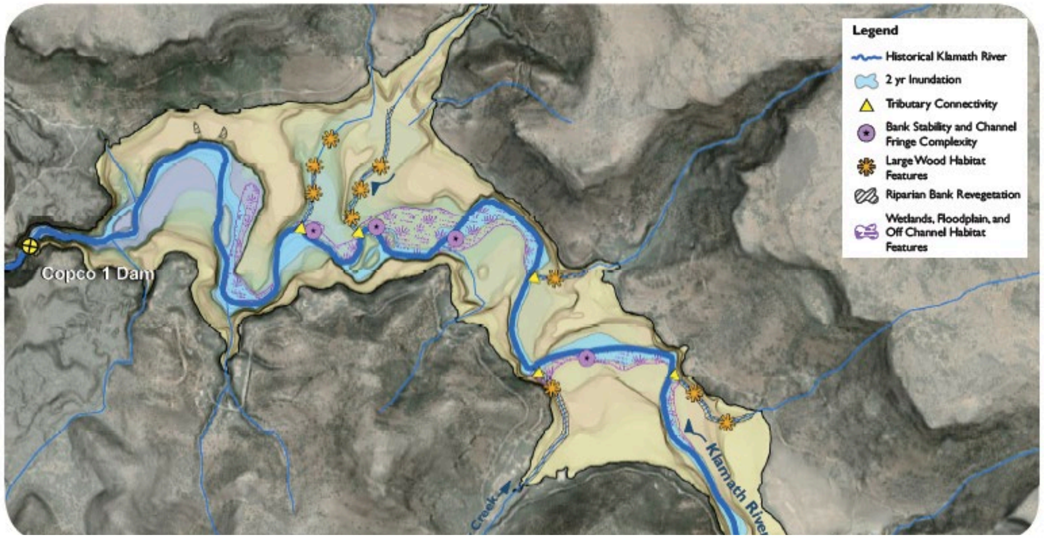
- Removal of sediment
- Demolition of existing gates
- Installation of new gates at Iron Gate and Copco No. 1 diversion tunnels

7. Dam and Hydropower Facility Removal

- Controlled release using modified infrastructure (January 1 start)
- Drawdown to tunnel inverts by March 15
- Full dam and hydropower facility removal

8. Reservoir Stabilization

- Stabilize remaining accumulated reservoir sediments (as appropriate)
- Fully restore reservoir areas to native habitats
- Monitoring and adaptive management



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9. Recreation Plan and Restoration

- New and enhanced recreation facilities to mitigate for impact to year-round Hell's Corner rafting corridor
- Developing Recreation Plan through stakeholder process
- Plan may include additional boating and fishing access and other new recreation features
- Will restore reservoir recreation areas to native habitats

10. Aquatic Resource Measures

- Measures to reduce dam removal-related effects on aquatic resources
- **AR-1 Mainstem spawning**
- **AR-2 Juvenile outmigration**
- **AR-6 Sucker relocation**
- **AR-7 Freshwater mussel relocation**

AR-1 Mainstem Spawning

- Monitor and remove sediment/debris from tributary confluences in Hydroelectric Reach and downstream from Iron Gate
- Complete spawning habitat surveys and augment spawning habitat as needed – November 2019

AR-2 Juvenile Outmigration

- Salvage yearling coho salmon from Klamath River – December 2020
- Monitor tributary conditions and salvage juveniles if turbidity and water temps exceed thresholds – 2021-2022
- Monitor and remove sediment/debris from tributary confluences in Hydroelectric Reach and downstream from Iron Gate – start in 2021

AR-6 Sucker Relocation

- Currently sampling to characterize demographics, genetics, and relative abundance – completed sampling in fall 2018, spring 2019
- Continue sampling in fall 2019, spring 2020
- Salvage Lost River and shortnose suckers and relocate to isolated water body per USFWS directive – fall 2020

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AR-7 Freshwater Mussels

- Determine taxa and current distribution downstream from Iron Gate Dam – May 2019
- Assess potential relocation habitats in the Hydroelectric Reach and in the vicinity of Klamath River-Trinity River confluence – May 2019
- Salvage and relocate mussels prior to dam removal – Fall 2020

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Aquatic Resources Data Collection

- Before Dam Removal
  - Sampling and salvage – suckers, freshwater mussels, juvenile salmonids
  - Observation and modification – tributary confluences, tributary spawning habitat
- After Dam Removal
  - Observation and modification – tributary confluences, mainstem spawning habitat

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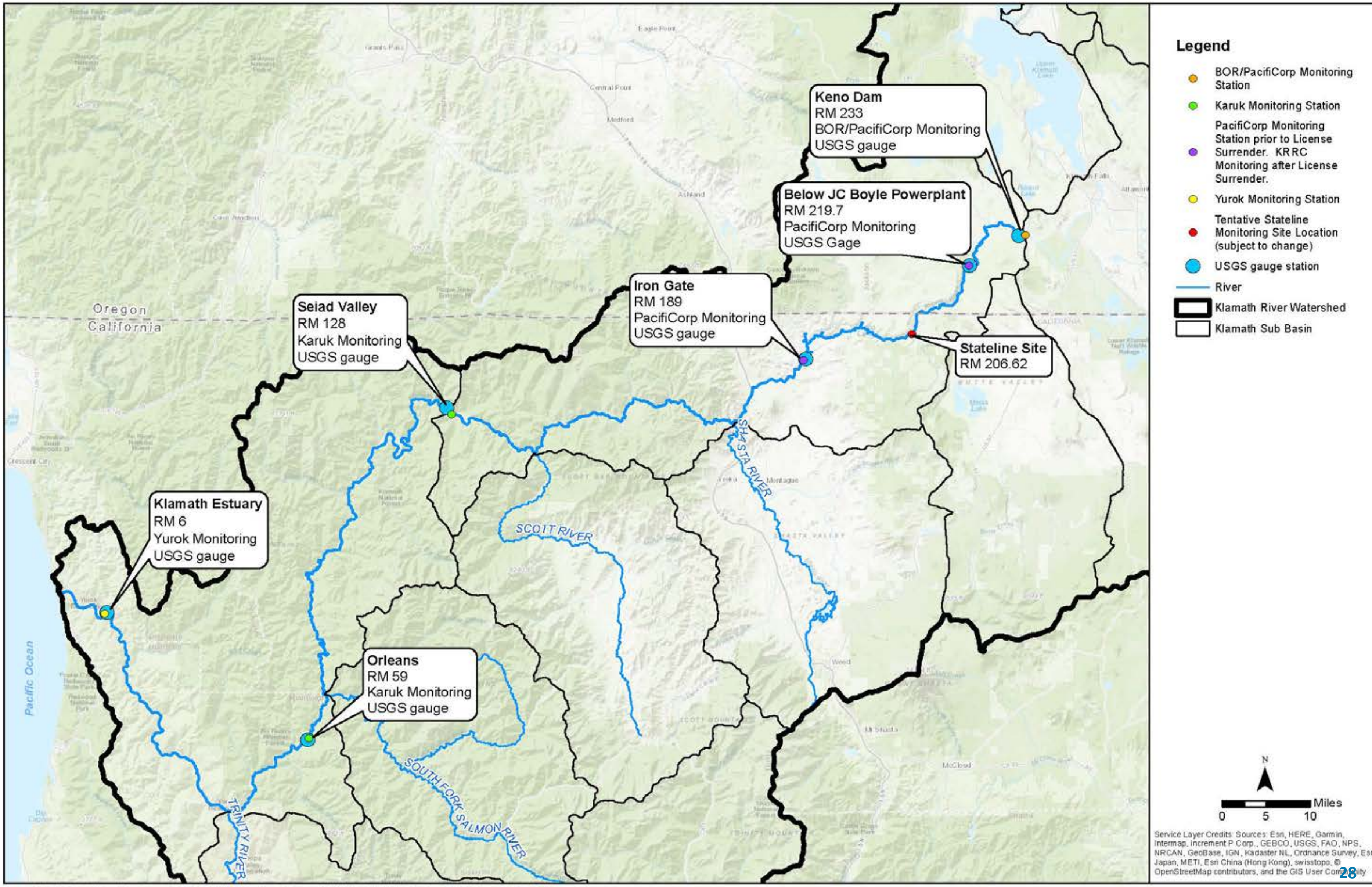
Water Quality Data Collection





4 – Next Steps

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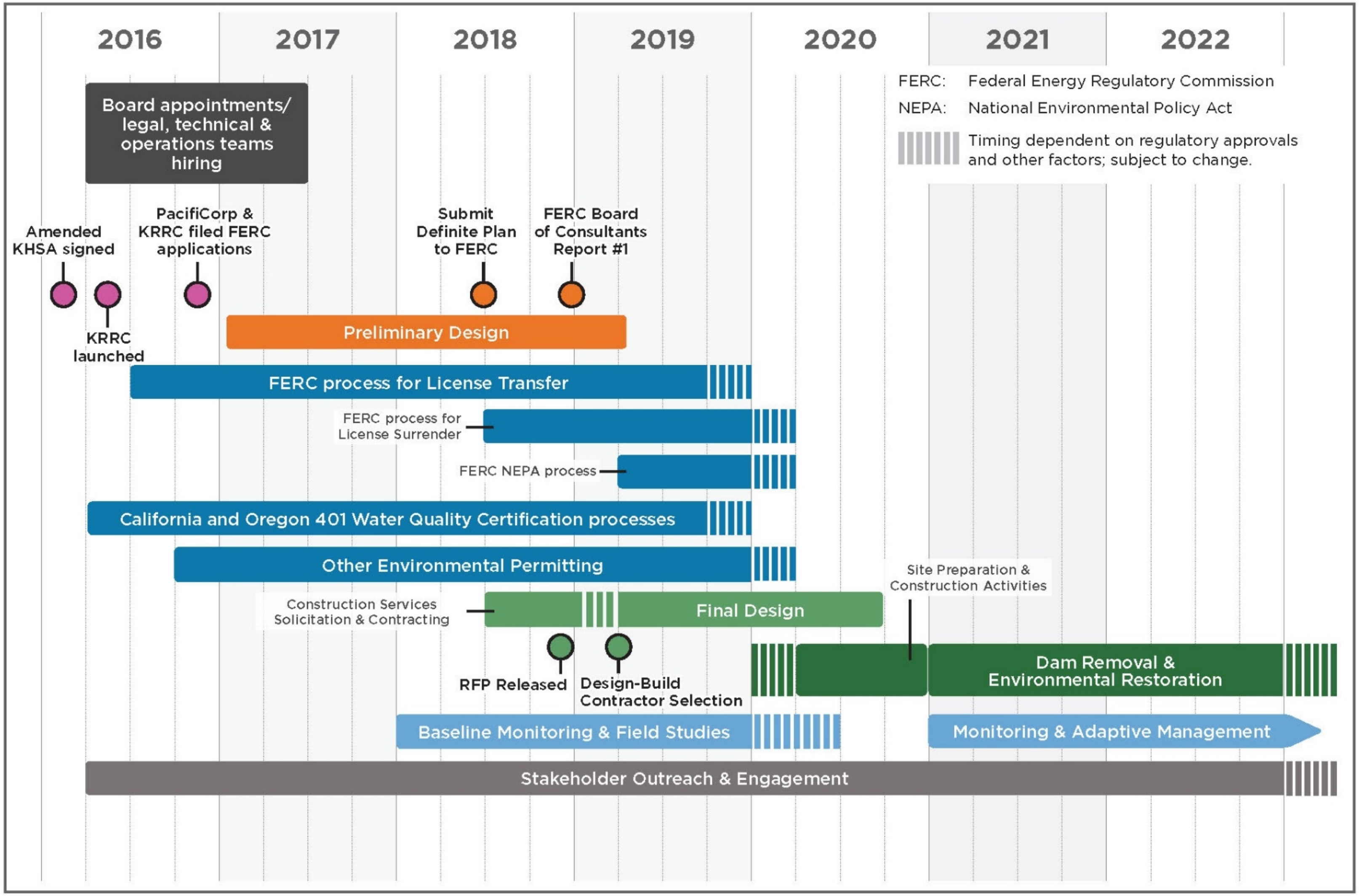
Next Steps

- Contractor begins preliminary work – May 2019
- Submit revised Definite Plan to FERC and Board of Consultants – July 29, 2019
- Respond to any further FERC AIR's and/or recommendations from BOC in future reports
- Spring 2019 sucker sampling reporting – May/June 2019
- Freshwater Mussel sampling – May/June 2019
- Tributary spawning habitat surveys – November 2019
- Yearling Coho sampling – December 2019
- Submit Clean Water Act Sec. 404 Application to Army Corps of Engineers - 2019

Anticipated Project Timeline



As of February 2019

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5 – Questions

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Thank you!

Mark Bransom, Chief Executive Officer
mark@klamathrenewal.org

Additional Slides

KRRC Board of Directors

State of California

- Lester Snow, *President*
- Leon Szeptycki, *Secretary/Treasurer*
- Michael Barr
- Ricardo Cano
- Nancy Vogel

State of Oregon

- Jim Root, *Vice President*
- Michael Carrier
- Theodore (Ted) Kulongoski
- Krystyna Wolniakowski

Karuk Tribe

- Wendy (Poppy) Ferris-George

Yurok Tribe

- Scott Williams

Non-Governmental

- Laura Rose Day
- Thomas (Tom) Jensen
- Brian Johnson

klamathrenewal.org/about-the-krrc/leadership/

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Signatories of the Amended KHSA

As of December 31, 2016

1. Department of the Interior
2. NOAA Fisheries
3. PacifiCorp
4. California Governor
5. Oregon Governor
6. California Fish and Wildlife
7. California Natural Resources Agency
8. Oregon Department of Environmental Quality
9. Oregon Department of Fish and Wildlife Department
10. Oregon Department of Water Resources
11. Yurok Tribe
12. Karuk Tribe
13. Humboldt County
14. American Rivers
15. California Trout
16. Pacific Coast Federation of Fishermen's Associations
17. Institute for Fisheries Resources
18. Federation of Fly Fishers
19. Trout Unlimited
20. Sustainable Northwest
21. Klamath River Renewal Corporation
22. Salmon River Restoration Council
23. Upper Klamath Water Users Association

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Yurok Tribe

Pre-Dam Removal Topographic Base-Line Data Collection on the Klamath River Collaboration In Action

Salmon Restoration Federation (SRF) Conference

April 26th, 2019

David (DJ) Bandrowski P.E. - Yurok Tribe

Jenny Curtis – USGS

Tony Jackson, PLS - USACE

What Does SRF 2016 and 2019 Have in Common?

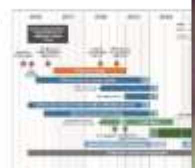
CONTRACTOR CHOSEN FOR REMOVAL OF KLAMATH RIVER DAMS

The long-term project to remove a number of the Klamath River's hydroelectric dams has entered its next major stage.

Posted: Apr. 25, 2019 3:49 PM
Posted By: Jamie Parfitt

KLAMATH FALLS, Ore. — The project to see four dams removed from along the Klamath River just entered a new phase, with the Klamath R[...] Renewal Corporation (KRRC) choosing a contractor to accomplish the task.

The Klamath River restoration project is one of the biggest dam removal in the world so far, particularly in terms of price tag.



According to KRRC, contractor Kiewit Infrastructure West Co. out of Fairfield, California has been awarded $18.1 million for "preliminary services," and will be granted more funds once they accomplish the project's design.

"Selecting Kiewit marks another key achievement and brings KRRC closer to completing the largest dam removal and river restoration project in U.S. history," said Mark Bransom, KRRC Chief Executive Officer. "Once implemented, the project will help restore the vitality of the Klamath River so that it can support all communities in the basin."

Kiewit recently completed emergency reconstruction of the Oroville Dam spillway in Butte County, California — the same area ravaged by the Camp Fire in 2018. Previously, the dam had repeatedly failed to meet regulator's safety standards. It began releasing water again in March of this year.

The April 6, 2016 signing ceremony in Requa, CA included chairmen of the Yurok, Karuk and Klamath Tribes, Governors of CA and OR and the U.S. Secretary of the Interior. Photo: Mark Lovelace.

The Washington Post

Business

States, federal agencies will seek removal of Klamath dams

By Jonathan J. Cooper | AP April 4

SACRAMENTO, Calif. — Oregon, California, the federal government and others have agreed to go forward with a plan to remove four hydroelectric dams in the Pacific Northwest without approval from a reluctant Congress, a spokesman for dam owner PacifiCorp said Monday.

The dam removal is part of an announcement planned Wednesday in Klamath, California, by the governors of both states and U.S. Interior Secretary Sally Jewell.

KLAMATH RIVER TOPOGRAPHIC BASE-LINE DATA COLLECTION

- **PROJECTS OVERALL GOAL AND OBJECTIVE:**

THE GOAL OF THIS ENTIRE PROJECT IS TO HAVE A PRE-DAM REMOVAL FOUNDATIONAL DATA SET THAT MANAGEMENT AND THE SCIENTIFIC COMMUNITY WILL BE ABLE TO UTILIZE TO BETTER UNDERSTAND THE EFFECTS OF DAM REMOVAL, TO BE ABLE TO MORE QUANTITATIVELY MEASURE GEOMORPHIC EVOLUTION, AND TO BE BETTER EQUIPPED TO MONITOR THE BIOLOGICAL AND PHYSICAL RESPONSE OF A NEW FREE FLOWING KLAMATH RIVER

Background - Why the Need for Baseline Data Collection

The Elwha River flows into the Strait of Juan de Fuca, carrying sediment once trapped behind dams. The gradual release has rebuilt riverbanks and created estuary habitat for Dungeness crabs, clams, and other species.

PHOTOGRAPH BY ELAINE THOMPSON, ASSOCIATED PRESS

World's Largest Dam Removal Unleashes U.S. River After Century of Electric Production

As Washington State's Elwha River runs free, a habitat for fish and wildlife is restored.

8 MINUTE READ

BY **MICHELLE NIJHUIS**, FOR NATIONAL GEOGRAPHIC

Project Implementation Schedule

- **Planning and Funding Development**
  - *2016-2018*
  - *Various Agencies and Organizations*

- **Pre-Project Data Collection and Reconnaissance:**
  - *Control Point Establishment (NGS, Caltrans, etc.)*
  - *Re-occupation in the Klamath River Corridor (Hwy 96 and 169)*
  - *New Control Development from Weitchpec to Hwy 101*
  - *Caltrans and Bureau of Reclamation*

- **Phase I – Aerial Imagery and Airborne Topo-Bathy LiDAR**
  - *Collection: June 2018*
  - *From the Estuary to Klamath Lake + Some Tributaries*
  - *Funding from: USGS; NOAA; KRRC;*
  - *Contract with USGS – 3D Elevation Program (3DEP)*
  - *Data Collection Performed by: Quantum Spatial Inc (QSI)*

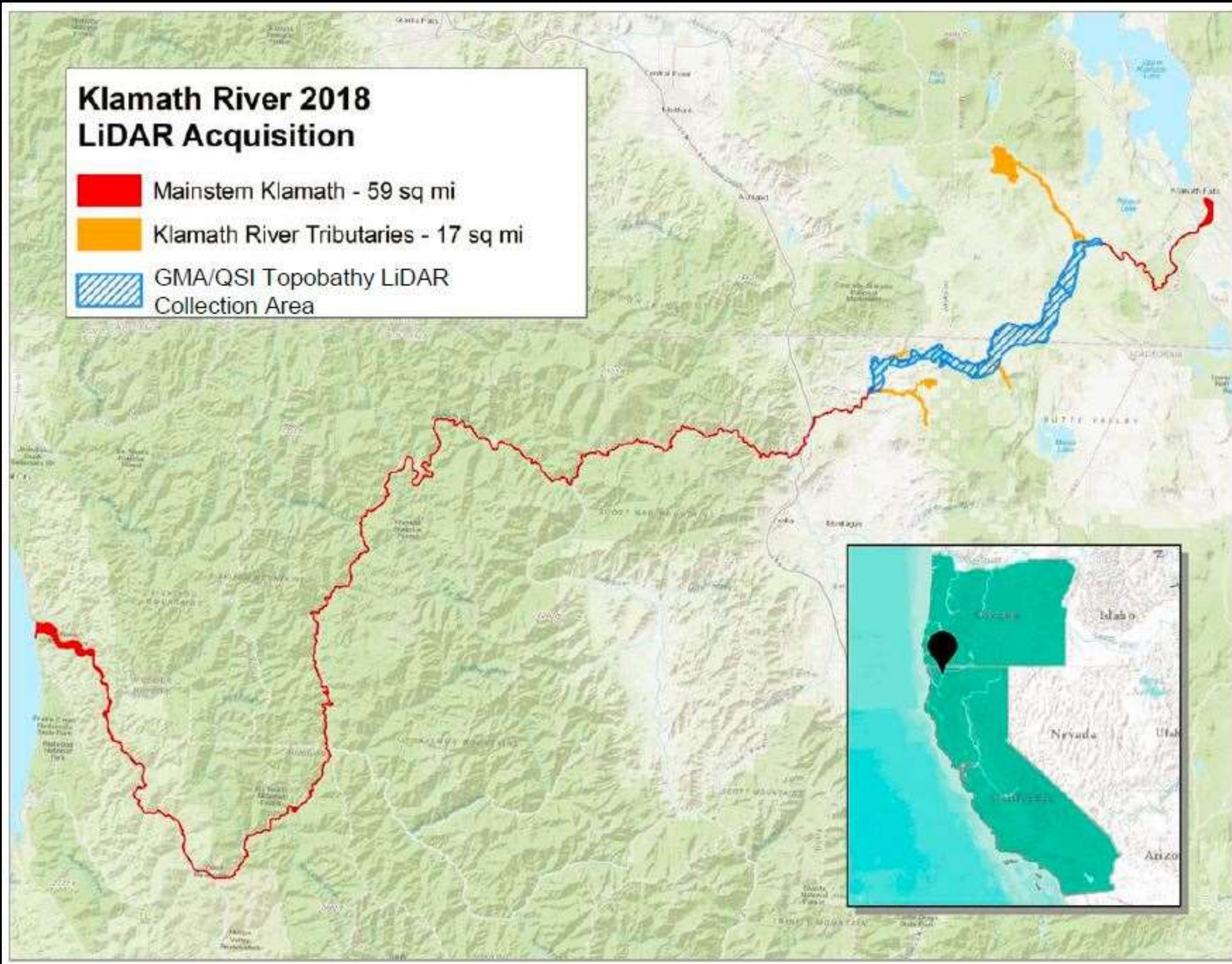
Project Implementation Schedule - Continued

- **Phase II – Boat-based Hydrographic Sonar Surveys**
  - *July – September 2018*
  - *190 Miles (Estuary to Iron Gate Dam)*
  - *Yurok Tribe, Hewlett Foundation, and*
  - *US Army Corps of Engineers (USACE) - Engineering Research and Development Center (ERDC)*

- **Phase III – Data Processing and Analysis**
  - *Stitching of the Airborne and Boat Based Data Together*
  - *Validation and Calibration of the Two Data Sets*
  - *Final Digital Elevation Model (DEM) of the Klamath Full River*
  - *TBD – Anticipated by February 2019*

- **Phase IV – 2D-Hydrodynamic Model of Existing Conditions**
  - *Approximately February through May 2019*
  - *Bureau of Reclamation – Sedimentation and River Hydraulics (SRH) Team out of the BOR Denver Technical Service Center (TSC)*

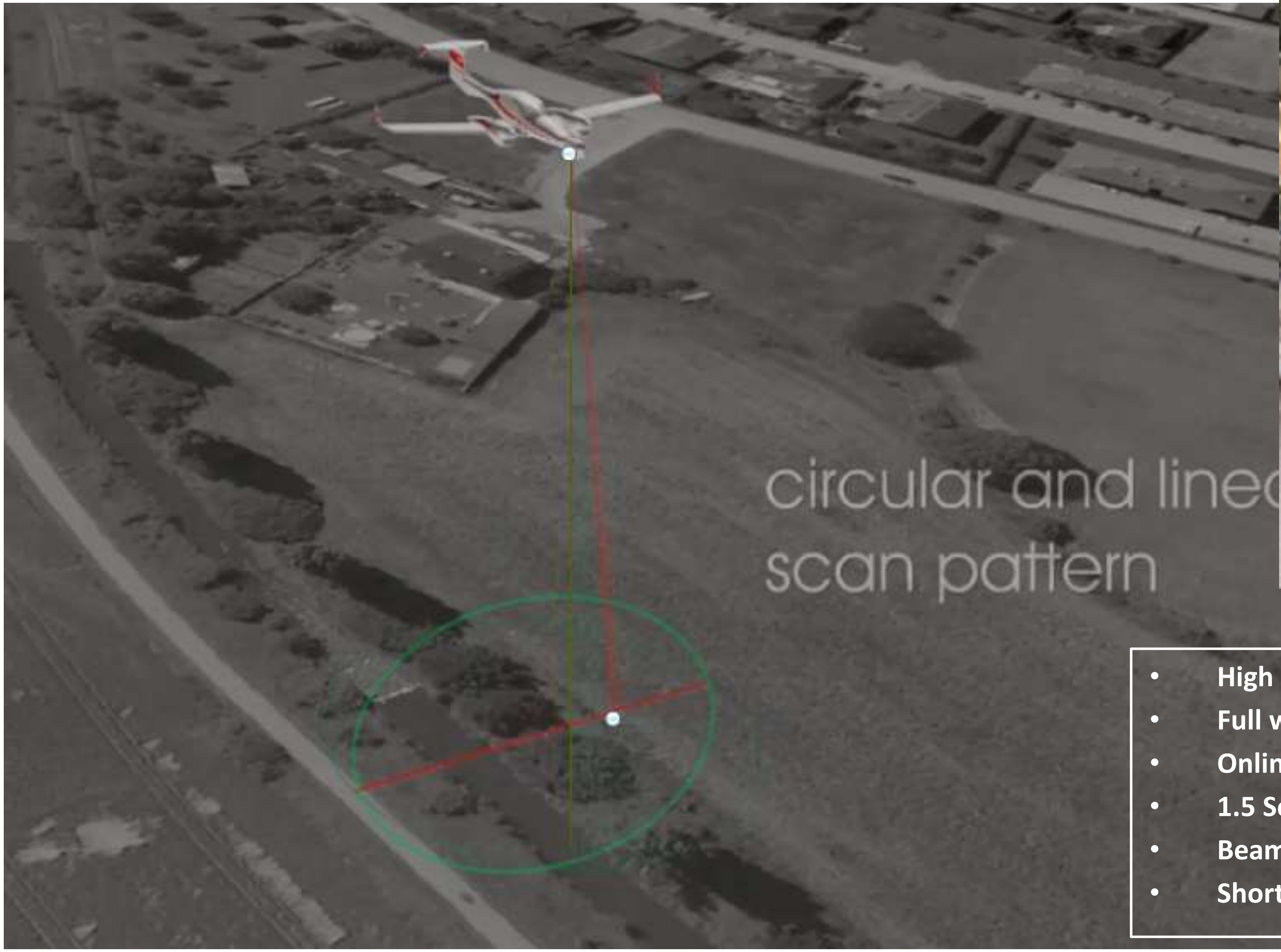
AIRBORNE DATA COLLECTION – MAP



Project Highlights and Specifications – Topobathy LiDAR

- **Acquisition Area**: 40,908 contracted acres; 45,744 buffered acres (by 25m)
  - Mainstem: 30,250 contracted Acres; 34,376 buffered acres
  - Tributaries (4 AOIs): 10,658 contracted acres; 11,368 buffered acres
- Reigl 880 Topobathy LiDAR Sensor, capable of measuring 1.5 Secchi depths
- Co-housed green and NIR lasers
- Helicopter-mounted with ABGPS/IMU
- For submerged topobathy LiDAR: Aggregate Nominal Pulse Spacing (ANPS) of 0.70 meters (2 pulses/m^2) … QL2
- For topographic LiDAR: ANPS of 0.35 meters (8 pulses/m^2) … QL1
- Average Flight Altitude: 400 m AGL
- Field of View = 40°; Side lap of 30%
- Acquisition: June 1-14, 2018
- 433 Flight Lines anticipated (1,453 nm)
- Project Spatial Reference System: UTM Zone 10, NAD83(2011), Meters
NAVD88, Geoid 12B, Meters

Topo-bathymetric Sensor



- High Pulse Rate (up to 550 kHz)
- Full waveform capable
- Online waveform digitizing
- 1.5 Secchi Depth “depth rating”
- Beam divergence
- Short pulse length


N383SH


RIEGL

Project Deliverables – LiDAR

Topographic-Bathymetric Point Cloud Classes (LAS Version 1.4)	
Class 1	Processed, but unclassified
Class 2	Bare-earth ground
Class 3	**Low Vegetation**
Class 4	**Medium Vegetation**
Class 5	**High Vegetation**
Class 7	Low Noise (low, manually identified, if necessary)
Class 9	NIR points classified as water
Class 18	High Noise (high, manually identified, if necessary)
Class 40	Bathymetric Point, Submerged Topography
Class 41	Water Surface
Class 45	Neither surface nor bottom

Note: Classes 7 & 18 are included as a convenience. It is **not** required that all "noise" be assigned to those Classes.

Project Highlights and Specifications - Imagery

- **Imagery Area**: 48,318 contracted acres; 53,957 buffered acres (by 25m)
  - Mainstem: 37,660 contracted Acres; 42,589 buffered acres
  - Tributaries (4 AOIs): 10,658 contracted acres; 11,368 buffered acres
- 4-band (R,G,B,NIR); 0.15 meter GSD
- ABGPS/IMU with Statistical Reports summarizing adjustments & accuracy
- No voids; Leaf-on; Cloud, cloud shadow, smoke, & haze-free
- No snow; non-flood conditions; no tide restrictions
- ≤ 30º sun angle; 60% Forward lap & 40% Side lap
- Acquisition Window: June 8-13 (all but 3 coastal lines), and June 23, 2018
- 63 Flight Lines anticipated, with 1,700 exposures
- 0.15-meter Orthoimage horizontal positional accuracy ≤ 0.76m NSSDA 95% confidence (0.44 RMSE) Error XY (0.30 m RMSE X or Y)
- Flight Diagram (flight lines, project boundary, image centers & IDs)
- Horizontal Spatial Reference System: UTM Zone 10, NAD83(2011), Meters

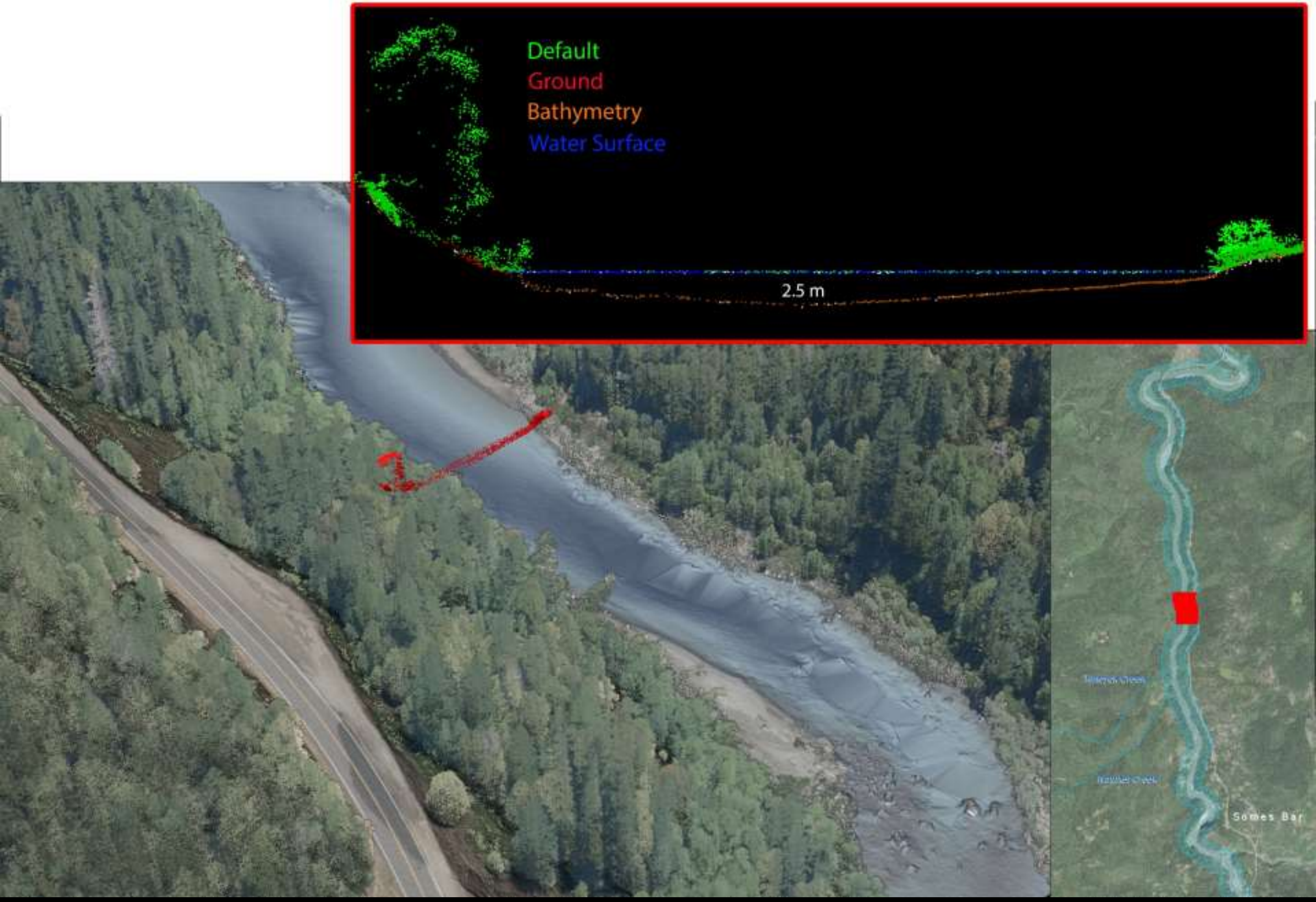
KLAMATH RIVER MOUTH – SONAR SURVEYS

Klamath River – Boat Based Sonar

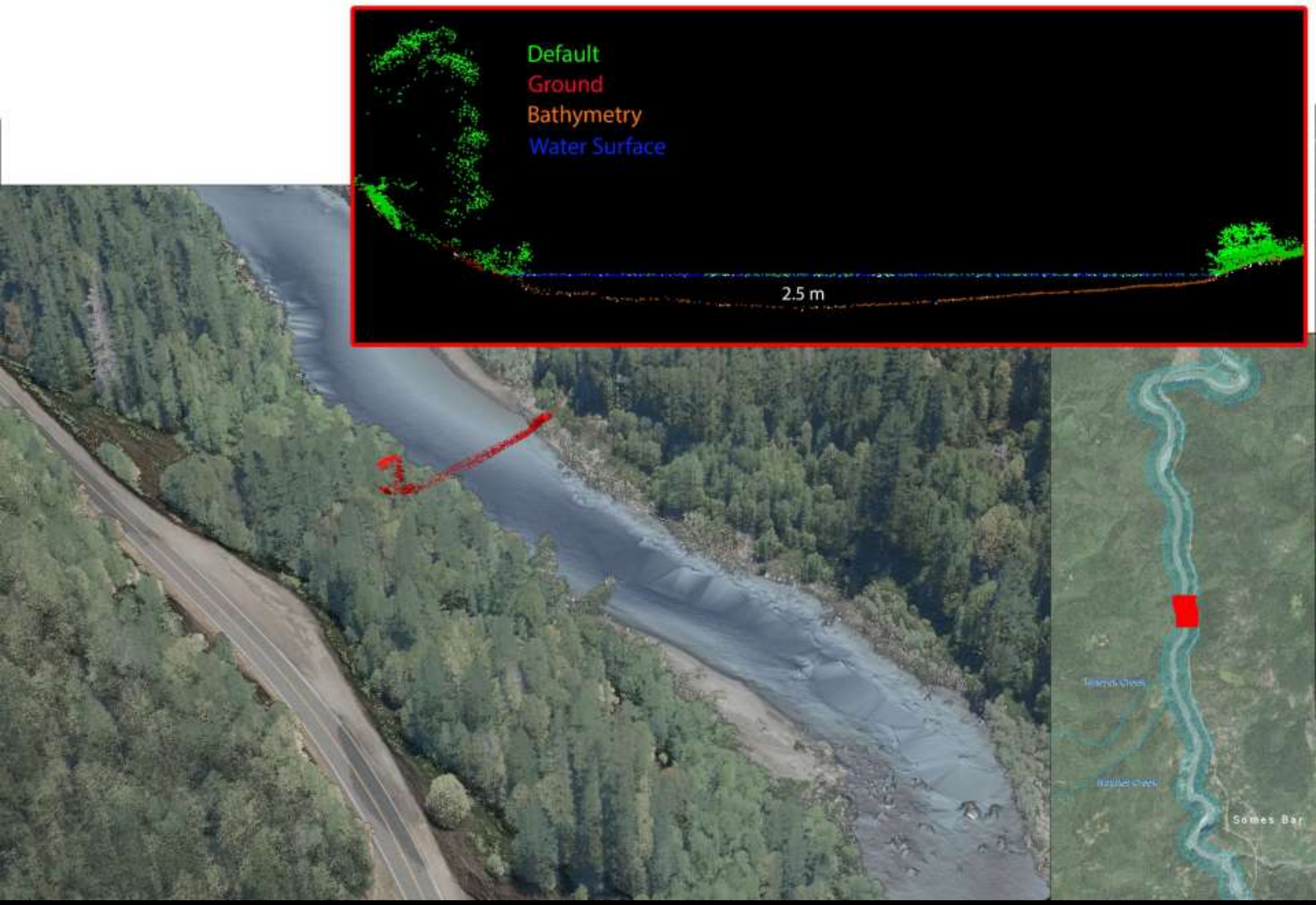
- **US Army Corps of Engineers - ERDC**
    - The instrumentation used was an ISS, or integrated survey system consisting of an Applanix POS MV inertial motion unit
    - Geoswath Plus 500 KHz multibeam echosounder, and a Velodyne 32E LIDAR system.
    - Each is fed through a hub to a single collection computer running Hypack Hysweep navigation and collection software and post-processed using Hypack MBMax processing software
    - Trajectory files from the vessel mounted POS MV IMU and files from a series of Trimble R8 GNSS base receivers collecting simultaneously on existing monuments during the survey are post processed using Applanix PosPac software.

Example Data Sets – Klamath River LiDAR Data Collection

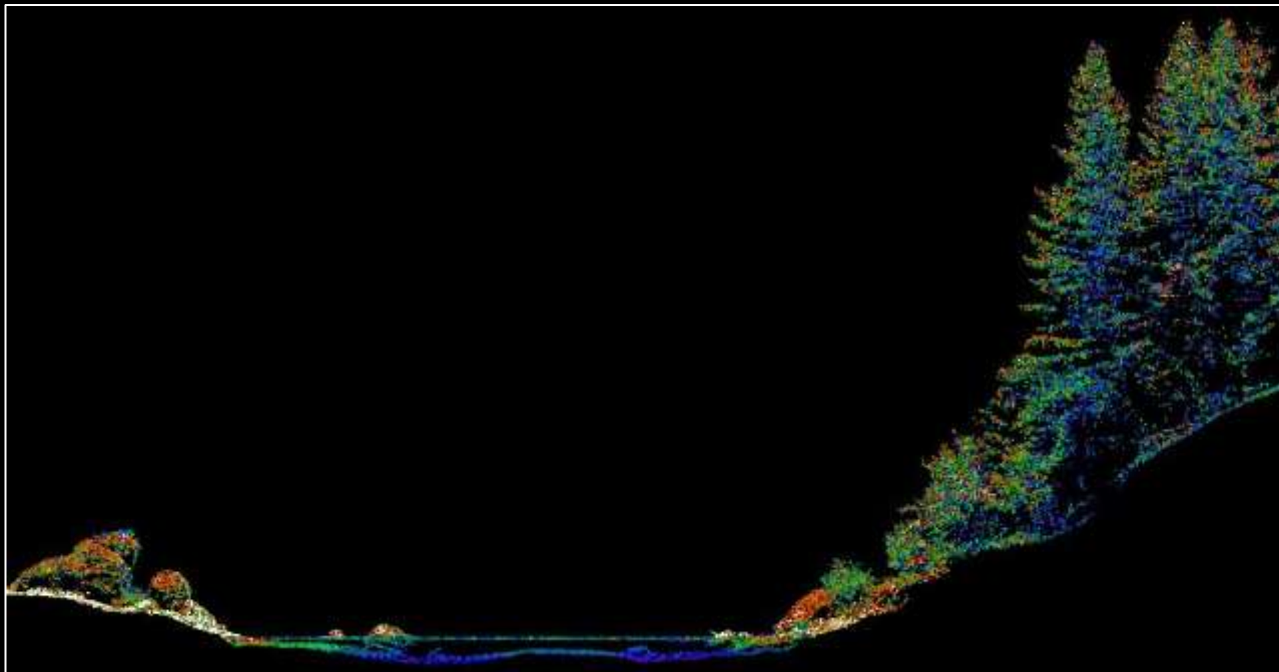
Example Data Sets – Klamath River LiDAR Data Collection

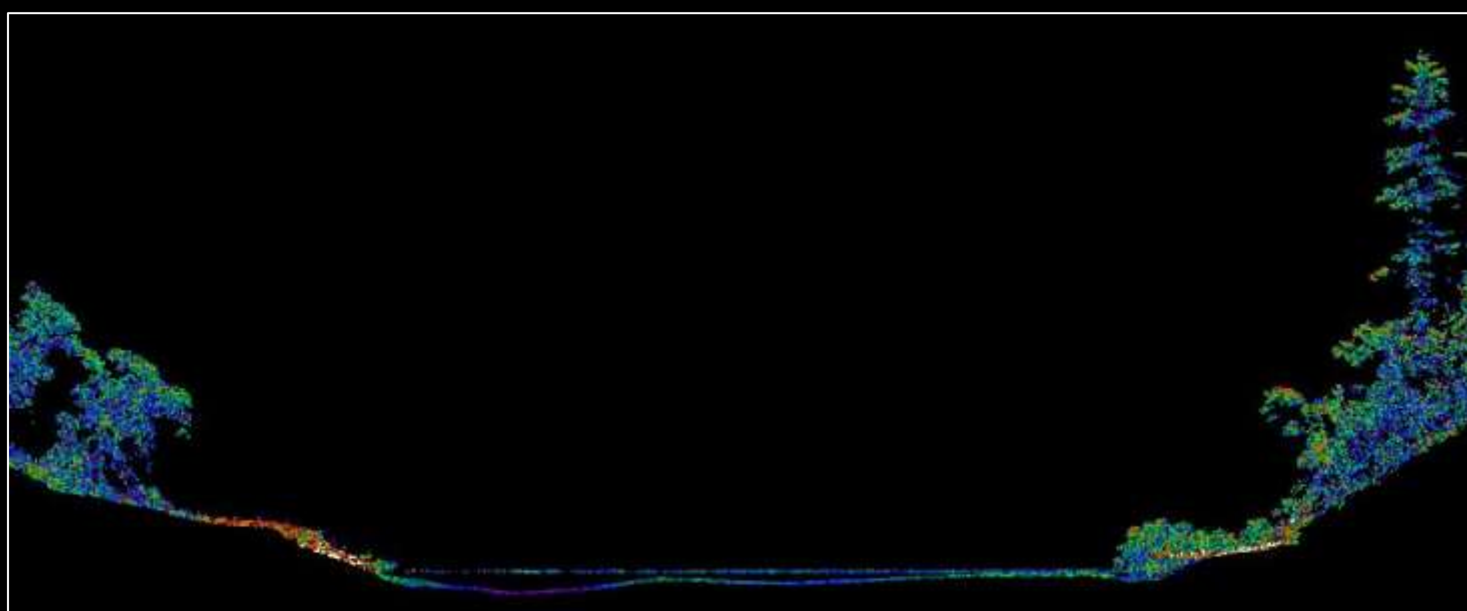


EXAMPLE DATA SETS – KLAMATH RIVER LiDAR DATA COLLECTION

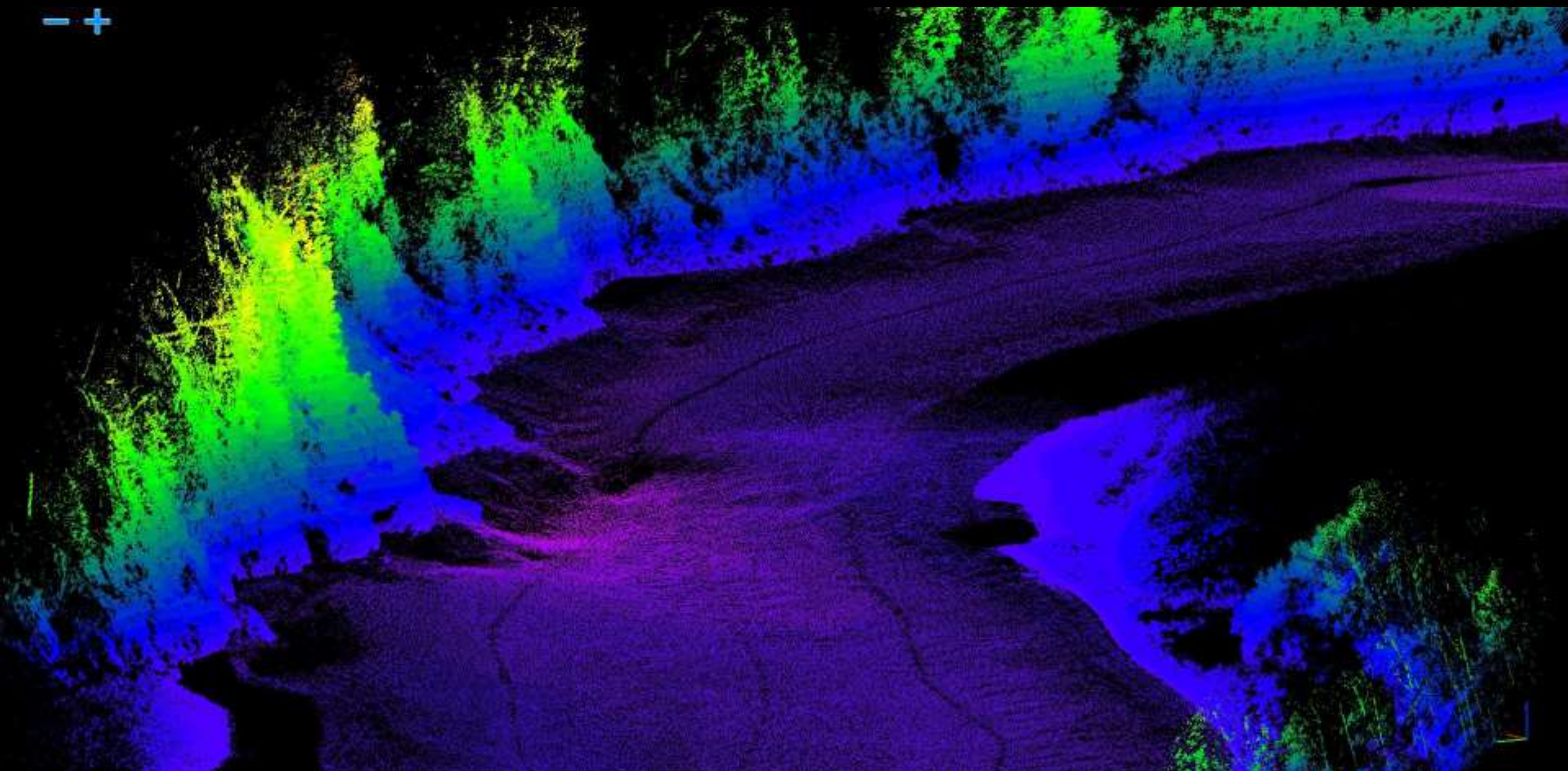


Example Data Sets – Klamath River LiDAR Data Collection





KLAMATH RIVER BOAT BASED MULTI-BEAM SONAR DATA COLLECTION



2D Hydrodynamic Flow Model Development

RECLAMATION

Managing Water in the West

Trinity River 40 Mile Hydraulic Model: Update with 2016 Topography

Technical Service Center
Sedimentation and River Hydraulics Group
Technical Report No. SRH-2018-11

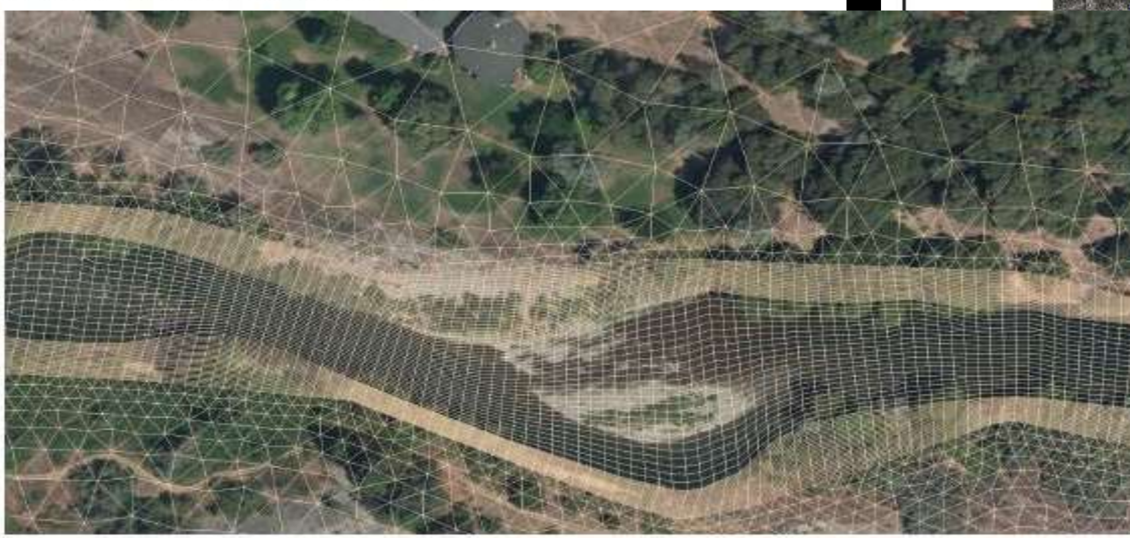


Figure 1. The new model mesh showing the bands of smaller mesh elements along the channel margins at the upstream end of Chapman Ranch, near Roundhouse.

U.S. Department of the Interior
Bureau of Reclamation
Sedimentation and River Hydraulics

March, 2018

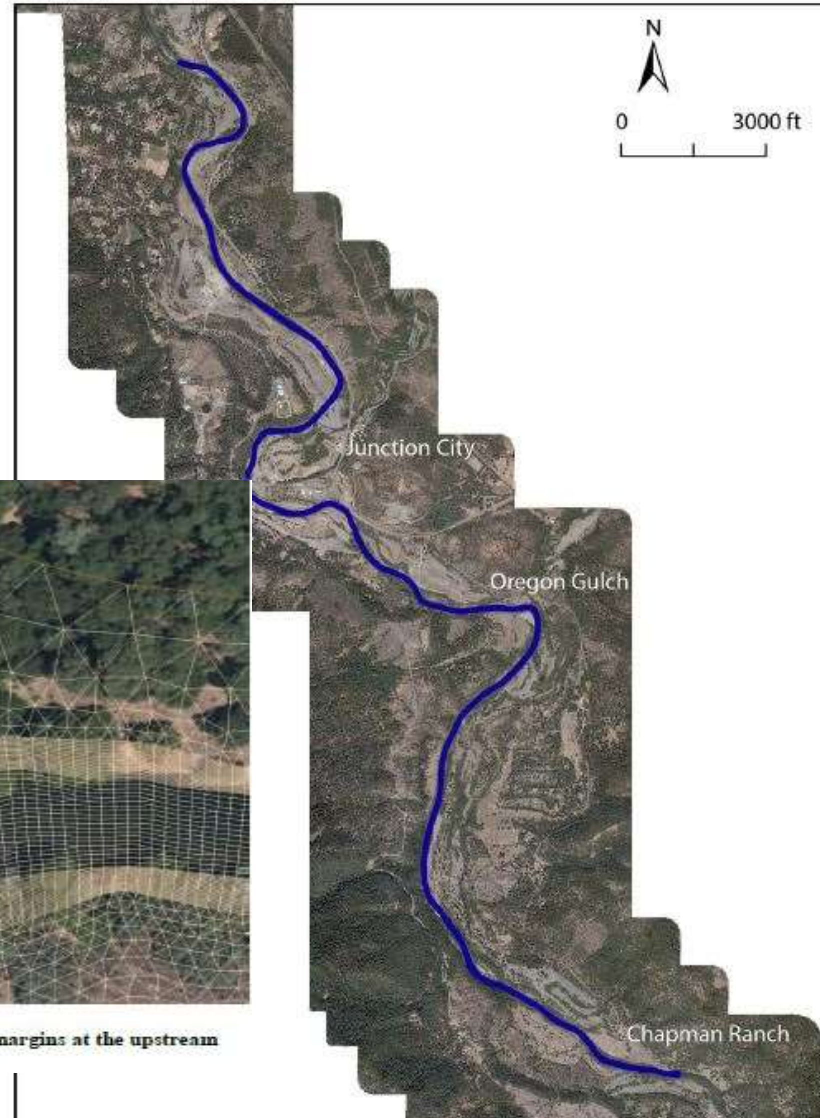
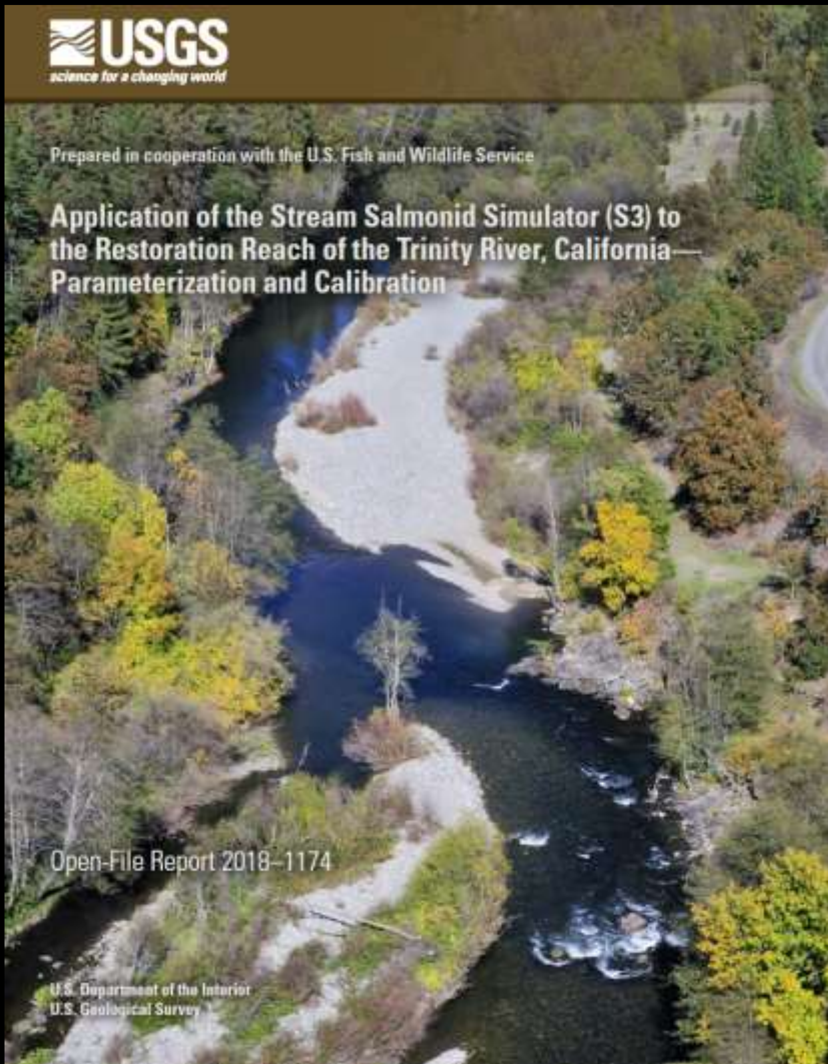


Figure 6. Observations of water surface elevation at 5450 cfs, shown in blue, extend from Chapman Ranch to downstream of Junction City.

How Can The Data and Models Be Used?



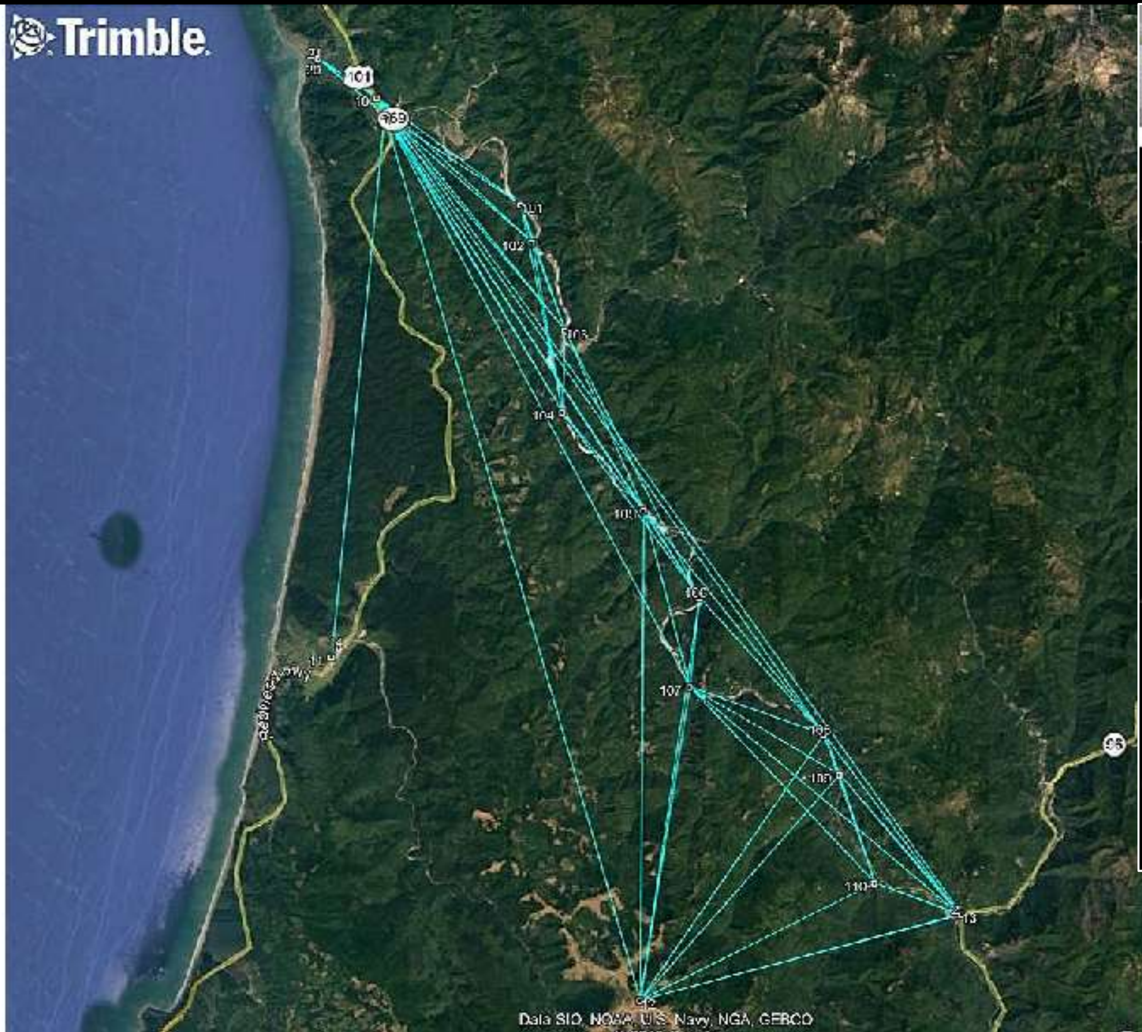
Discussion

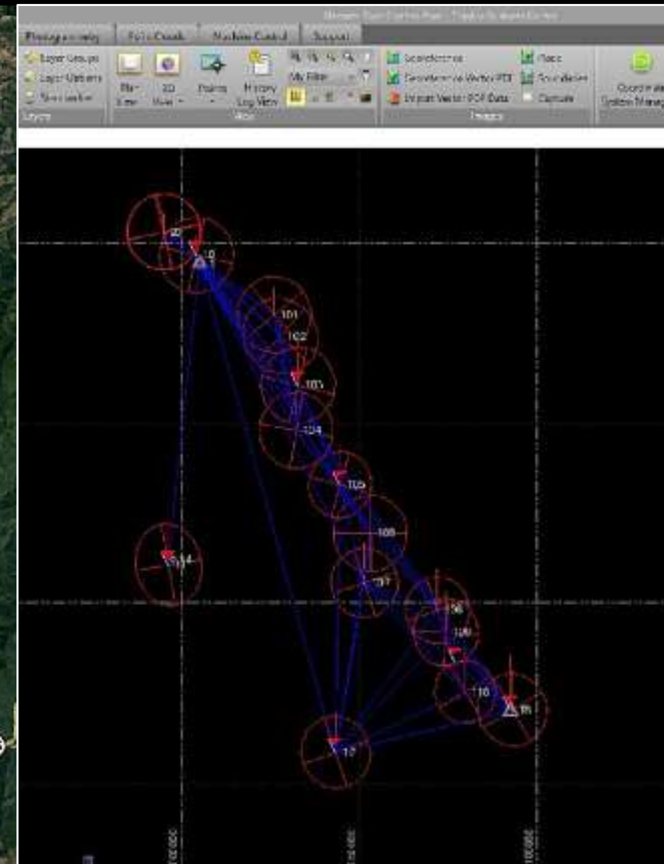
In this report, we constructed and parameterized the S3 as the fish production model to support the Trinity River decision support system (DSS). The structure of S3 makes it a particularly useful fish production model for the DSS because population dynamics are sensitive to (1) water temperature, (2) daily flow management, and (3) habitat quality and quantity. Each of these variables are key management parameters under consideration in the Trinity River Restoration Program. Furthermore, the Trinity River S3 model is unique and unprecedented among detailed simulation models of fish populations owing to (1) state-of-the-art sub-models forming key drivers in S3 (e.g., hydrodynamics and fish habitat models), (2) high-quality abundance estimates available for evaluating model output, (3) calibration of the model to estimate key demographic parameters, and (4) comparison of alternative hypotheses about the mechanisms of density-dependence driving population dynamics.

Inputs for the Trinity River S3 model were constructed from state-of-the-art models of spatially explicit hydrodynamics (Bradley, 2016) and quantitative fish habitat relationships (Som and others, 2017). Because of their complexity and computational burden, two-dimensional hydrodynamic models typically focus on modeling relatively short reaches of river (e.g., hundreds of meters). For example, the Klamath River S3 model relied on 2D hydrodynamic models for eight reaches throughout the Klamath River, which required extrapolating habitat quantity from the 2D models to un-modeled reaches (Perry and others, 2018b). In contrast, the SRH-2D model was applied to the entire 40-mile Restoration Reach, providing two-dimensional hydrodynamic output for every MHU in the S3 model. Thus, extrapolation from modeled to un-modeled habitat units was unnecessary. One tradeoff of constructing a hydrodynamic model for the entire 40-mile Restoration Reach is that computational cells were larger than those from the 2D model, a characteristic required to achieve computational feasibility. During initial stages of model development, we worked closely with the SRH-2D modeling team to evaluate accuracy and precision of the model to predict water velocity, a key habitat parameter. This analysis resulted in modifications to the model to decrease cell size and increase the number of cells near the shore to obtain sufficiently accurate depth and velocity estimates for predicting juvenile habitat capacity.

We used a novel technique for estimating the habitat capacity of meso-habitat units from the output of the SRH-2D hydrodynamic model. Often, habitat quality and quantity is measured in terms of the amount of suitable habitat (e.g., square meters, acres, or hectares), which may be quantified using presence-only data with habitat suitability criteria (Som and others, 2016) or presence-absence data with logistic regression (Tiffan and others, 2006). However, standard models for density-dependence use carrying capacity, not the amount of suitable habitat. Capacity can be estimated from suitable habitat area given an estimate of the maximum density within suitable habitat. For example, Beechie and others (2015) estimated reach-level capacity of the Trinity River by assigning different fish densities to habitat categories with different suitabilities of depth, velocity, and cover. In contrast to this approach, the model developed by Som and others (2018) uses continuous measures of depth, velocity, and cover distance (i.e., not categorized) to estimate the expected distribution of fish density given the predicted mean fish density and the estimated spatial and temporal variation in density. Given that we define capacity as the upper bound for the number of fish that a habitat unit can hold, we estimate capacity as the 95th percentile of the distribution of fish density, as predicted by the habitat covariates.

KLAMATH RIVER NEW CONTROL NETWORK - BOR





Tell me and I'll forget. Show me, and I may not remember. Involve me, and I'll understand.

- Native American Saying -

DJ Bandrowski P.E., Project Engineer

djbandrowski@yuroktribe.nsn.us

906-225-9137

Applying Genetic Markers for Spring and Fall Chinook to Questions in the Klamath Basin

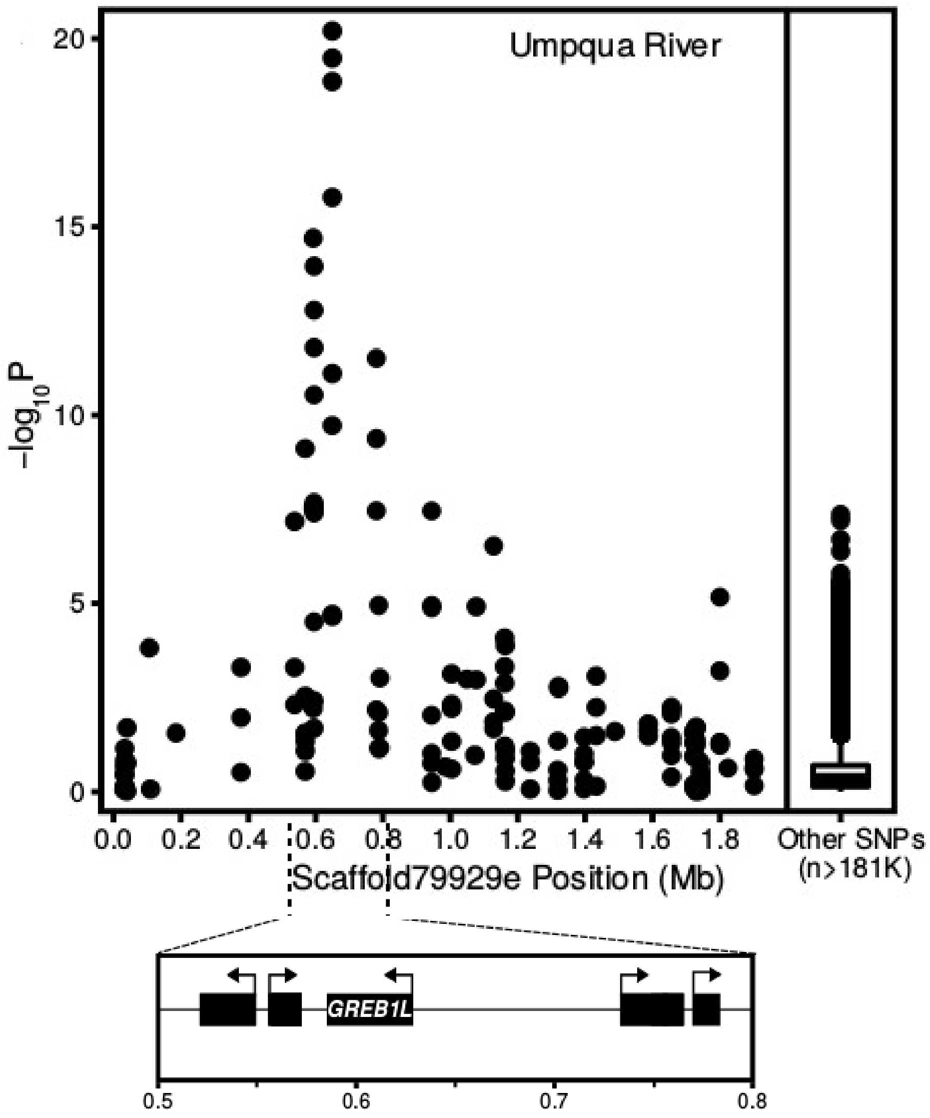
Tasha Thompson

Outline

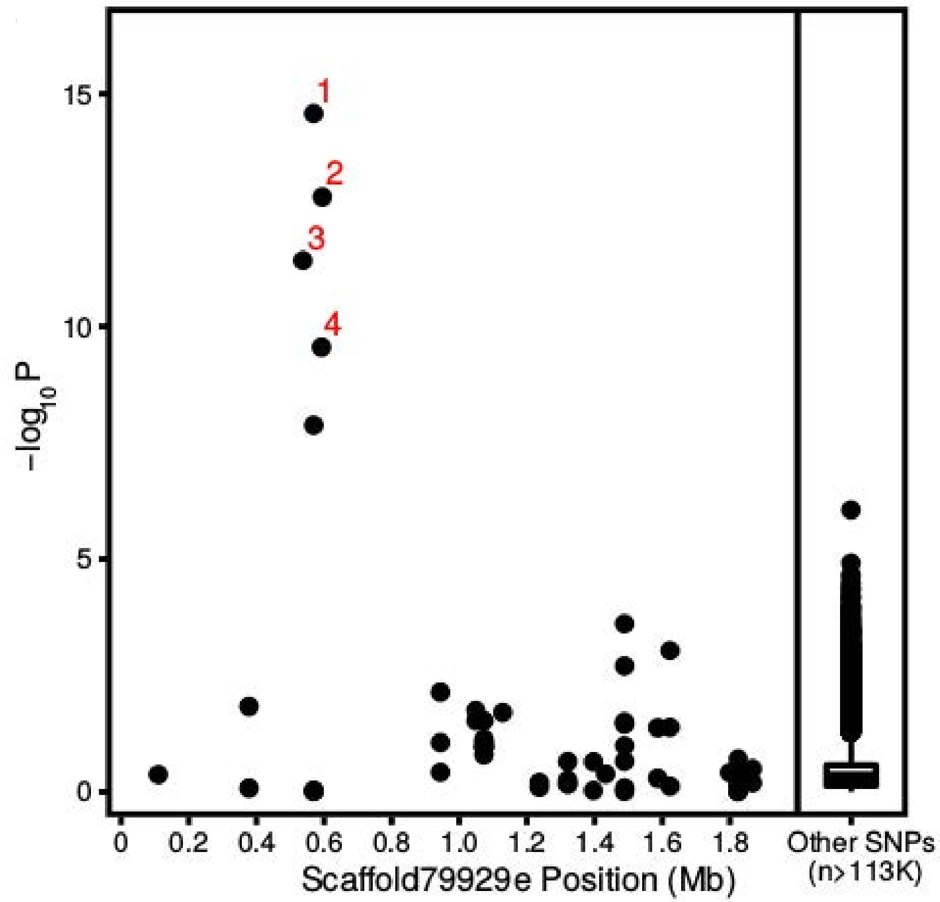
- Marker discovery
- Marker validation
- Applications for monitoring Salmon River spring-run Chinook
- Applications for upper Klamath restoration

Previous study identified a genetic region strongly associated with premature vs. mature migration in steelhead and Chinook

Steelhead



Chinook



GREB1L region

Prince *et al.* 2017

Premature:
Spring Chinook/
Summer steelhead

PP=homozygous premature

PM=heterozygous

MM=homozygous mature

Mature:
Fall Chinook/
Winter steelhead

Steelhead

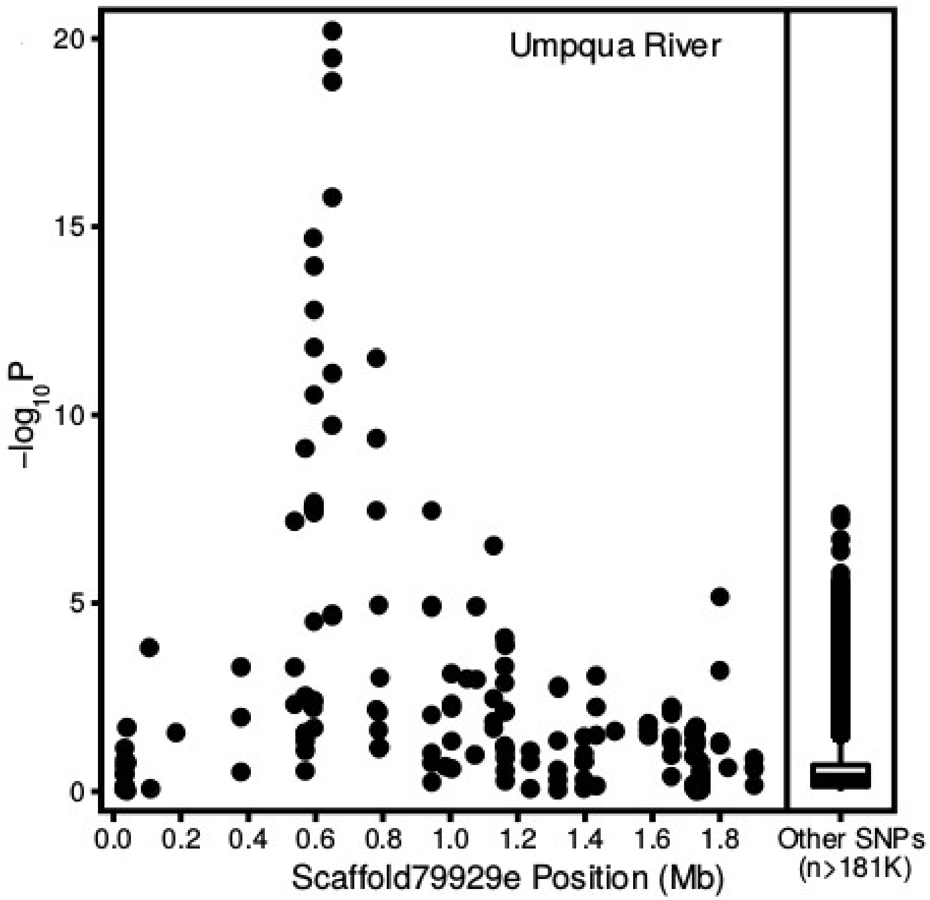
Location	Predicted phenotype	Top Prince et al. SNP
Eel River	Summer-run	PP
Eel River	Summer-run	PP
Eel River	Summer-run	PP
Eel River	Summer-run	PP
Eel River	Summer-run	PP
Eel River	Summer-run	PP
Eel River	Summer-run	PP
New River	Summer-run	PP
New River	Summer-run	PP
New River	Summer-run	PP
New River	Summer-run	PP
New River	Summer-run	PP
Siletz River	Summer-run	PP
Siletz River	Summer-run	PP
Siletz River	Summer-run	PP
Siletz River	Summer-run	PP
Umpqua River	Summer-run	PP
Umpqua River	Summer-run	PP
Umpqua River	Summer-run	PP
Umpqua River	Summer-run	PP
Umpqua River	Summer-run	PP
Eel River	Winter-run	MM
Eel River	Winter-run	MM
Eel River	Winter-run	MM
Eel River	Winter-run	MM
Eel River	Winter-run	MM
Scott Creek	Winter-run	MM
Scott Creek	Winter-run	MM
Scott Creek	Winter-run	MM
Scott Creek	Winter-run	MM
Scott Creek	Winter-run	MM
Scott Creek	Winter-run	MM
Scott Creek	Winter-run	MM
Siletz River	Winter-run	MM
Siletz River	Winter-run	PM
Umpqua River	Winter-run	MM
Umpqua River	Winter-run	MM
Umpqua River	Winter-run	MM
Umpqua River	Winter-run	MM
Umpqua River	Winter-run	MM
Umpqua River	Winter-run	MM
Umpqua River	Winter-run	PM
Umpqua River	Winter-run	MM
Umpqua River	Winter-run	MM
Umpqua River	Winter-run	MM
Umpqua River	Winter-run	MM

Chinook

Location	Predicted phenotype	Top Prince et al. SNP
Nooksack River	Spring-run	PP
Nooksack River	Spring-run	PP
Nooksack River	Spring-run	PM
North Umpqua River	Spring-run	PP
North Umpqua River	Spring-run	PP
North Umpqua River	Spring-run	PP
North Umpqua River	Spring-run	PP
Puyallup River	Spring-run	PP
Puyallup River	Spring-run	PP
Puyallup River	Spring-run	PP
Puyallup River	Spring-run	PP
Puyallup River	Spring-run	PP
Rogue River	Spring-run	PP
Rogue River	Spring-run	PP
Rogue River	Spring-run	PP
Rogue River	Spring-run	PP
Salmon River	Spring-run	PP
Trinity River	Spring-run	PP
Trinity River	Spring-run	PP
Trinity River	Spring-run	PP
Trinity River	Spring-run	PP
Nooksack River	Fall-run	PM
Nooksack River	Fall-run	PM
Nooksack River	Fall-run	MM
Puyallup River	Fall-run	MM
Puyallup River	Fall-run	MM
Puyallup River	Fall-run	PM
Puyallup River	Fall-run	MM
Puyallup River	Fall-run	PM
Rogue River	Fall-run	PP
Rogue River	Fall-run	MM
Rogue River	Fall-run	PM
Rogue River	Fall-run	PM
Salmon River	Fall-run	PP
Siletz River	Fall-run	MM
Siletz River	Fall-run	MM
Siletz River	Fall-run	PM
Siletz River	Fall-run	MM
South Umpqua River	Fall-run	MM
South Umpqua River	Fall-run	PM
South Umpqua River	Fall-run	MM
Trinity River	Fall-run	PP
Trinity River	Fall-run	PM
Trinity River	Fall-run	PP
Trinity River	Fall-run	PP
Trinity River	Fall-run	PM

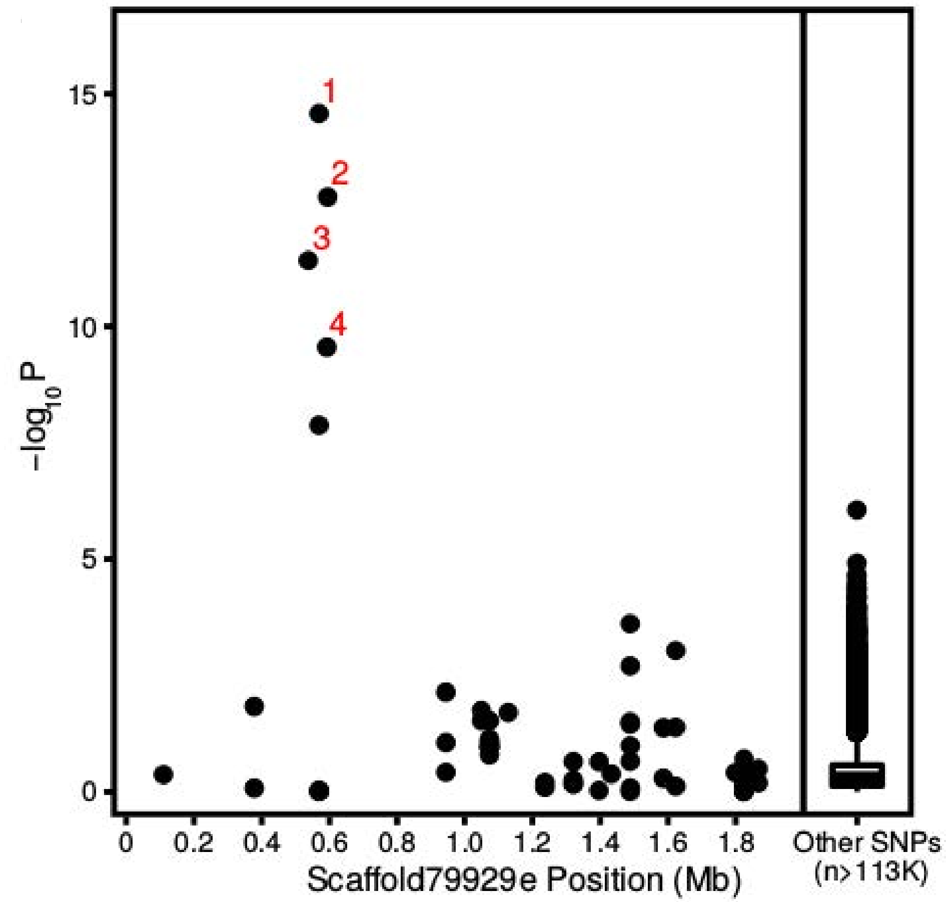
Chinook analysis was lower resolution and had missing data in region with highest association in steelhead

Steelhead



GREB1L region

Chinook

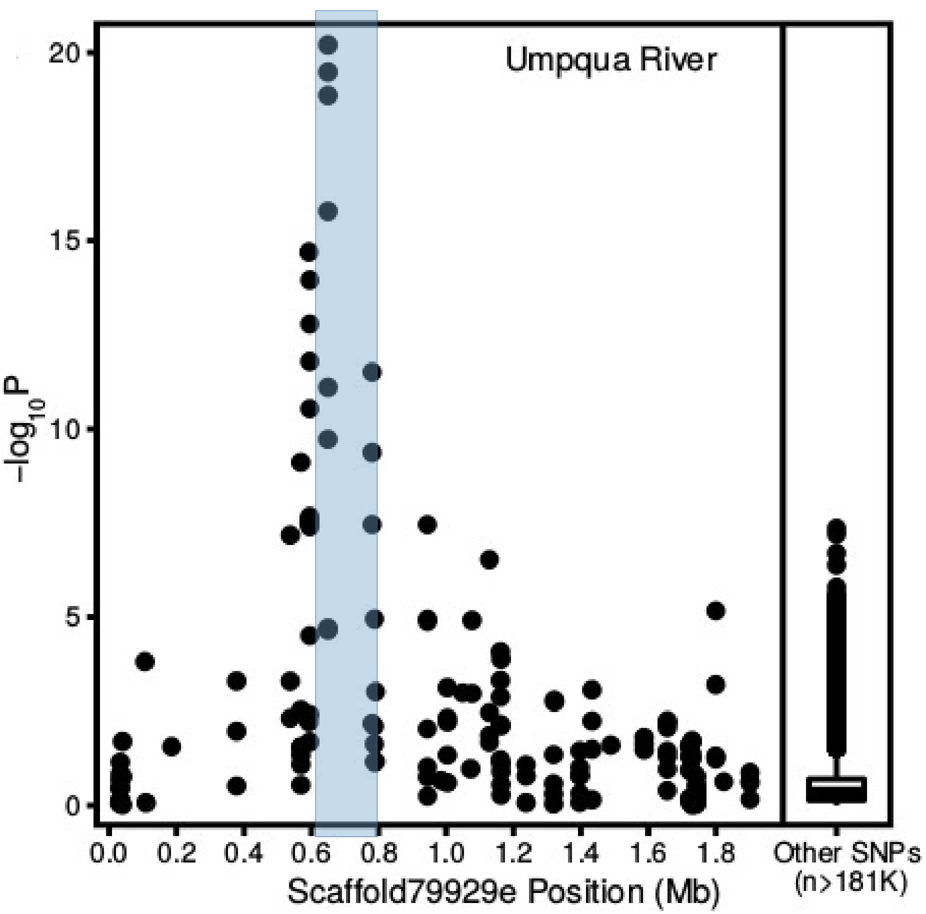


GREB1L region

Prince *et al.* 2017

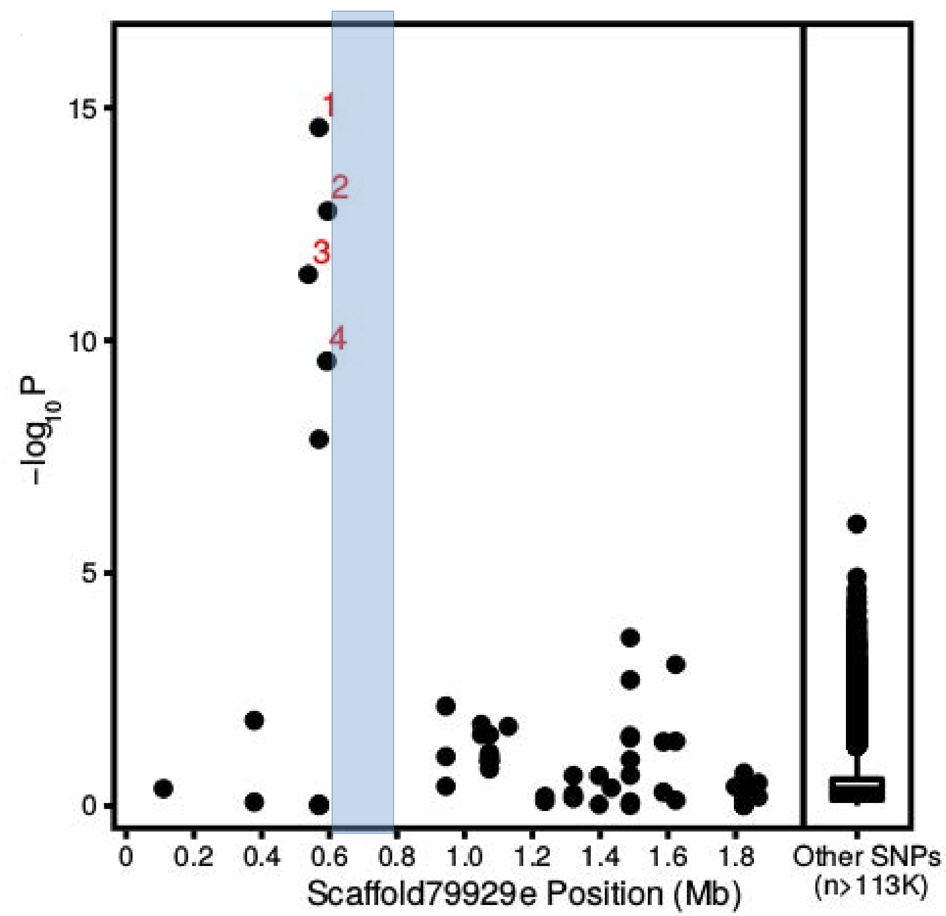
Chinook analysis was lower resolution and had missing data in region with highest association in steelhead

Steelhead



GREB1L region

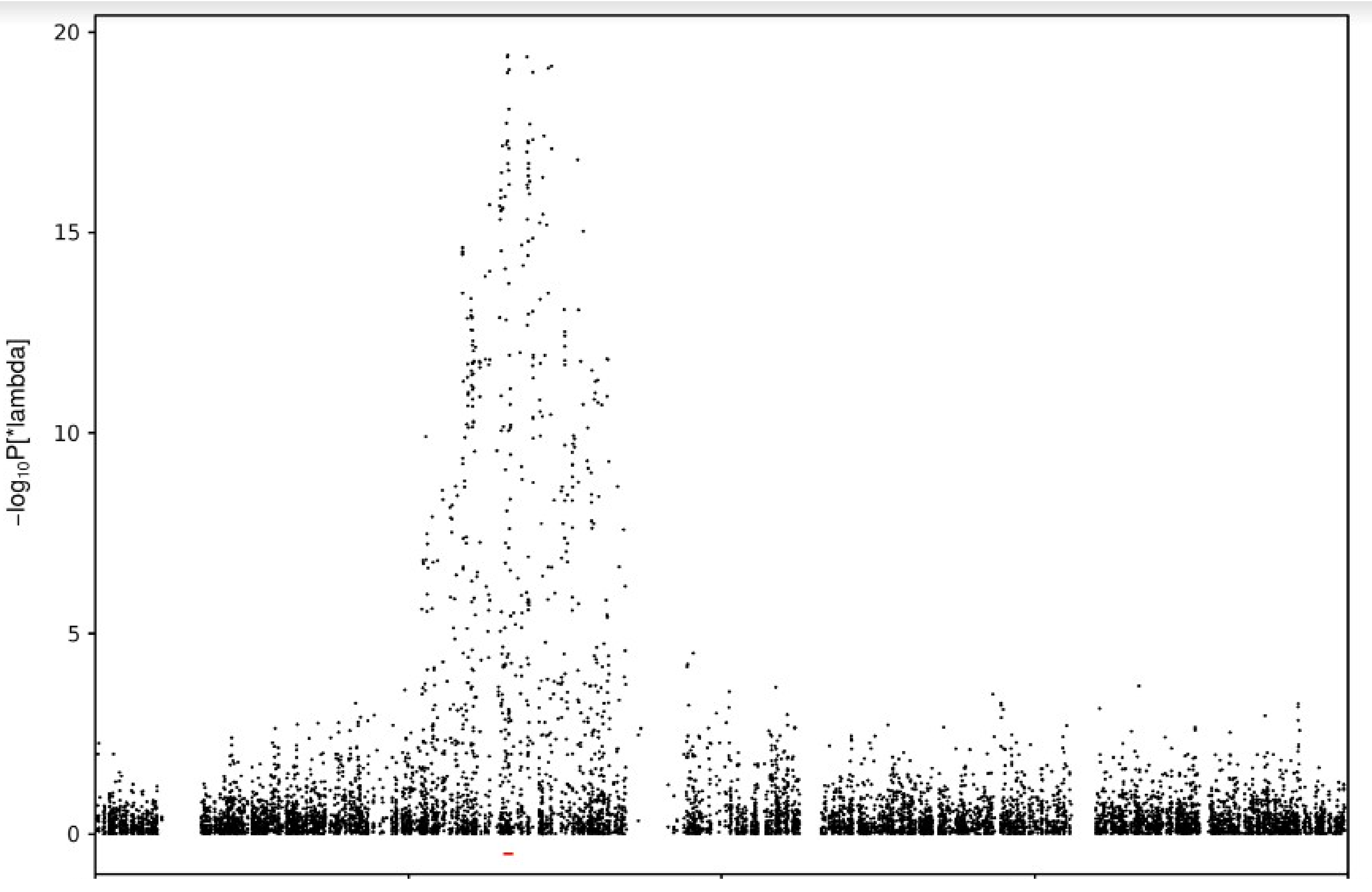
Chinook



GREB1L region

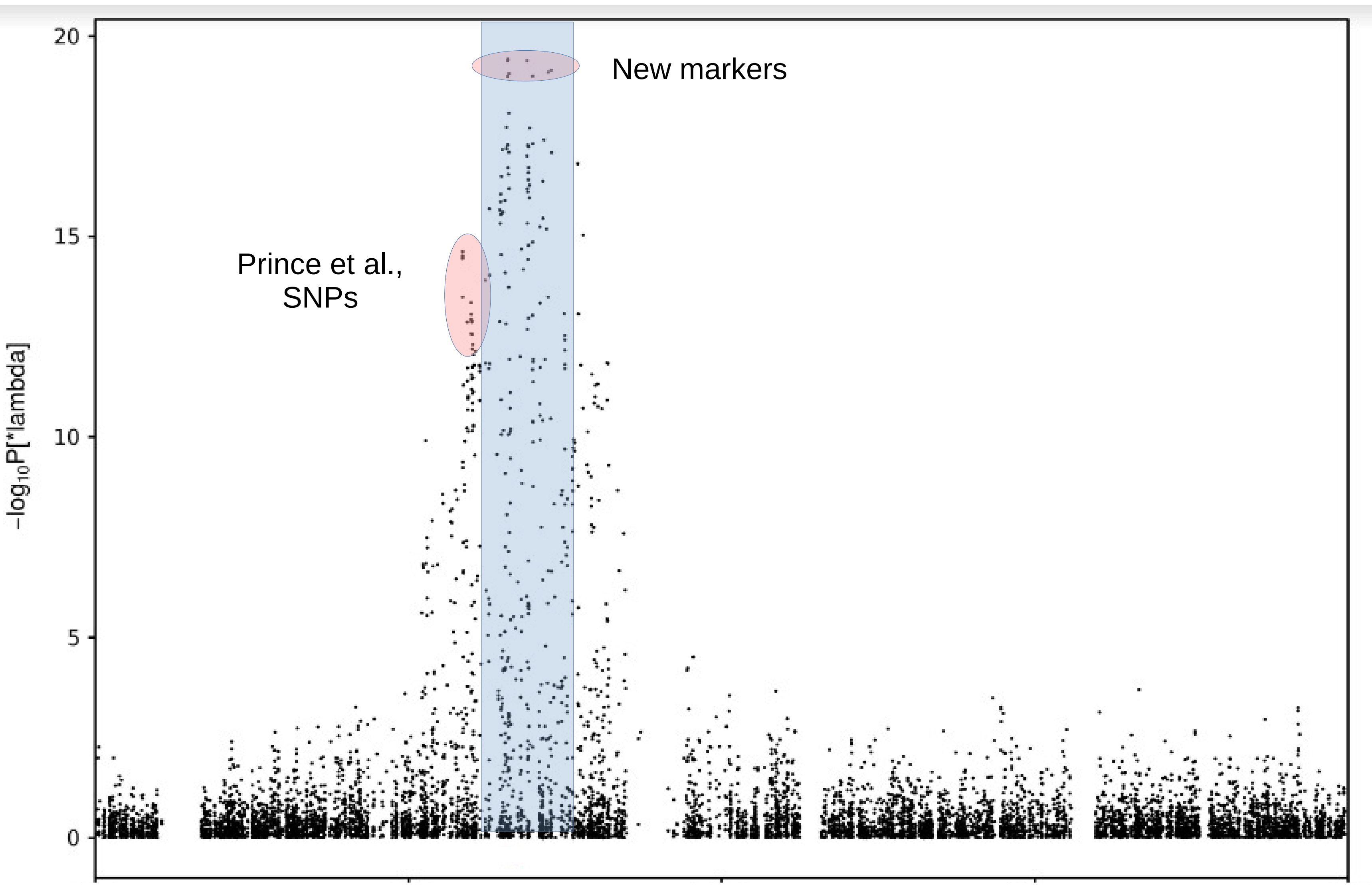
Prince *et al.* 2017

Higher-resolution analysis of *GREB1L* region in Chinook revealed SNPs with stronger associations



GREB1L region

Higher-resolution analysis of *GREB1L* region in Chinook revealed SNPs with stronger associations



GREB1L region

Chinook

Spring-run

PP=homozygous premature

PM=heterozygous

MM=homozygous mature

Fall-run

Location	Predicted phenotype	Top Prince et al. SNP
Nooksack River	Spring-run	PP
Nooksack River	Spring-run	PP
Nooksack River	Spring-run	PM
North Umpqua River	Spring-run	PP
North Umpqua River	Spring-run	PP
North Umpqua River	Spring-run	PP
North Umpqua River	Spring-run	PP
Puyallup River	Spring-run	PP
Puyallup River	Spring-run	PP
Puyallup River	Spring-run	PP
Puyallup River	Spring-run	PP
Puyallup River	Spring-run	PP
Rogue River	Spring-run	PP
Rogue River	Spring-run	PP
Rogue River	Spring-run	PP
Rogue River	Spring-run	PP
Salmon River	Spring-run	PP
Trinity River	Spring-run	PP
Trinity River	Spring-run	PP
Trinity River	Spring-run	PP
Trinity River	Spring-run	PP
Nooksack River	Fall-run	PM
Nooksack River	Fall-run	PM
Nooksack River	Fall-run	MM
Puyallup River	Fall-run	MM
Puyallup River	Fall-run	MM
Puyallup River	Fall-run	PM
Puyallup River	Fall-run	MM
Puyallup River	Fall-run	PM
Rogue River	Fall-run	PP
Rogue River	Fall-run	MM
Rogue River	Fall-run	PM
Rogue River	Fall-run	PM
Salmon River	Fall-run	PP
Siletz River	Fall-run	MM
Siletz River	Fall-run	MM
Siletz River	Fall-run	PM
Siletz River	Fall-run	MM
South Umpqua River	Fall-run	MM
South Umpqua River	Fall-run	PM
South Umpqua River	Fall-run	MM
Trinity River	Fall-run	PP
Trinity River	Fall-run	PM
Trinity River	Fall-run	PP
Trinity River	Fall-run	PP
Trinity River	Fall-run	PM

Chinook

Spring-run

PP=homozygous premature

PM=heterozygous

MM=homozygous mature

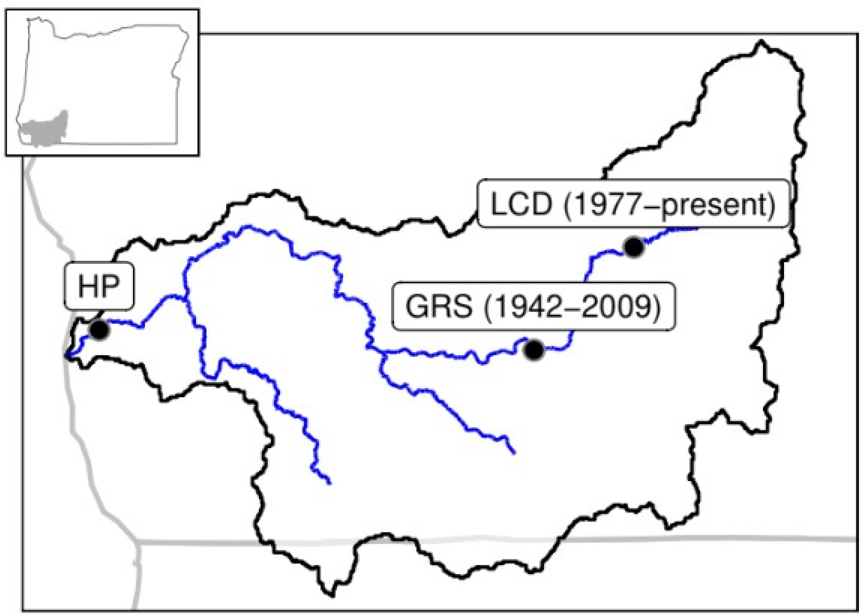
Fall-run

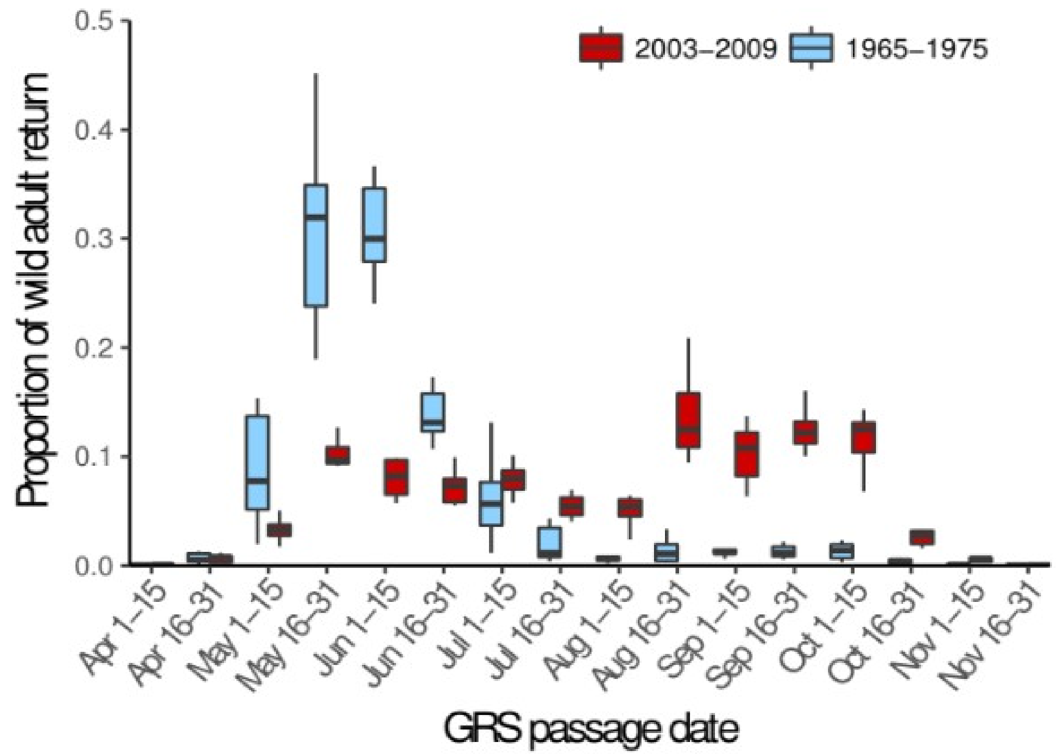
Location	Predicted phenotype	Top Prince et al. SNP	New SNP 1	New SNP 2
Nooksack River	Spring-run	PP	PP	PP
Nooksack River	Spring-run	PP	PP	PP
Nooksack River	Spring-run	PM	PM	PM
North Umpqua River	Spring-run	PP	PP	PP
North Umpqua River	Spring-run	PP	PP	PP
North Umpqua River	Spring-run	PP	PP	PP
North Umpqua River	Spring-run	PP	PP	PP
Puyallup River	Spring-run	PP	PP	PP
Puyallup River	Spring-run	PP	PP	PP
Puyallup River	Spring-run	PP	PP	PP
Puyallup River	Spring-run	PP	PP	PP
Puyallup River	Spring-run	PP	PP	PP
Rogue River	Spring-run	PP	PP	PP
Rogue River	Spring-run	PP	PP	PP
Rogue River	Spring-run	PP	PP	PP
Rogue River	Spring-run	PP	PP	PP
Salmon River	Spring-run	PP	PP	PP
Trinity River	Spring-run	PP	PP	PP
Trinity River	Spring-run	PP	PP	PP
Trinity River	Spring-run	PP	PP	PP
Trinity River	Spring-run	PP	PP	PP
Nooksack River	Fall-run	PM	MM	MM
Nooksack River	Fall-run	PM	MM	MM
Nooksack River	Fall-run	MM	MM	MM
Puyallup River	Fall-run	MM	MM	MM
Puyallup River	Fall-run	MM	MM	MM
Puyallup River	Fall-run	PM	PM	PM
Puyallup River	Fall-run	MM	MM	MM
Puyallup River	Fall-run	PM	MM	MM
Rogue River	Fall-run	PP	MM	MM
Rogue River	Fall-run	MM	MM	MM
Rogue River	Fall-run	PM	MM	MM
Rogue River	Fall-run	PM	MM	MM
Salmon River	Fall-run	PP	MM	MM
Siletz River	Fall-run	MM	MM	MM
Siletz River	Fall-run	MM	MM	MM
Siletz River	Fall-run	PM	MM	MM
Siletz River	Fall-run	MM	MM	MM
South Umpqua River	Fall-run	MM	MM	MM
South Umpqua River	Fall-run	PM	MM	MM
South Umpqua River	Fall-run	MM	MM	MM
Trinity River	Fall-run	PP	MM	MM
Trinity River	Fall-run	PM	MM	MM
Trinity River	Fall-run	PP	MM	MM
Trinity River	Fall-run	PP	MM	MM
Trinity River	Fall-run	PM	MM	MM

Outline

- Marker discovery
- Marker validation
- Applications for monitoring Salmon River spring-run Chinook
- Applications for upper Klamath restoration

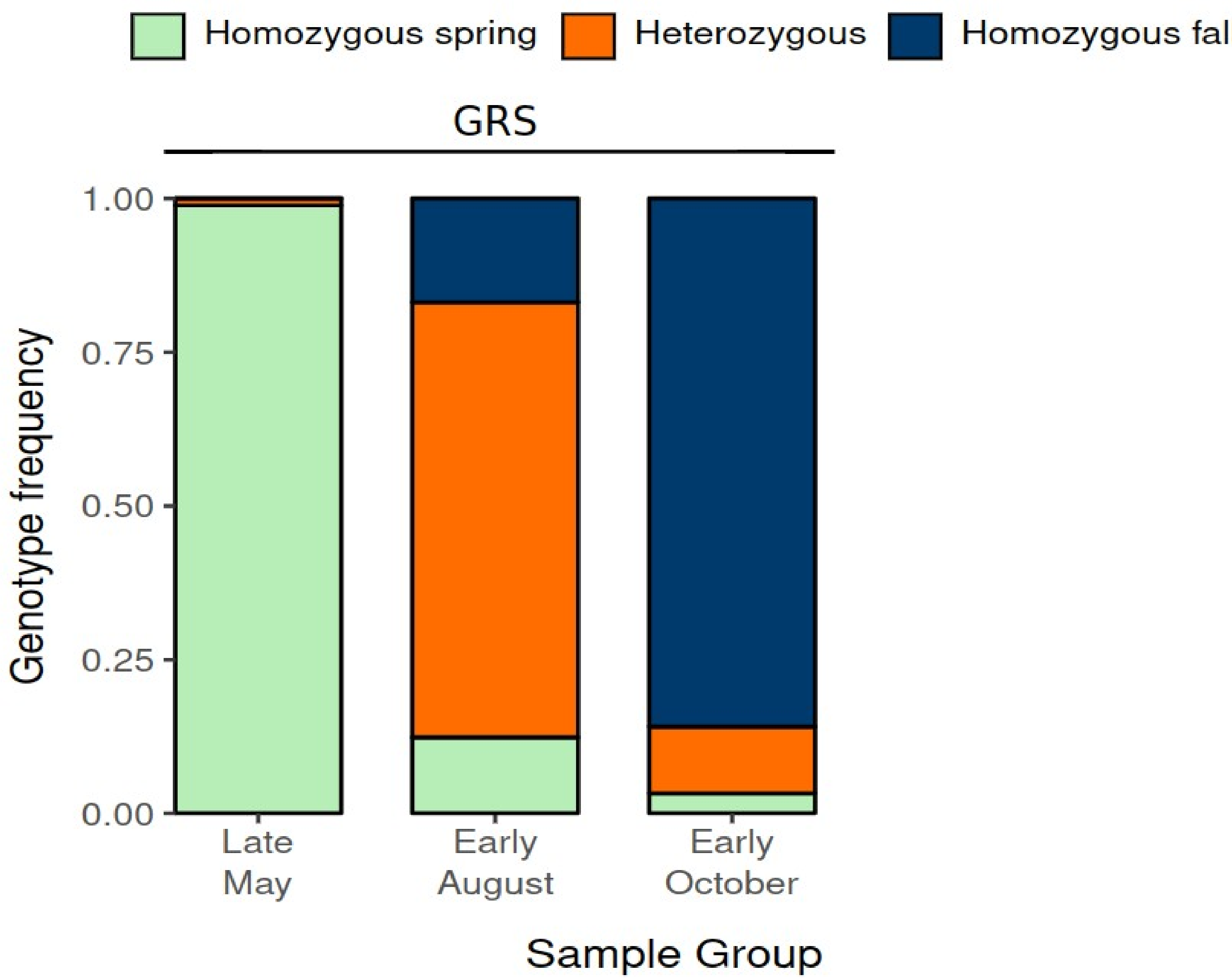
Rogue River, OR Chinook experienced a major shift in adult migration time after construction of Lost Creek Dam in 1977





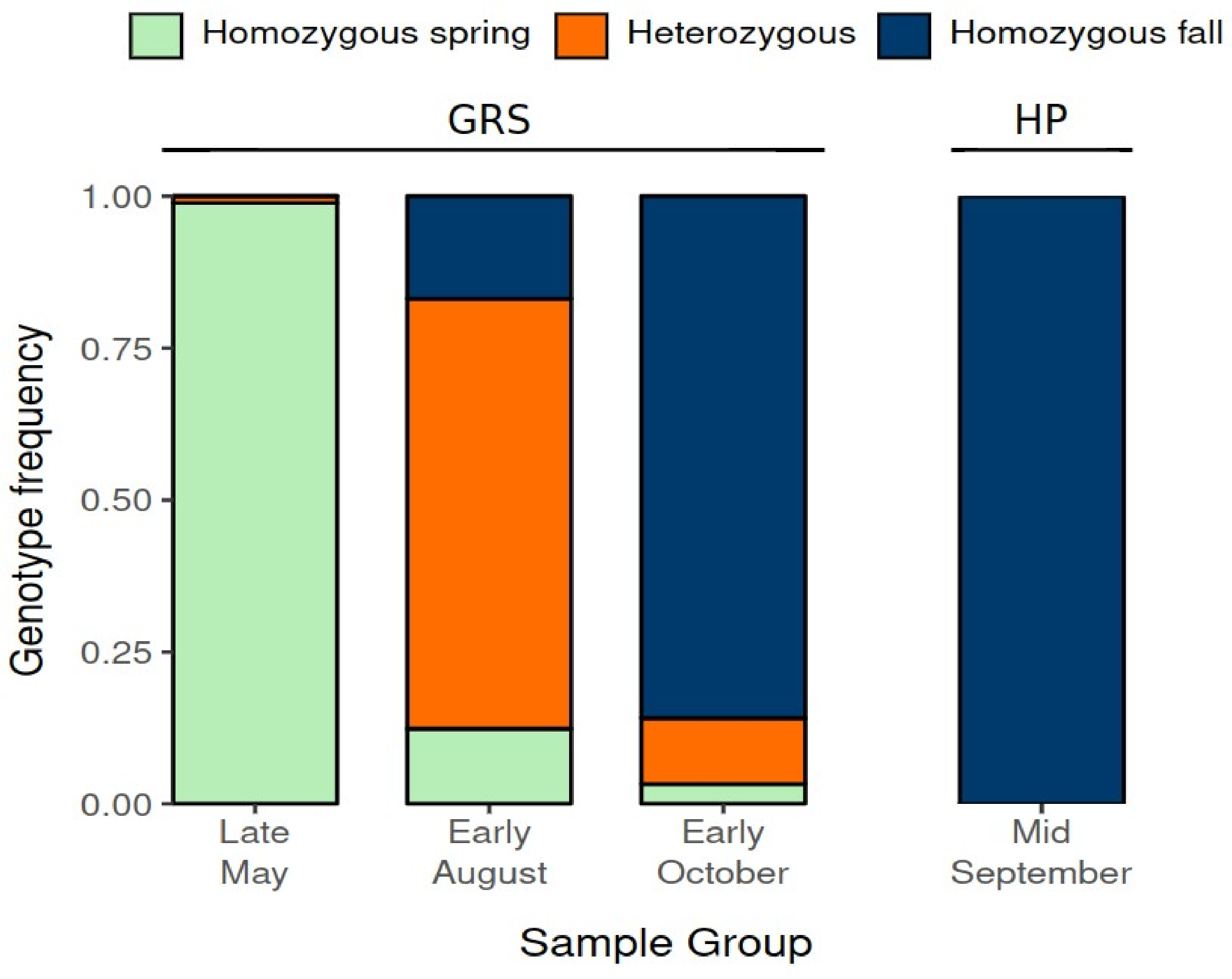
Thompson *et al.*, 2019

Genotyping Rogue River Chinook that passed GRS during three time windows reveals heterozygotes have an intermediate phenotype



Thompson *et al.*, 2019

Mid-September HP results suggest homozygous-spring and heterozygous fish from GRS early-October had entered freshwater earlier in the year

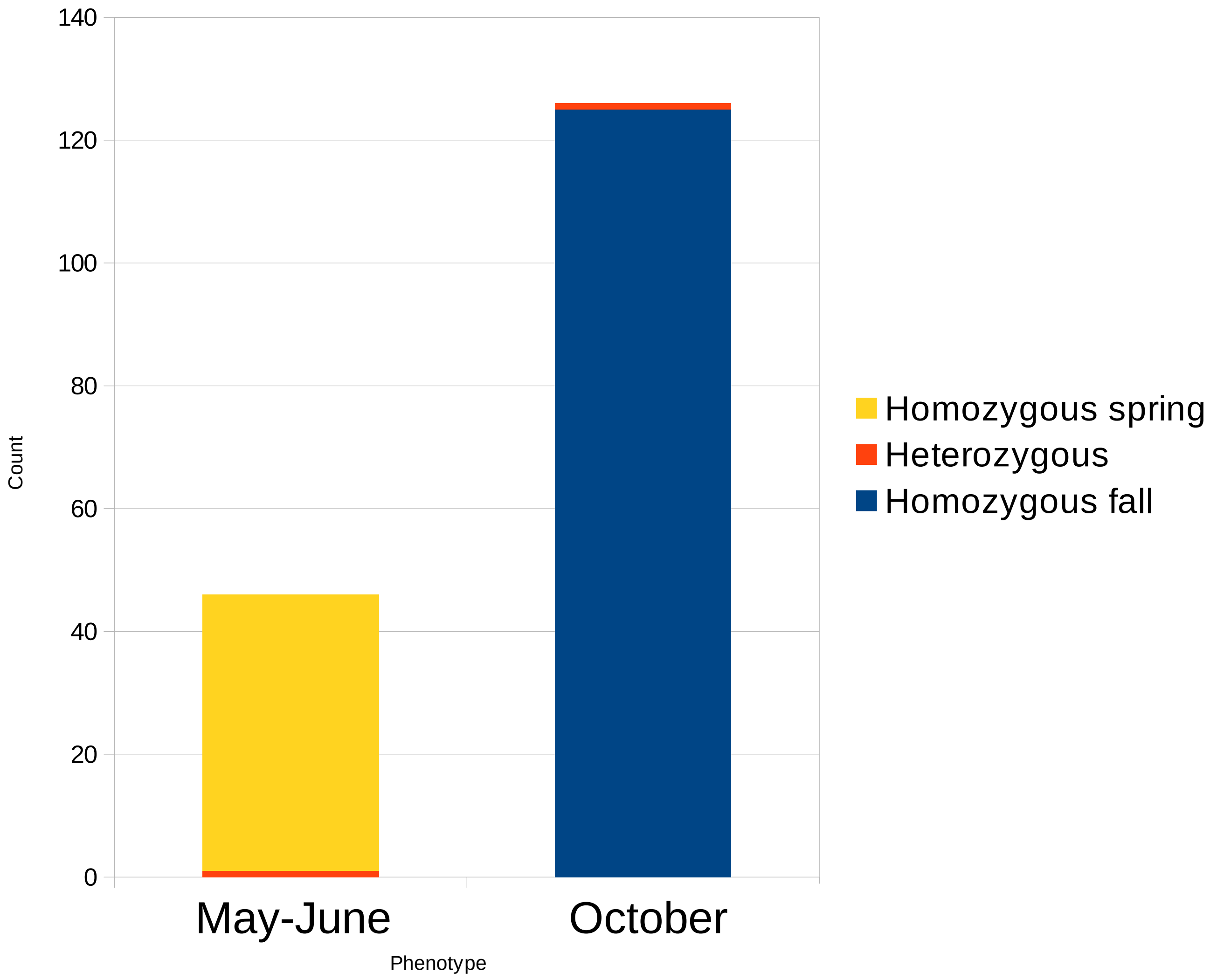


Thompson *et al.*, 2019

Results are further supported by validation in the South Fork Trinity

South Fork Trinity						
Sandy Bar Weir	5/15/1992	SS		Sandy Bar Weir	10/14/1993	FF
Sandy Bar Weir	5/21/1992	SS		Sandy Bar Weir	10/15/1993	FF
Sandy Bar Weir	5/25/1992	SS		Sandy Bar Weir	10/15/1993	FF
Sandy Bar Weir	6/12/1993	SS		Sandy Bar Weir	10/15/1993	FF
Sandy Bar Weir	6/21/1993	SS		Sandy Bar Weir	10/15/1993	FF
Sandy Bar Weir	6/25/1993	SS		Sandy Bar Weir	10/24/1993	FF
Forest Glen	6/25/1993	SS		Sandy Bar Weir	10/25/1993	FF
Sandy Bar Weir	6/26/1993	SS		Sandy Bar Weir	10/25/1993	FF
Sandy Bar Weir	6/28/1993	SS		Sandy Bar Weir	10/28/1993	FF
Sandy Bar Weir	6/29/1993	SS		Sandy Bar Weir	10/29/1993	FF
Sandy Bar Weir	6/29/1993	SS		Sandy Bar Weir	10/29/1993	FF
Forest Glen	6/30/1993	SS		Sandy Bar Weir	10/29/1993	FF
Forest Glen	7/2/1993	SS		Sandy Bar Weir	10/29/1993	FF
Sandy Bar Weir	7/3/1993	SS		Sandy Bar Weir	10/29/1993	FF
Sandy Bar Weir	7/6/1993	SS		Sandy Bar Weir	10/30/1993	FF
Sandy Bar Weir	7/7/1993	SS		Sandy Bar Weir	11/2/1993	FF
Sandy Bar Weir	7/8/1993	SS		Sandy Bar Weir	11/3/1993	FF
Sandy Bar Weir	7/8/1993	SS		Sandy Bar Weir	11/3/1993	FF
Sandy Bar Weir	7/13/1993	SS		Sandy Bar Weir	11/3/1993	FF
Sandy Bar Weir	7/16/1993	SS		Sandy Bar Weir	11/3/1993	FF
Sandy Bar Weir	7/20/1993	SS		Sandy Bar Weir	11/3/1993	FF
Sandy Bar Weir	7/23/1993	SS		Sandy Bar Weir	11/11/1993	FF
Sandy Bar Weir	7/23/1993	SS		Sandy Bar Weir	11/12/1993	FF
Sandy Bar Weir	7/24/1993	SS		Sandy Bar Weir	11/12/1993	FF
Sandy Bar Weir	7/24/1993	SS		Sandy Bar Weir	11/12/1993	FF
Sandy Bar Weir	7/24/1993	SS		Sandy Bar Weir	11/14/1993	FF
Sandy Bar Weir	7/24/1993	SS		Sandy Bar Weir	11/14/1993	FF
Sandy Bar Weir	7/24/1993	SS		Sandy Bar Weir	11/15/1993	FF
Sandy Bar Weir	7/31/1993	SF		Sandy Bar Weir	11/15/1993	FF

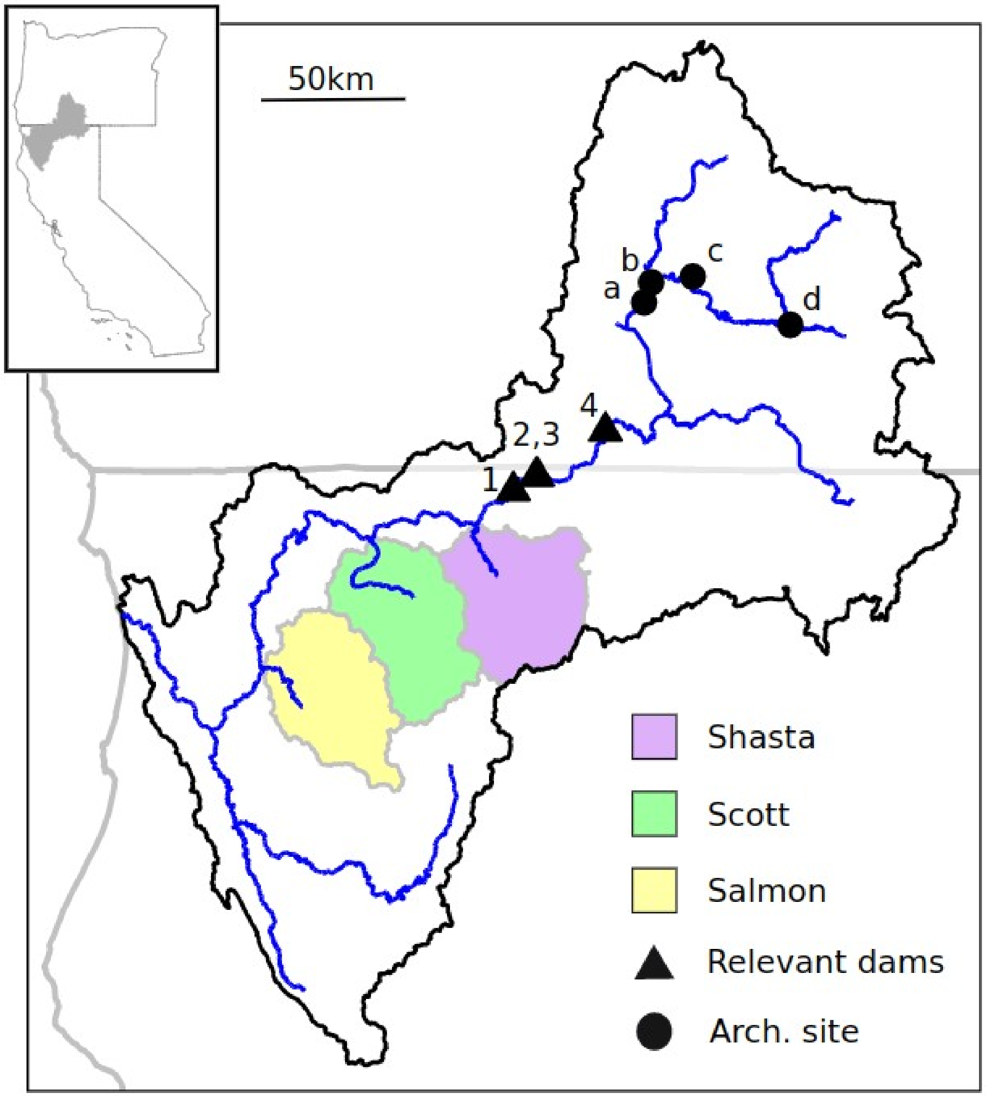
And in the Chehalis River, WA



Outline

- Marker discovery
- Marker validation
- Applications for monitoring Salmon River spring-run Chinook
- Applications for upper Klamath restoration

Wild spring-run Chinook have been extirpated from most of the Klamath basin

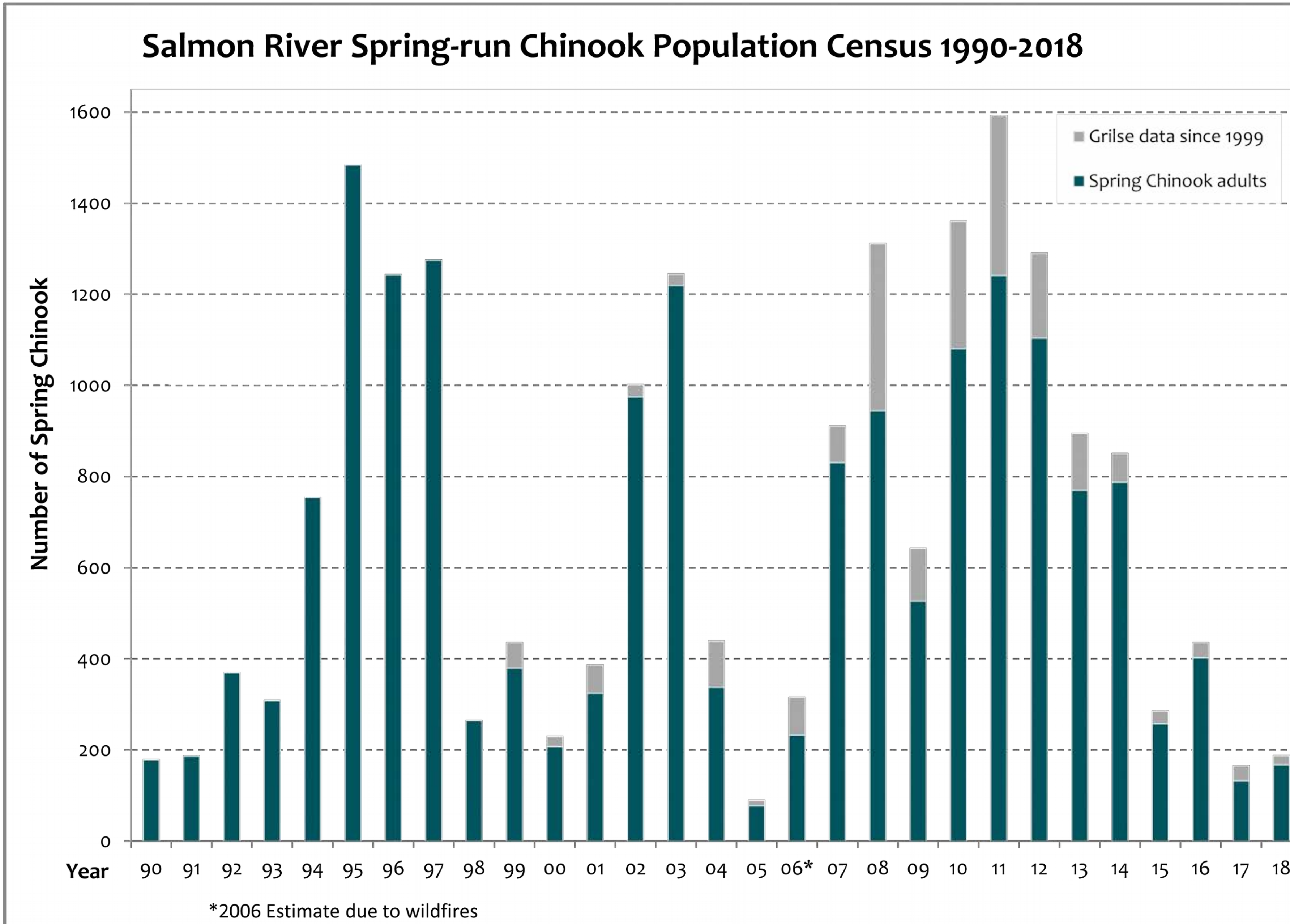


Shasta: spring Chinook extirpated in 1930’s

Scott: spring Chinook extirpated in 1970’s

Salmon: spring Chinook still present

Thompson *et al.*, 2019


Salmon River Spring-run Chinook Population Census 1990-2018
Number of Spring Chinook
1600
1400
1200
1000
800
600
400
200
0
Grilse data since 1999
Spring Chinook adults
Year
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06*
07
08
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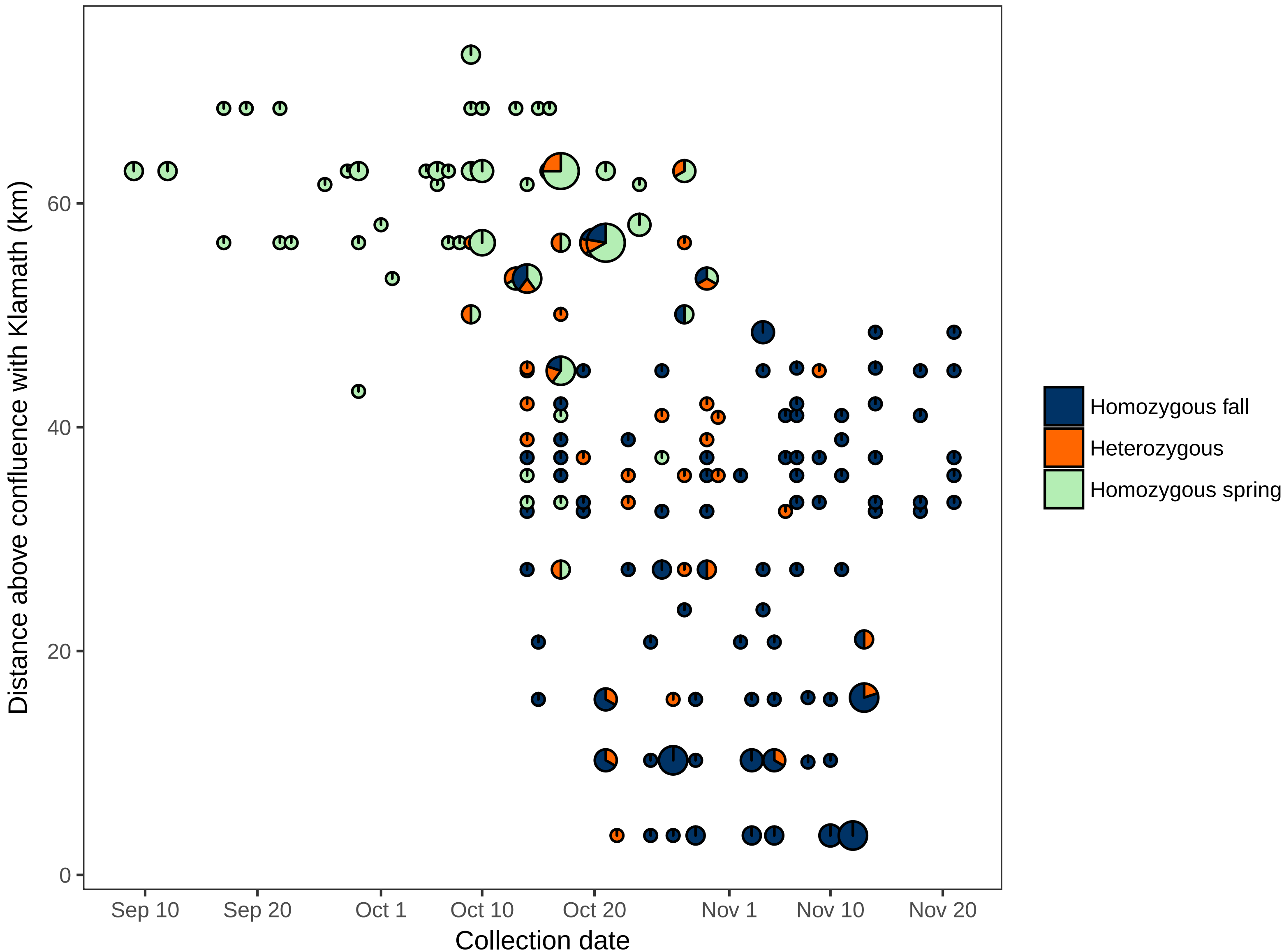
*2006 Estimate due to wildfires

Analysis of carcass samples reveals spatio-temporal differences between spring-run and fall-run Chinook in the Salmon River



Analysis of out-migrating smolts may be useful for monitoring the spring-run allele frequency in the Salmon River

Preliminary analysis:

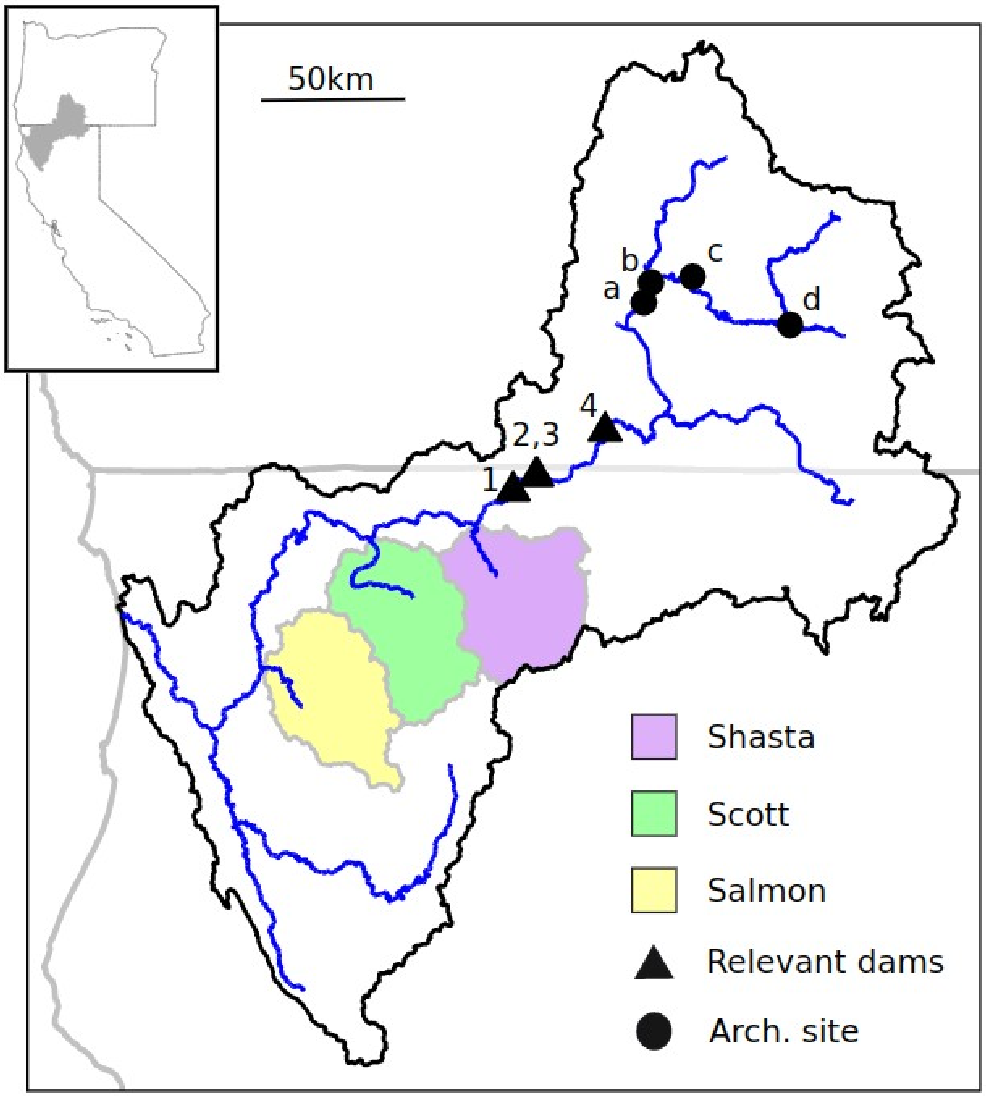
116 smolt samples collected in 2017

Spring-run allele frequency: 0.2

Outline

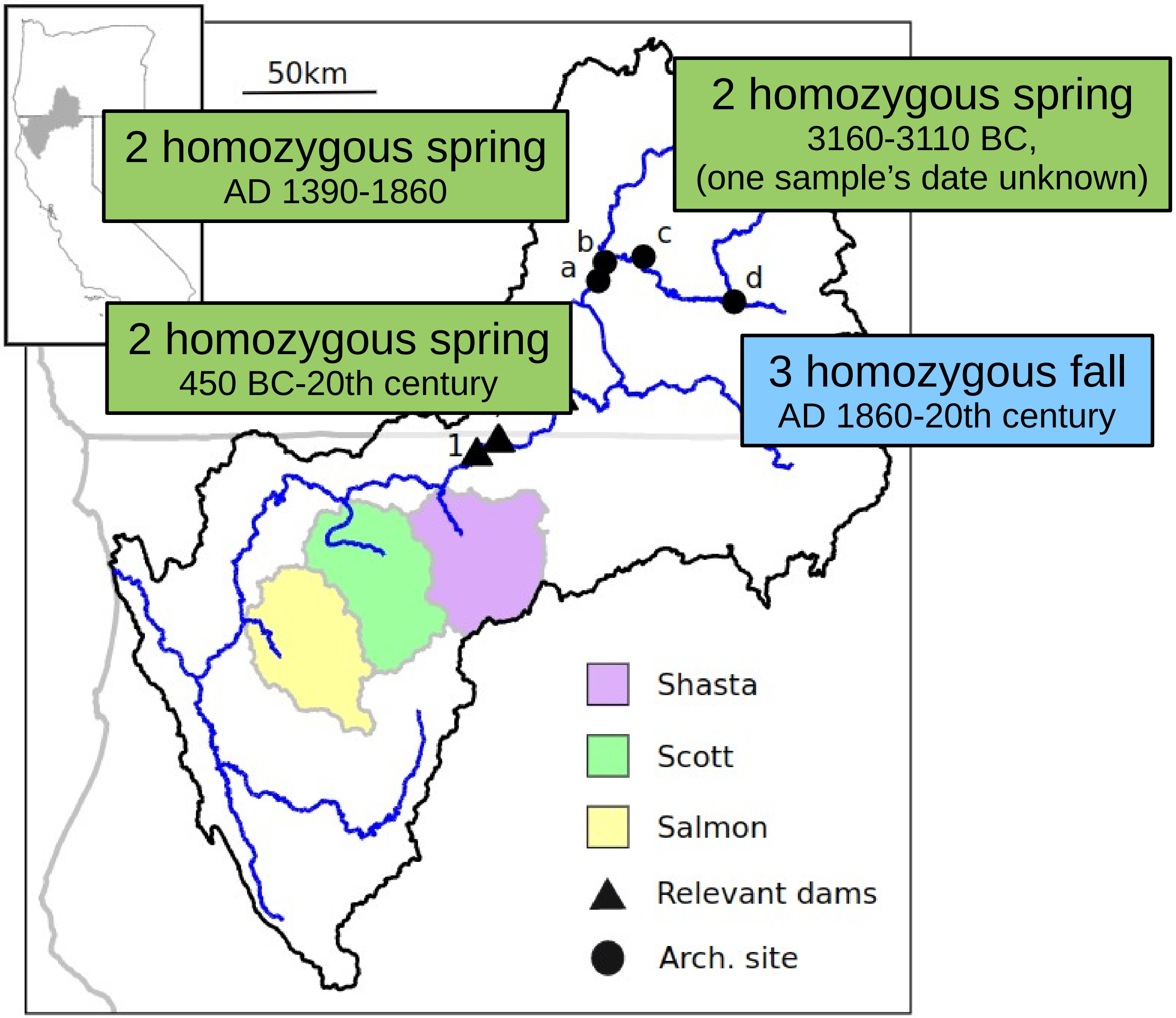
- Marker discovery
- Marker validation
- Applications for monitoring Salmon River spring-run Chinook
- Applications for upper Klamath restoration

Klamath dam removal provides an unprecedented opportunity to restore Chinook to historical habitat



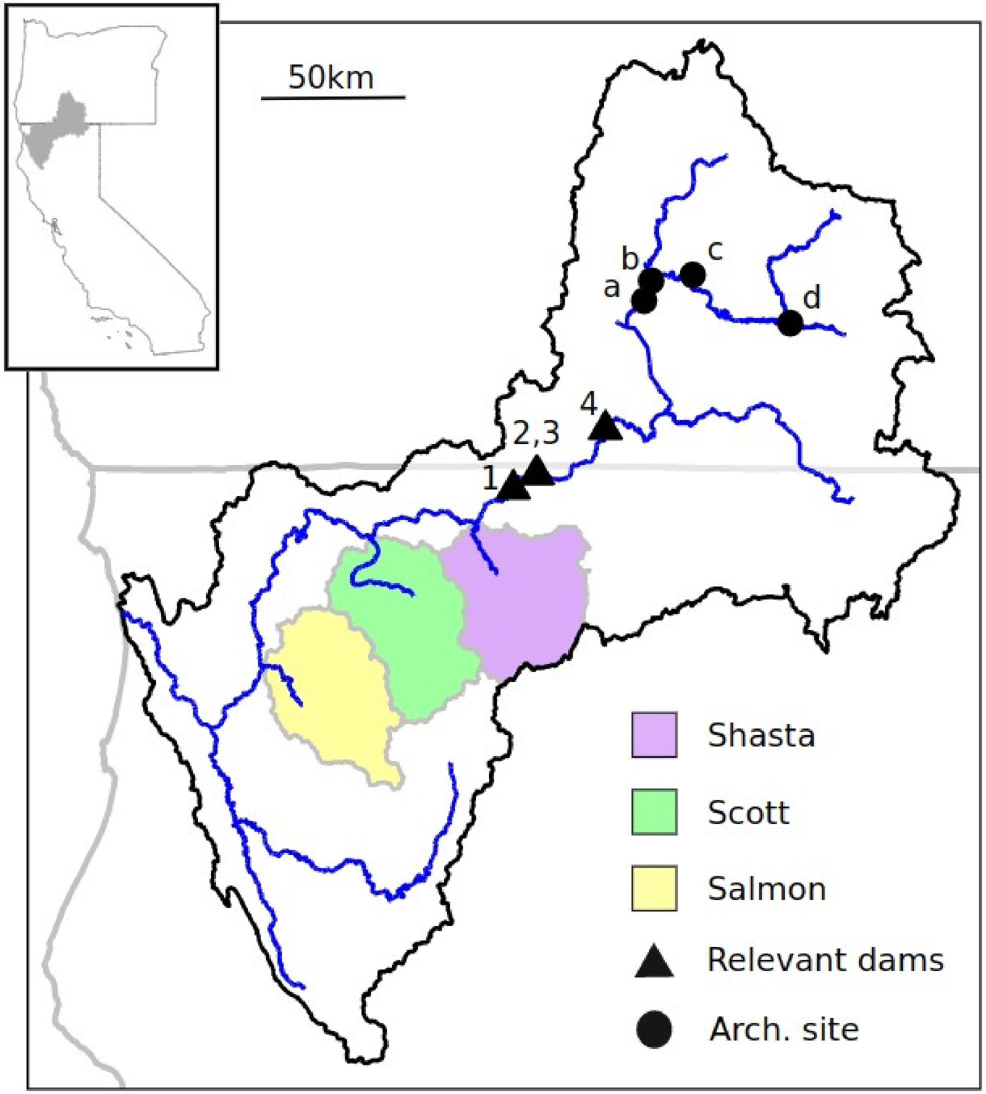
Thompson *et al.*, 2019

Historical documentation and genetic analysis of archaeological samples supports the presence of both spring-run and fall-run Chinook above the Klamath dams



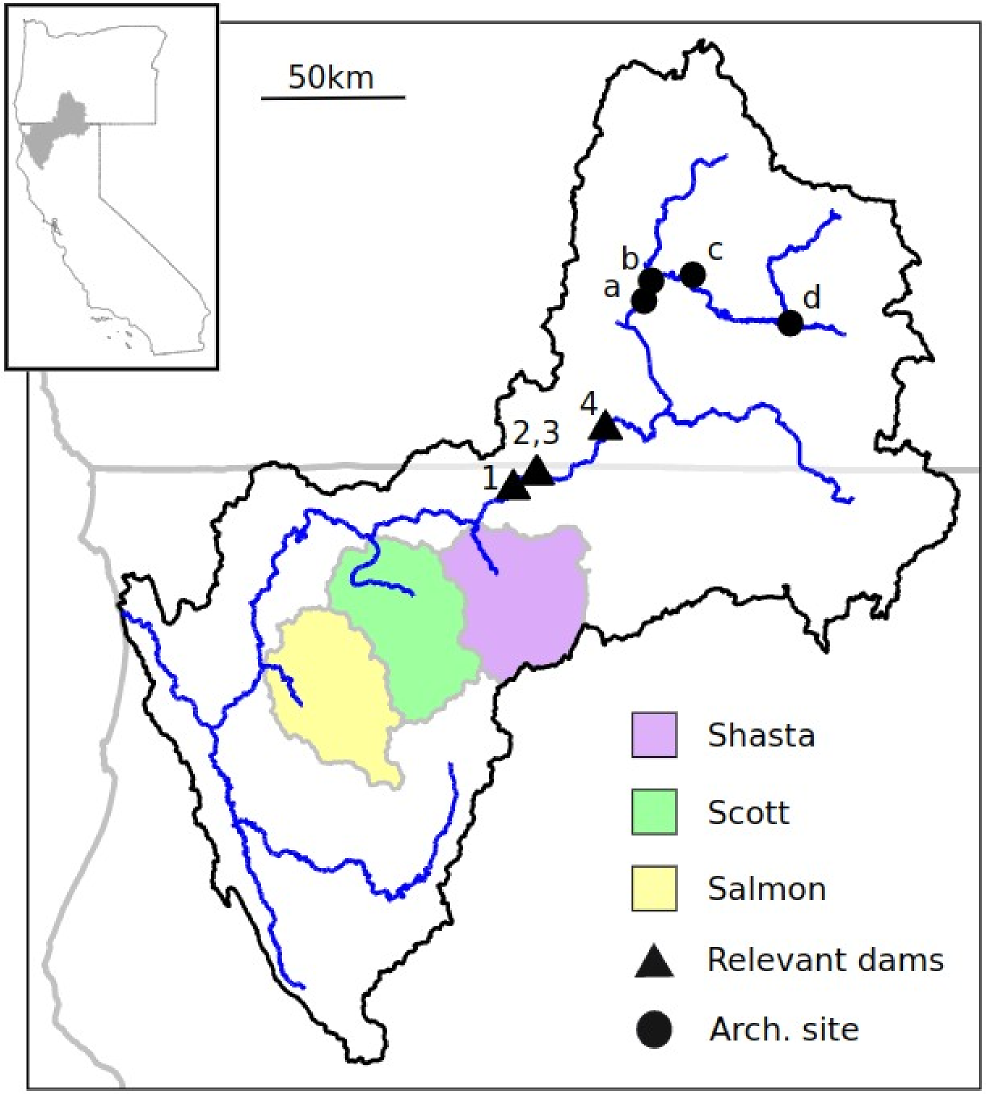
Thompson et al., *in prep*

Where are spring alleles for restoring upper Klamath spring Chinook going to come from?



Thompson *et al.*, 2019

Can heterozygotes serve as a reservoir of spring alleles to restore spring Chinook after dam removal?

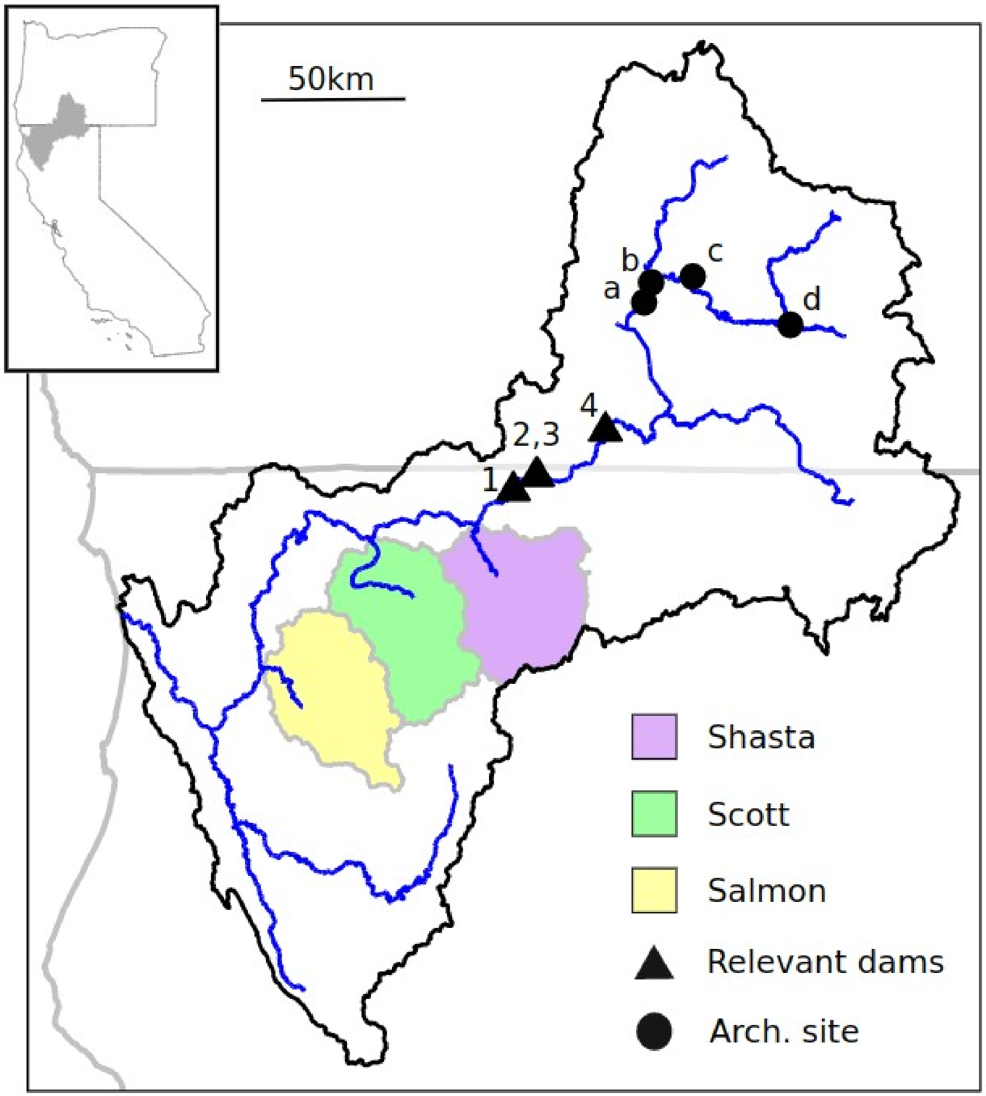


Shasta: spring Chinook extirpated in 1930's

Scott: spring Chinook extirpated in 1970's

Thompson *et al.*, 2019

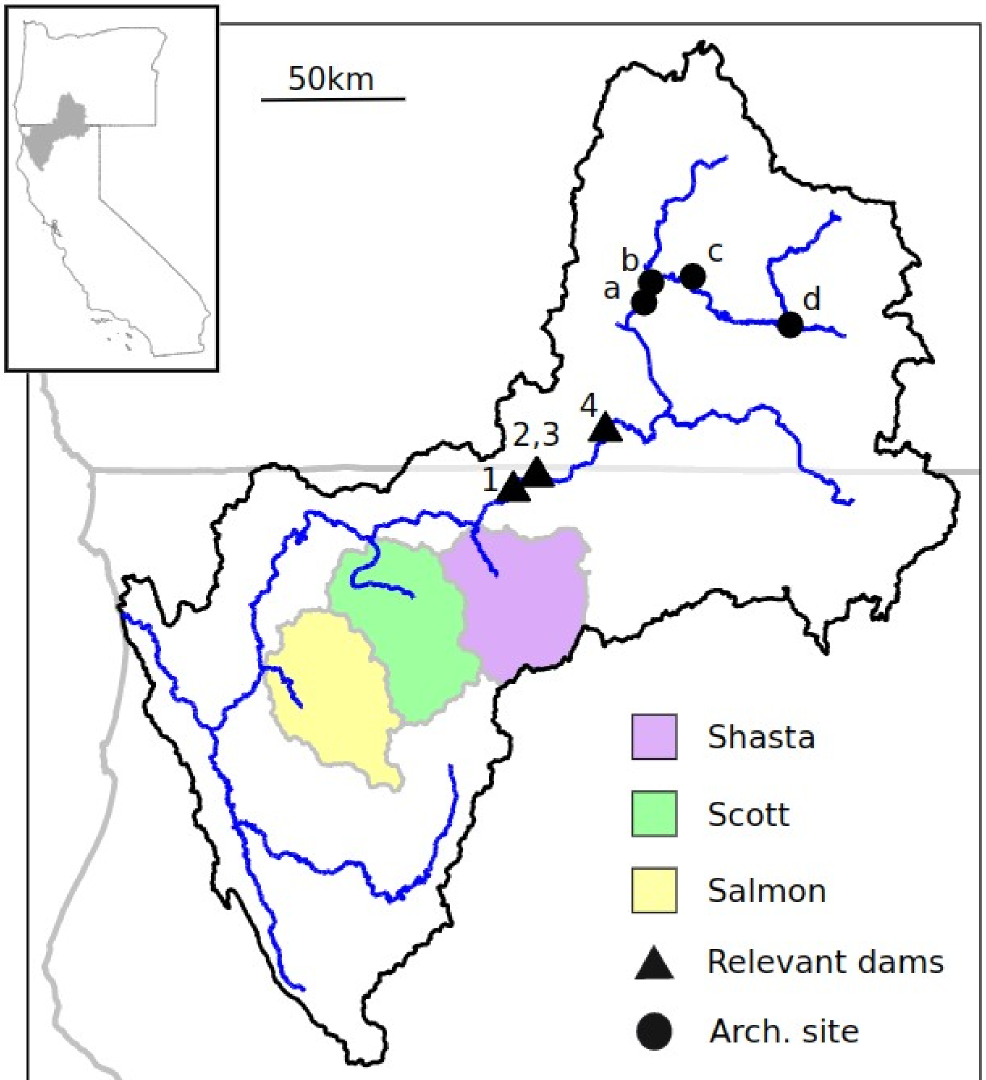
Genotyping smolt samples across juvenile outmigration period reveals spring allele frequencies in the Salmon, Shasta, and Scott



Location	Date spring Chinook last observed	Number of samples	Spring-run allele frequency
Salmon	present	116	**0.20**
Shasta	1930's	440	
Scott	1970's	432	

Thompson *et al.*, 2019

Spring alleles have not been maintained in the Shasta or Scott at frequencies that could be used to restore upper Klamath spring Chinook



Location	Date spring Chinook last observed	Number of samples	Spring-run allele frequency
Salmon	present	116	0.20
Shasta	1930's	440	**0.002 (~20 hets/year)**
Scott	1970's	432	**0.002 (~20 hets/year)**

Thompson *et al.*, 2019

Summary and conclusions

- Higher-resolution analysis of *GREB1L* led to discovery of new markers for migration type
- Validation of markers indicates they appear to be diagnostic for spring vs. fall migration type
- Markers could be useful for monitoring and informing spring-run management in the in the Salmon River
- Both spring and fall Chinook were found in ancient samples from above Klamath dams
- Heterozygotes are not acting as reservoirs of spring-run alleles in tributaries that have lost the spring-run phenotype
- The decline of spring-run Chinook can make restoration challenging even when the spring-run still exists in the basin

Acknowledgments

- Renee M. Bellinger
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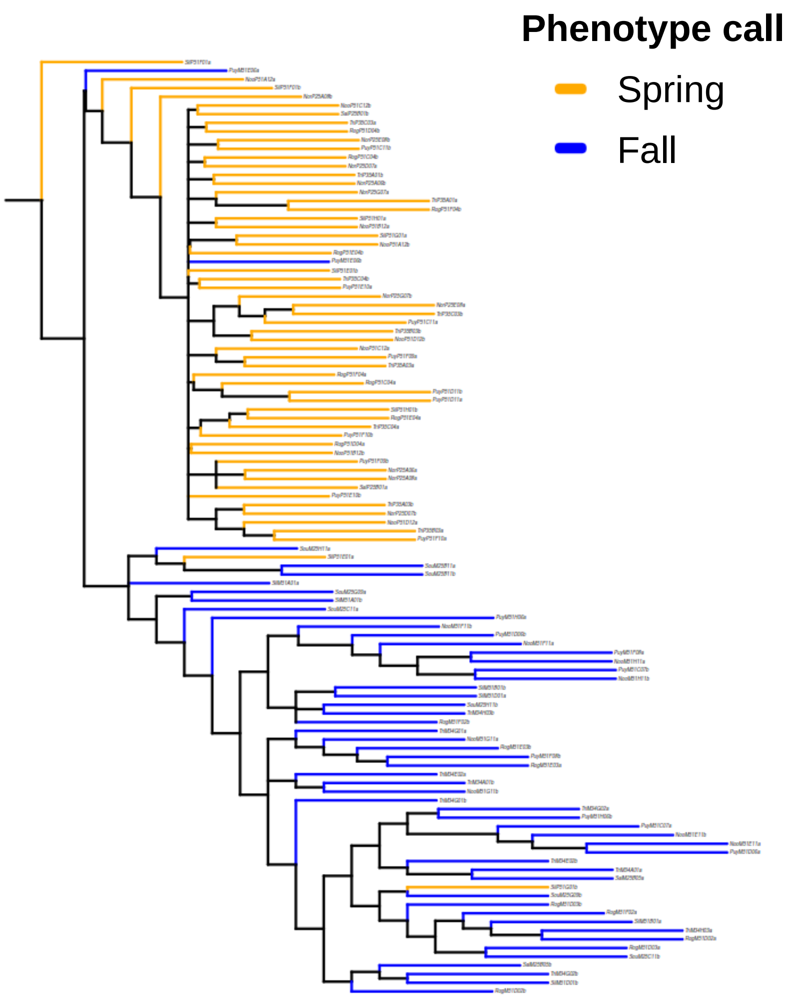
- Michelle Pepping
- Alexander E. Stevenson
- Antonia T. Rodrigues
- Matthew R. Sloat
- Camilla F. Speller
- Dongya Y. Yang
- Virginia L. Butler
- Michael A. Banks
- Michael R. Miller

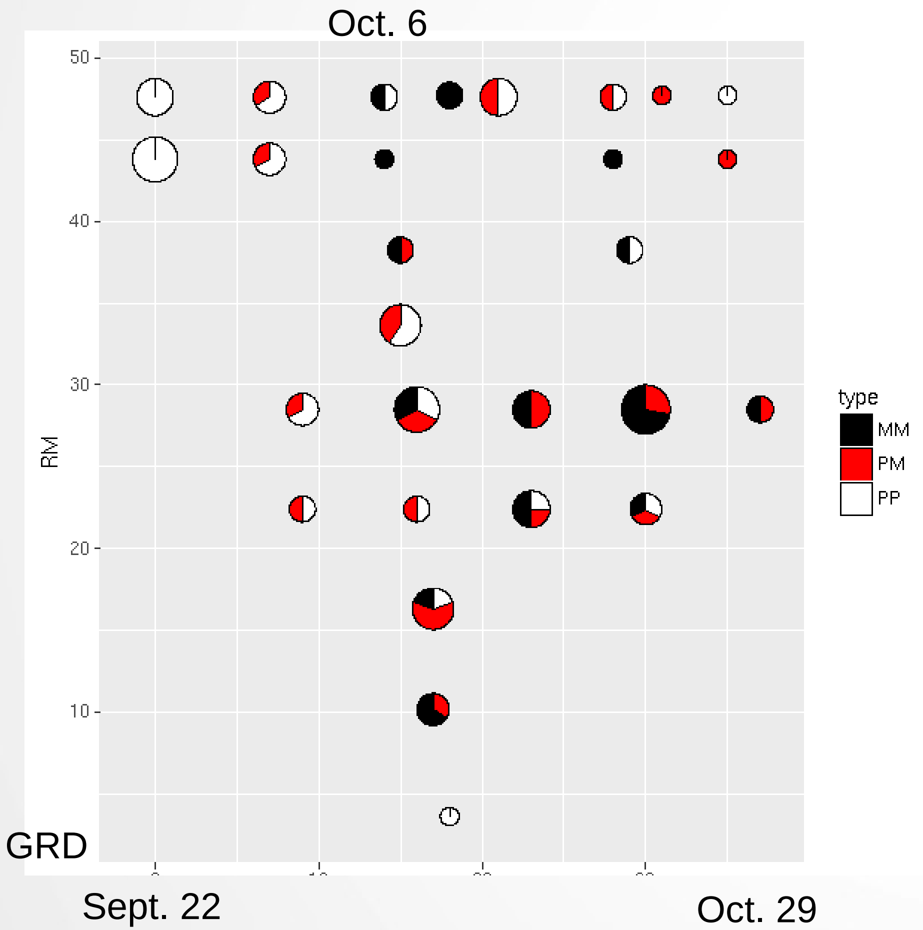
- **Many, many more!!!**

Evolutionary analysis of coastal Chinook reveals monophyletic origin for spring-run alleles

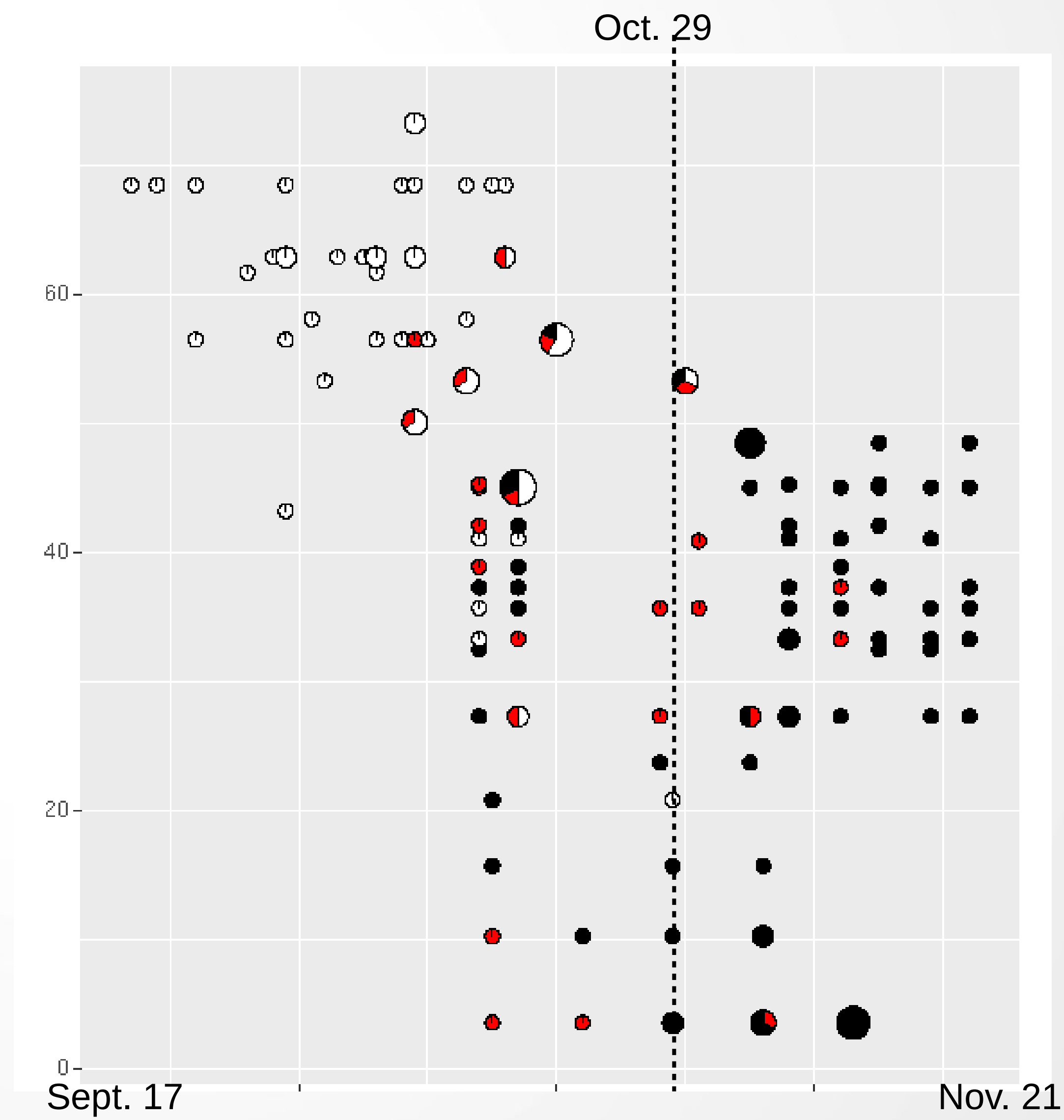


Rogue and Salmon River carcass survey genotyping results

Rogue River

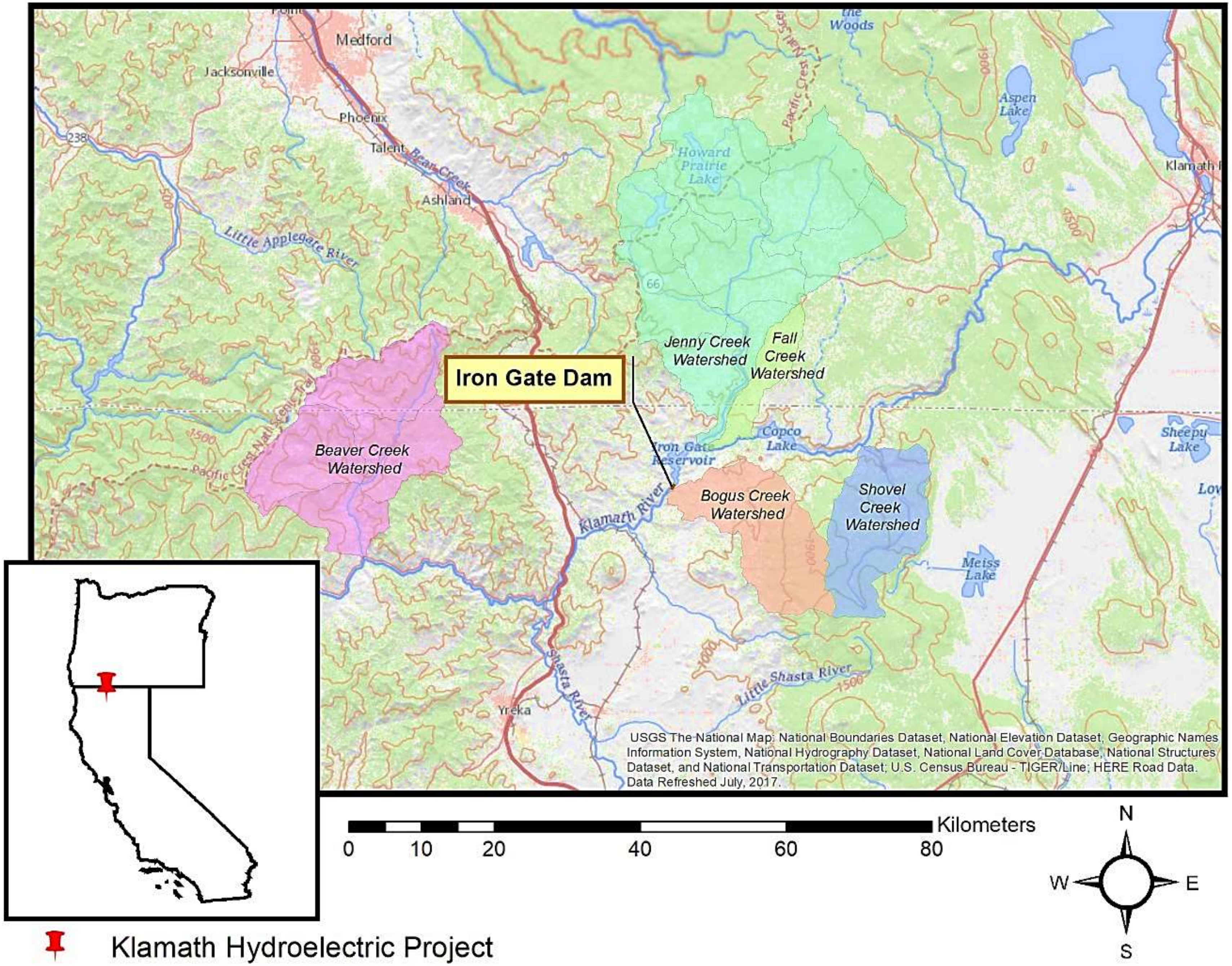


Salmon River

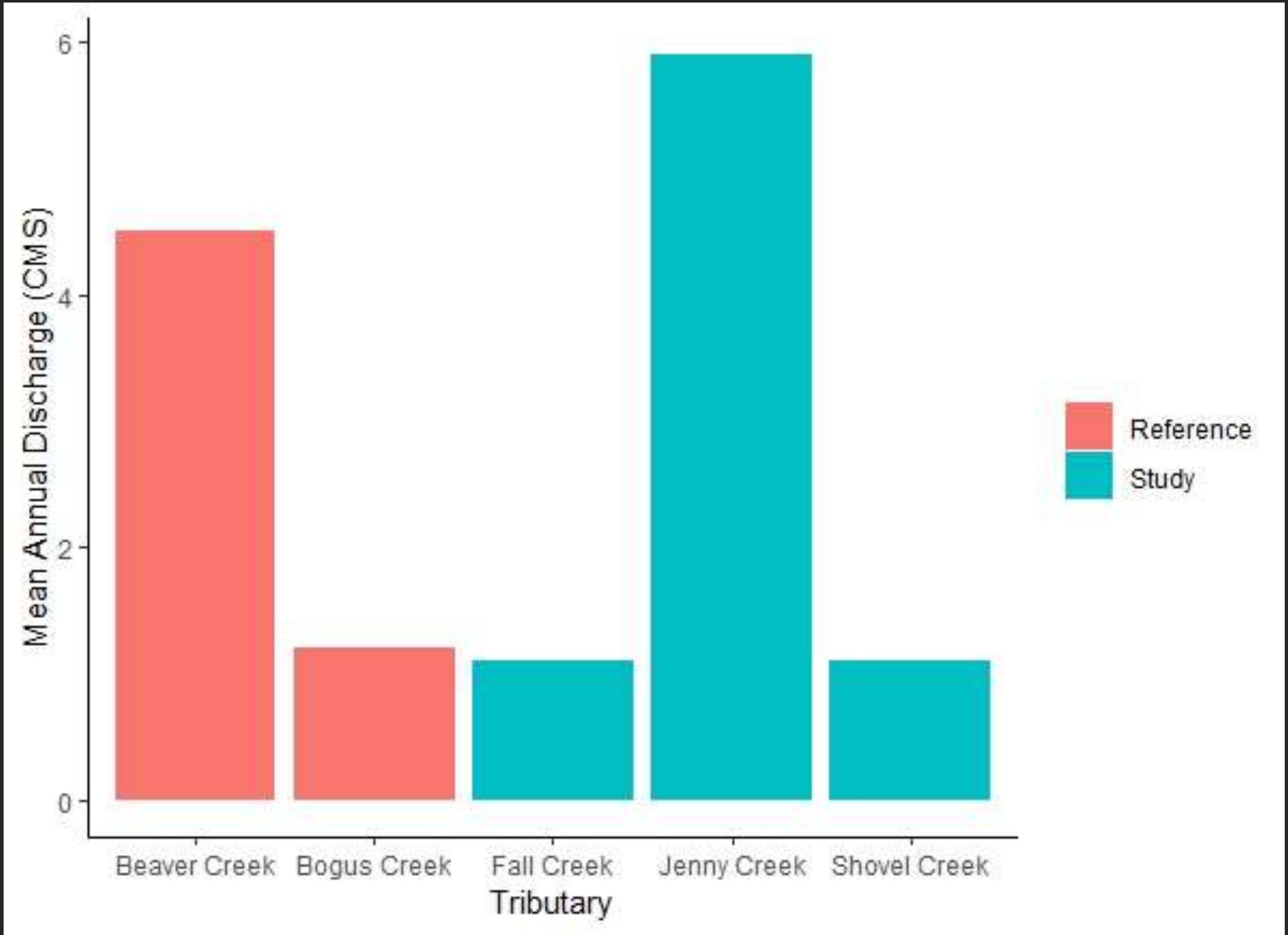


Recolonization Potential of Coho Salmon in Tributaries to the Klamath River Post-Dam Removal

Max Ramos &
Dr. Darren Ward
Humboldt State University
Fisheries Biology
Department of Natural Resources


Medford
Jacksonville
Phoenix
Talent
Bear Creek
Ashland
Little Applegate River
Howard Prairie Lake
Aspen Lake
Jenny Creek Watershed
Fall Creek Watershed
Iron Gate Dam
Copco Lake
Iron Gate Reservoir
Beaver Creek Watershed
Bogus Creek Watershed
Shovel Creek Watershed
Klamath River
Sheepy Lake
Meiss Lake
Shasta River
Little Shasta River
Yreka
USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line; HERE Road Data. Data Refreshed July, 2017.
Kilometers
0 10 20 40 60 80
N
W
E
S
Klamath Hydroelectric Project

Mean Annual Flow

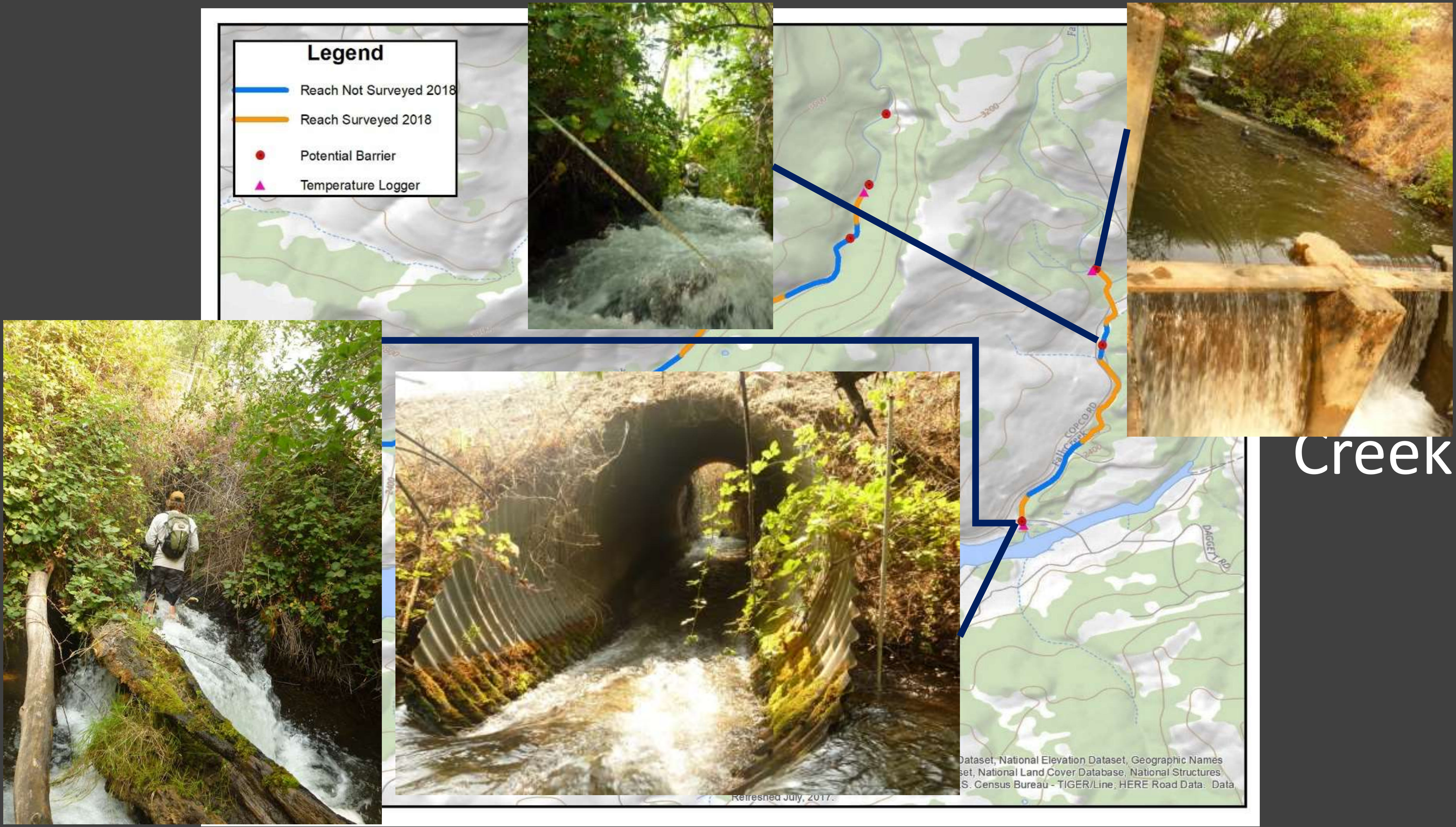


What is the potential for three tributaries to the Klamath River above Iron Gate Dam to support the recolonization of coho salmon (*Oncorhynchus kisutch*)?

Habitat Limiting Factors Model (HLFM);

Intrinsic Potential (IP) Model;

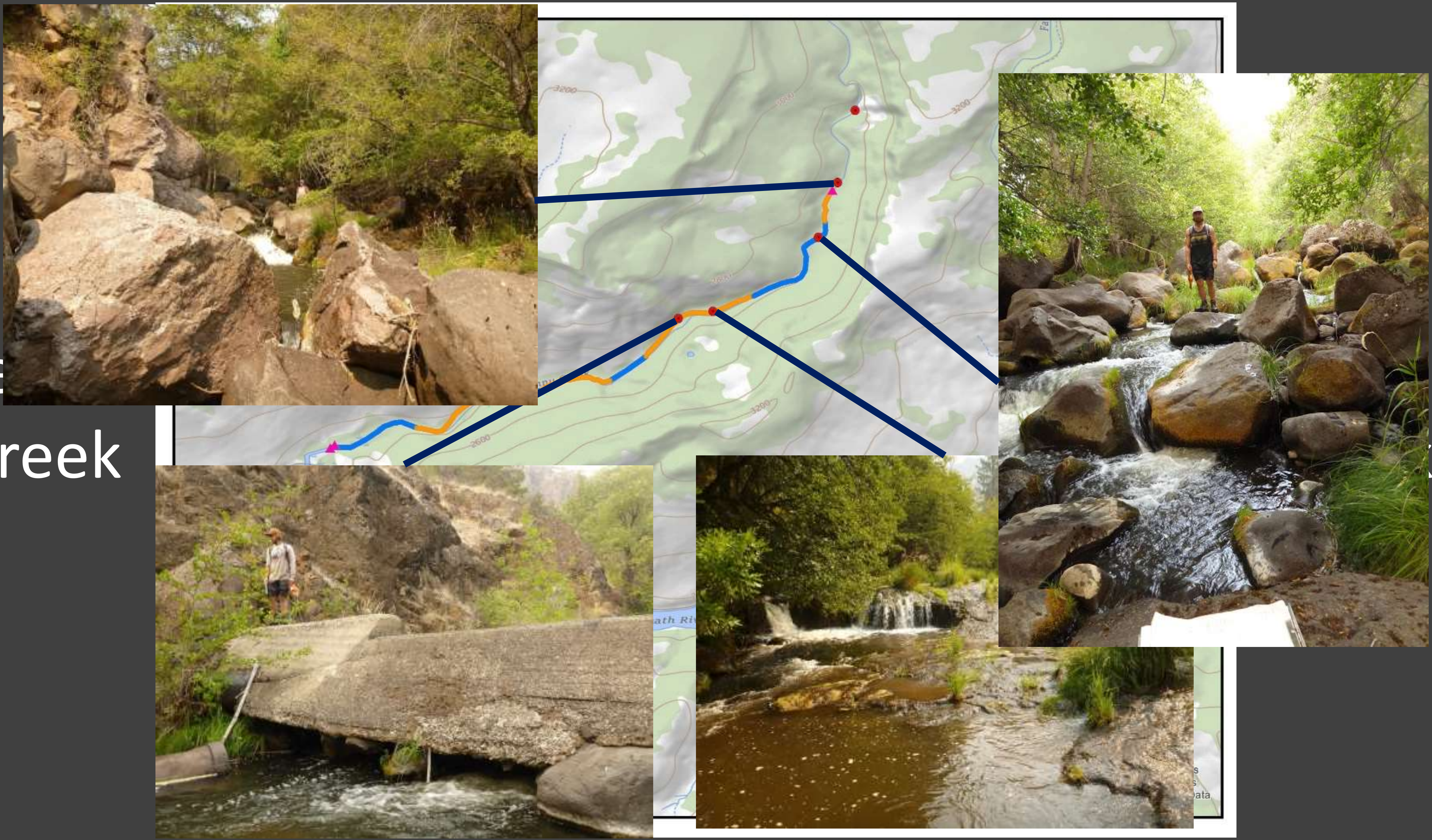
Single-Season Occupancy Model (In Development).

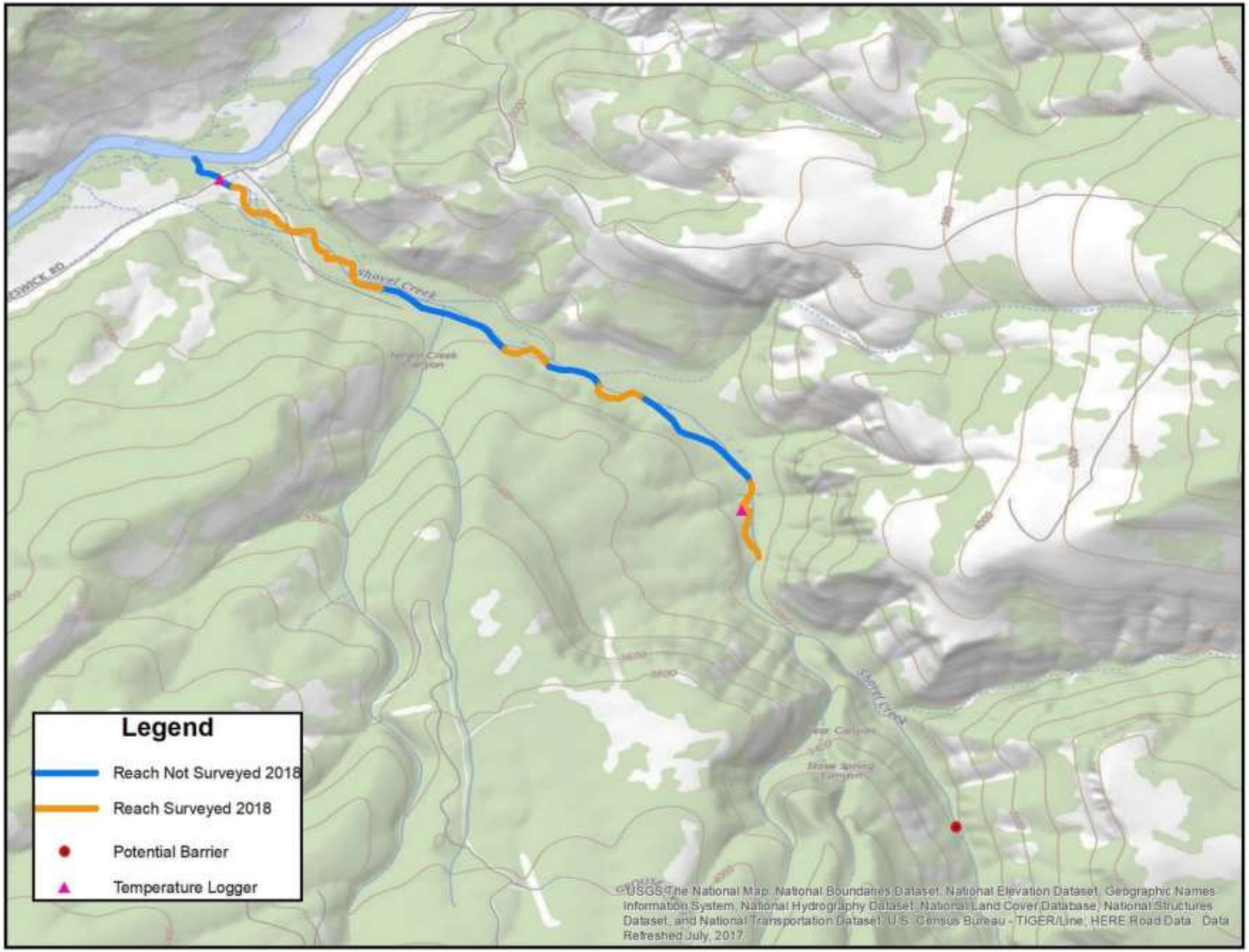

Legend
Reach Not Surveyed 2018
Reach Surveyed 2018
Potential Barrier
Temperature Logger
COPCO RD
DAGGETT RD
Dataset, National Elevation Dataset, Geographic Names
set, National Land Cover Database, National Structures
S. Census Bureau - TIGER/Line; HERE Road Data. Data
Refreshed July, 2017.

Creek

Je

Creek

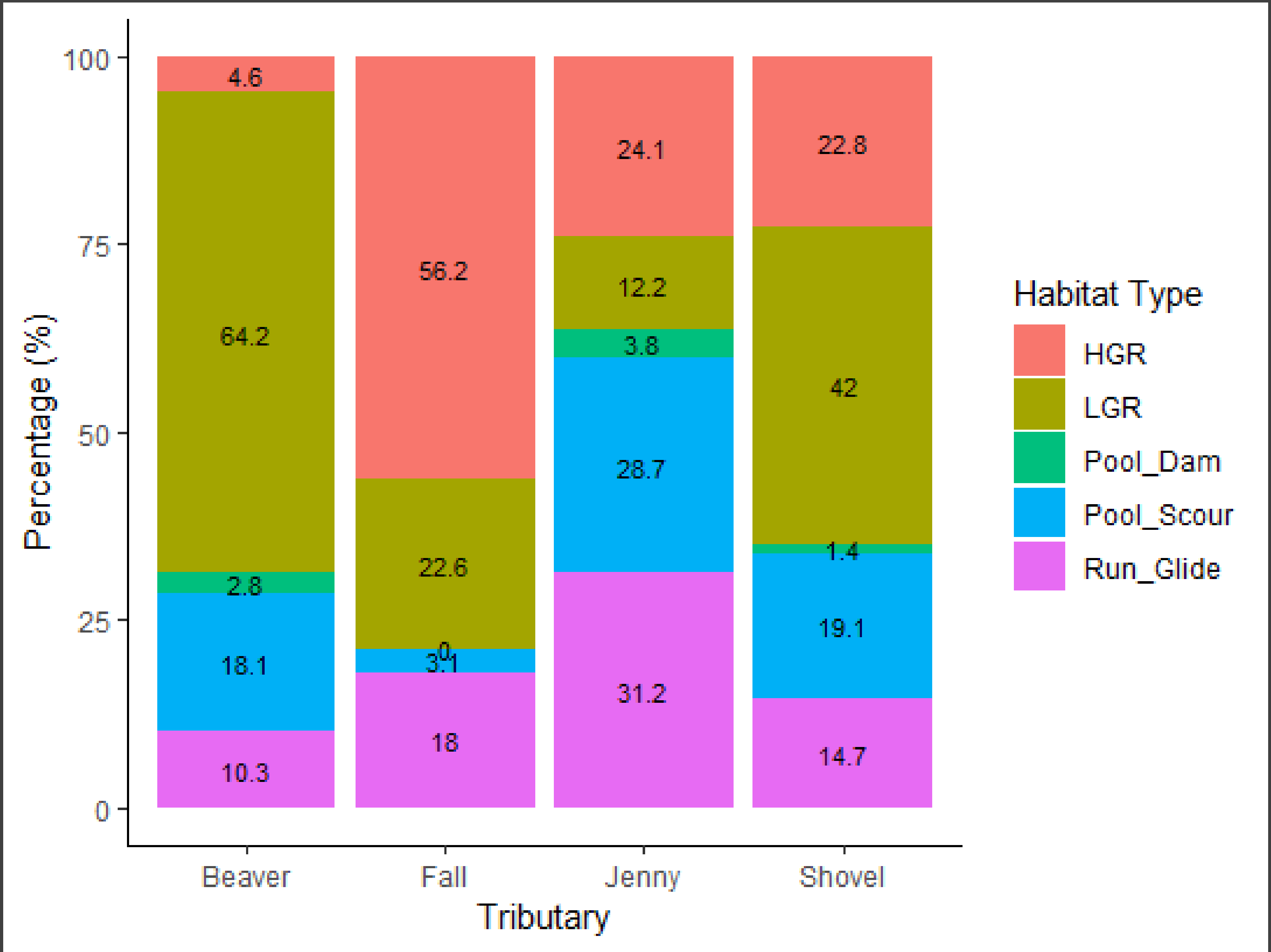




Shovel Creek

Beaver and Bogus creeks


7 8 9 10



HGR = High Gradient Riffle

LGR = Low Gradient Riffle

Pool_Dam = Dammed Pool

Pool_Scour = Scoured Pool

Run_Glide = Run or Glide

HLFM Structure

Juvenile density (#/m^2) by habitat type

Habitat type	Summer
Cascades	0.2
Rapids	0.1
Riffles	0.1
Glides	0.8
Trench pools	1.8
Plunge pools	1.5
Lateral scour pools	1.7
Mid-channel scour pools	1.7
Dammed pools	1.8
Alcoves	0.9
Beaver ponds	1.8
Backwater pools	1.2

Tributary	Length (m)	Total Summer Juvenile Rearing Capacity	Capacity/meter
Jenny	3,300	24,000	7.3
Fall	1,800	4,400	2.5
Shovel	3,200	10,200	3.2

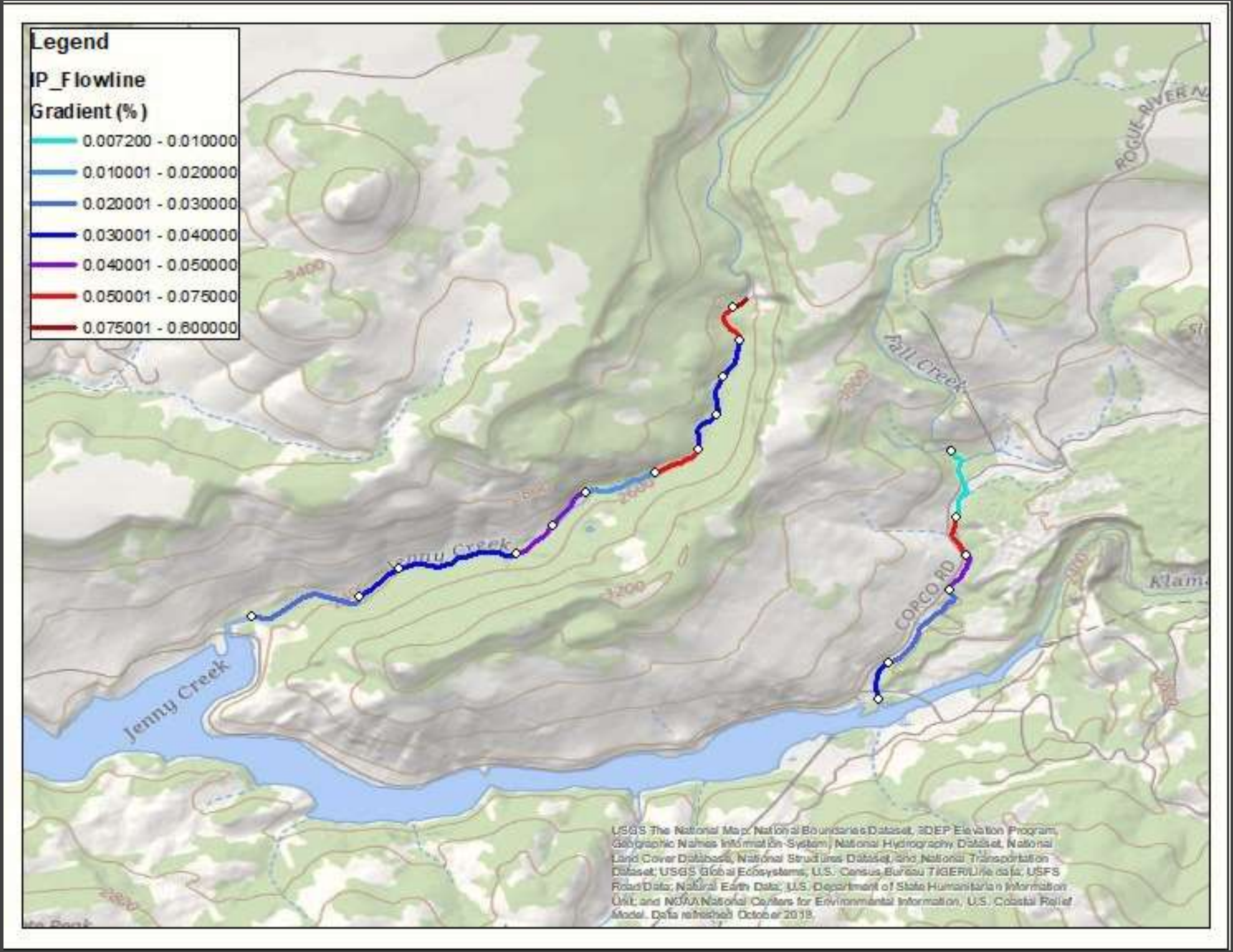
HLFM RESULTS

IP Model Structure

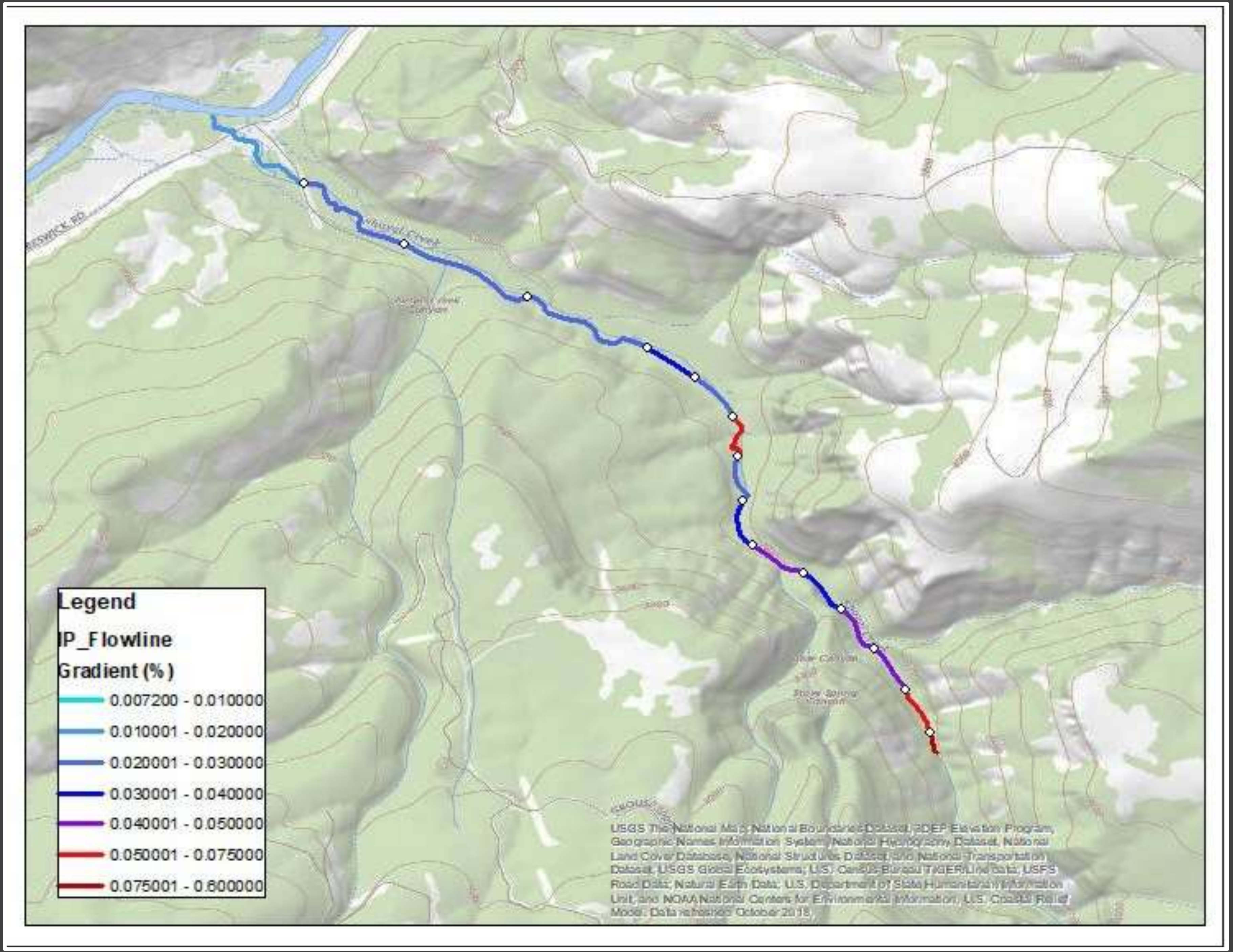
1. Mean Annual Flow (m^3/s)
2. Instream Channel Gradient (%)
3. Valley Width Index

*Geospatial Information System (GIS) based approach

Jenny Creek

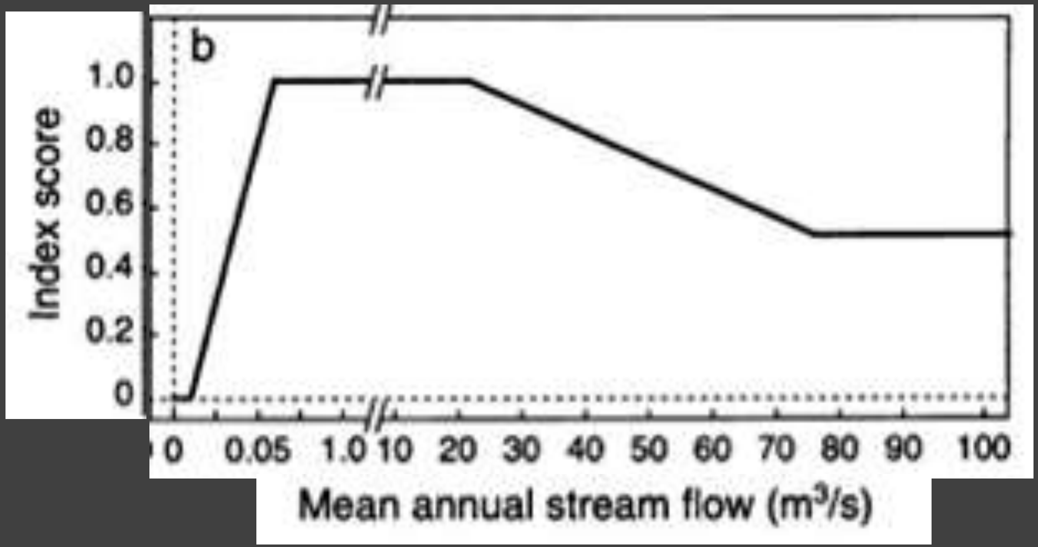


Fall Creek



Shovel Creek

Mean Annual Flow(f_D)



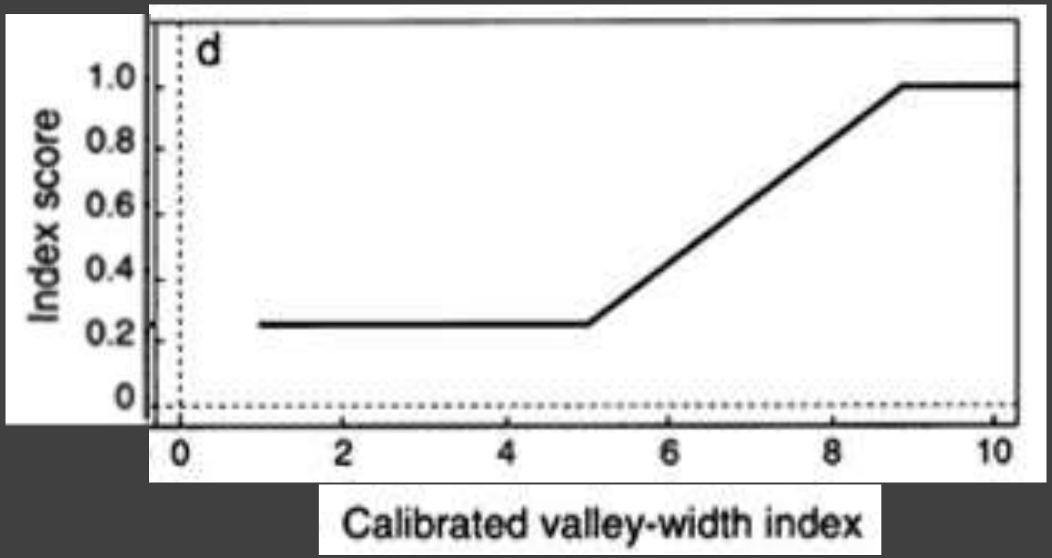
$$IP_D = (f_D * D_k)$$

$$IP_V = (f_V * V_k)$$

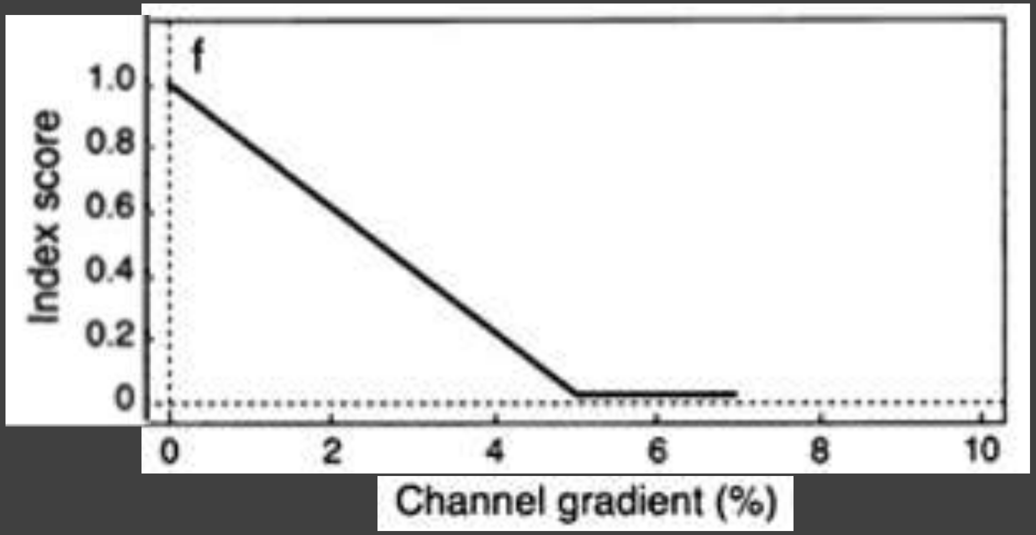
$$IP_G = (F_G * G_k)$$

$$IP_{score} = (IP_D * IP_V * IP_G)^{1/3}$$

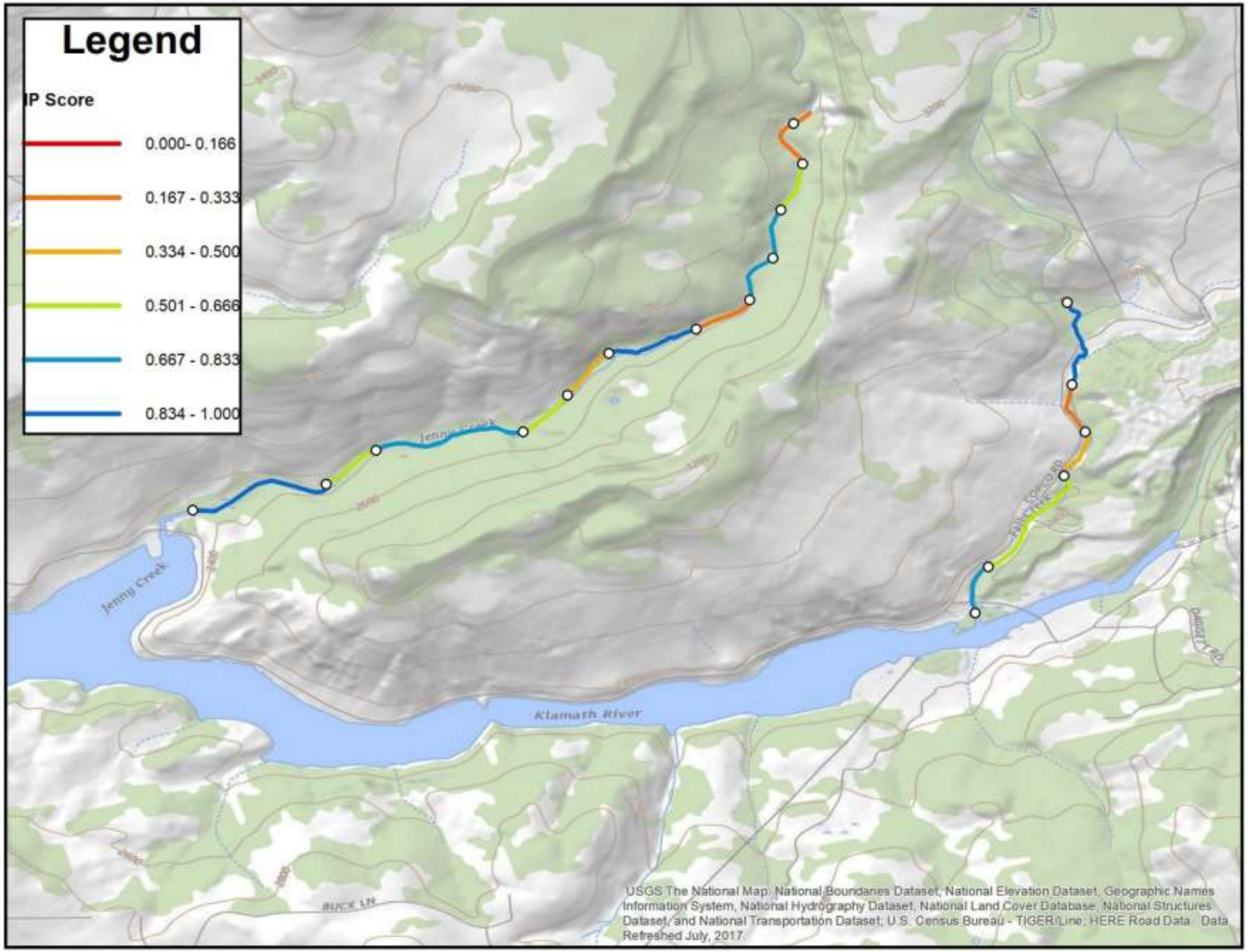
Valley Width Index (f_V)



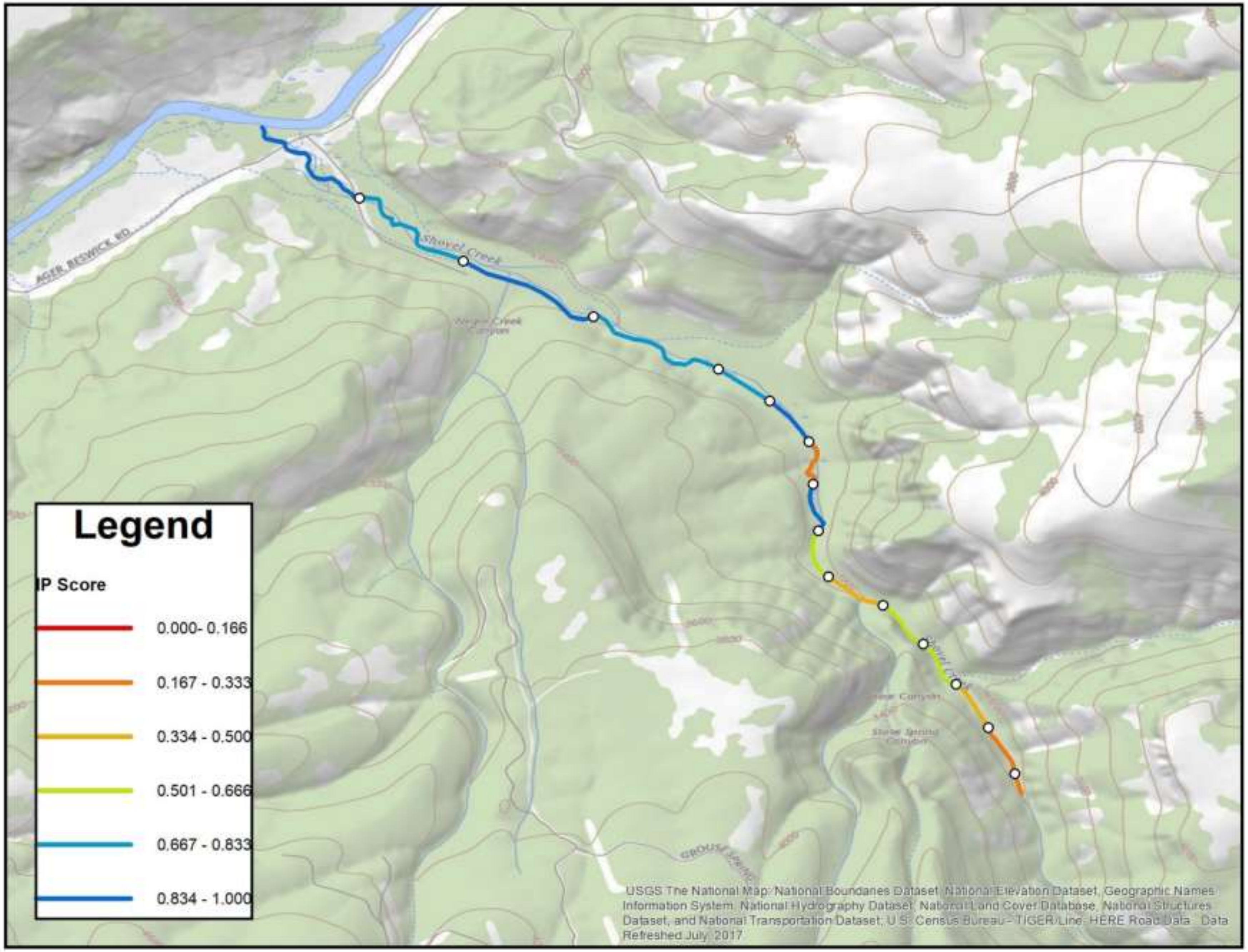
Channel Gradient (f_G)



Jenny Creek



Fall Creek



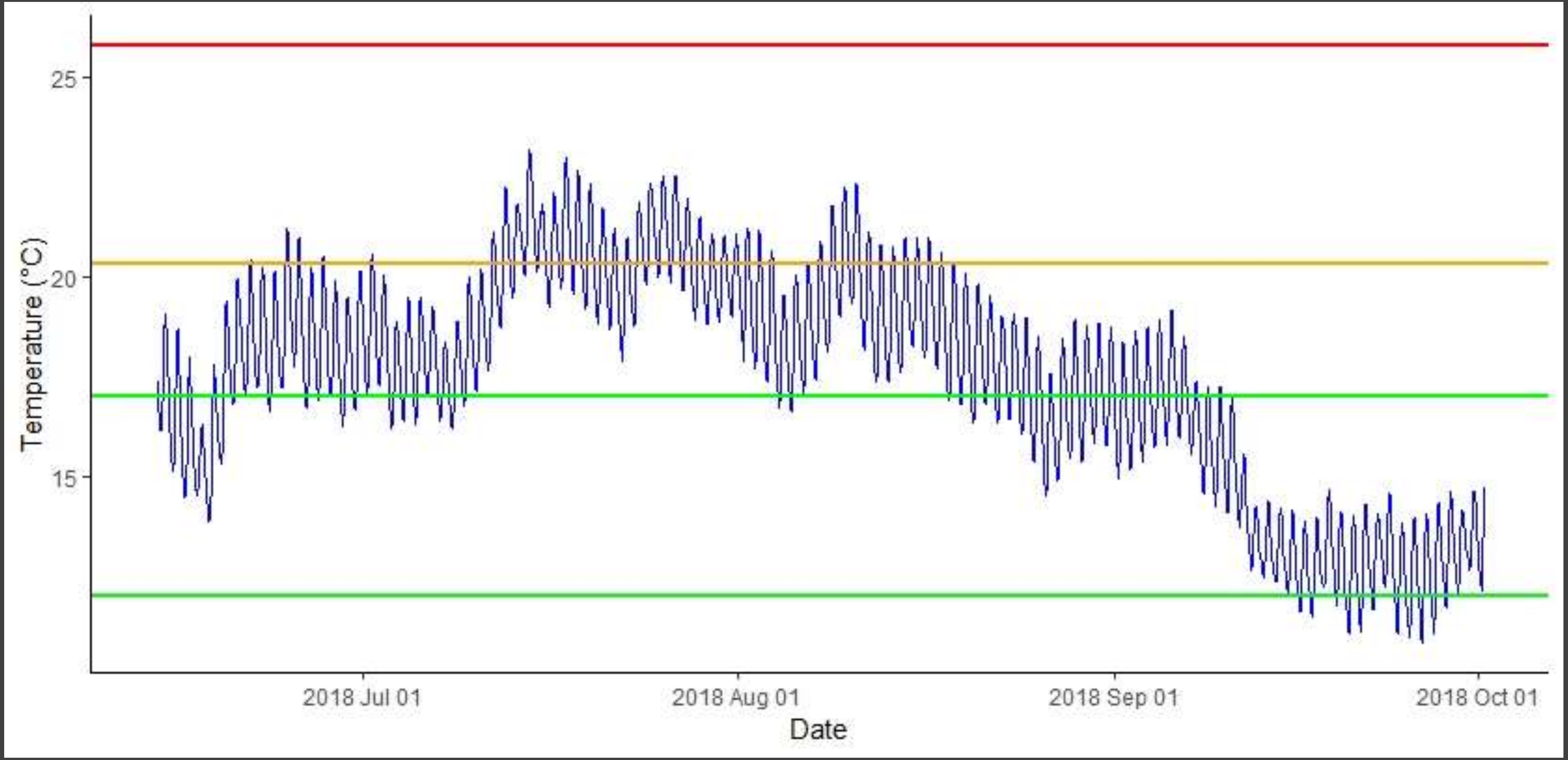
Shovel Creek

Tributary:	Jenny	Fall	Shovel
IP meters (m)	2100	1100	3100

IP Results

Jenny Creek

Upper Lethal Temperature (UTL) = 25.8 °C

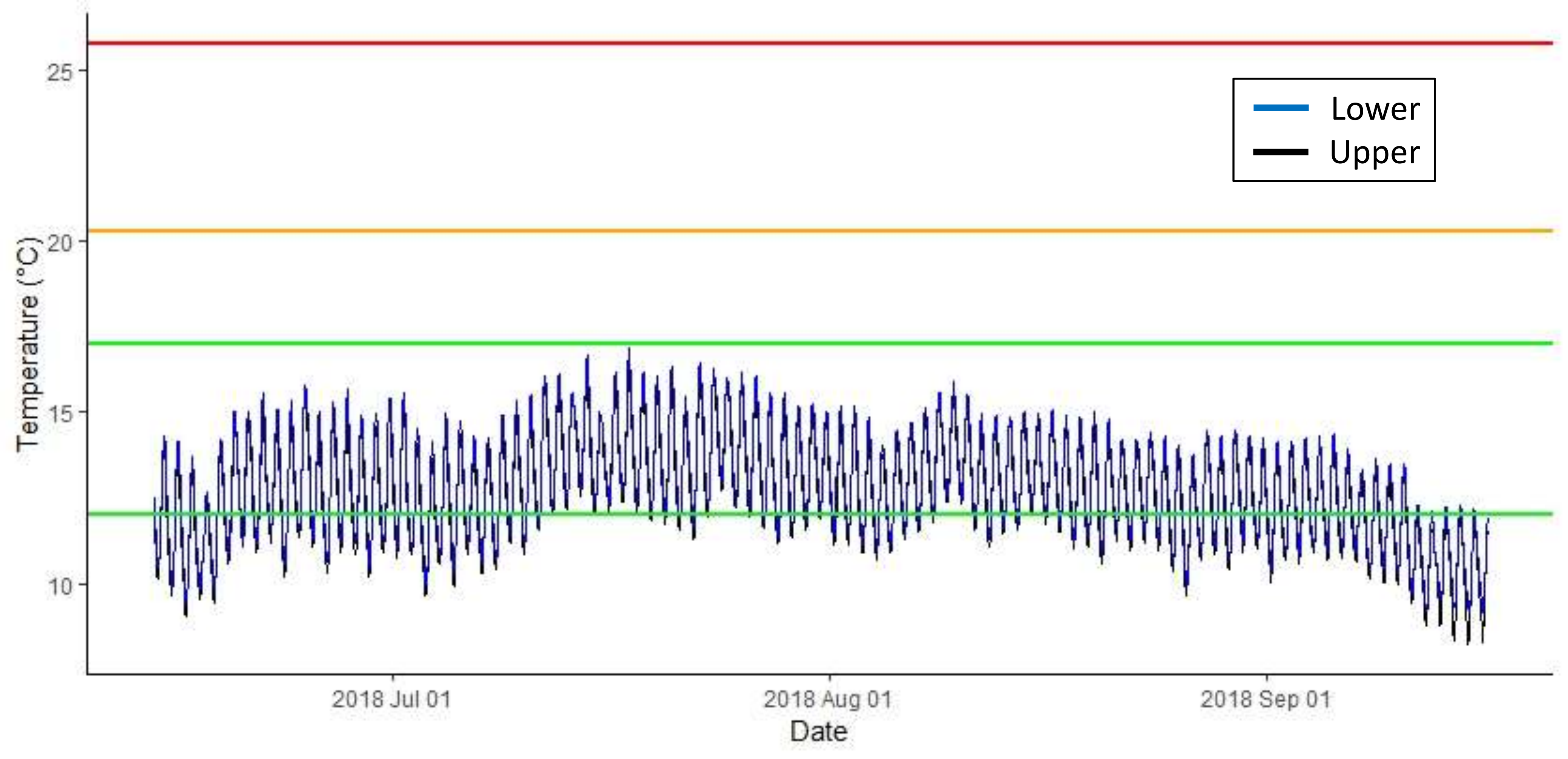


Cessation of growth = 20.3 °C

Recommended range for juvenile coho rearing = 12 - 17 °C

*Thermal limits established by Richter et al. 2005

Fall Creek



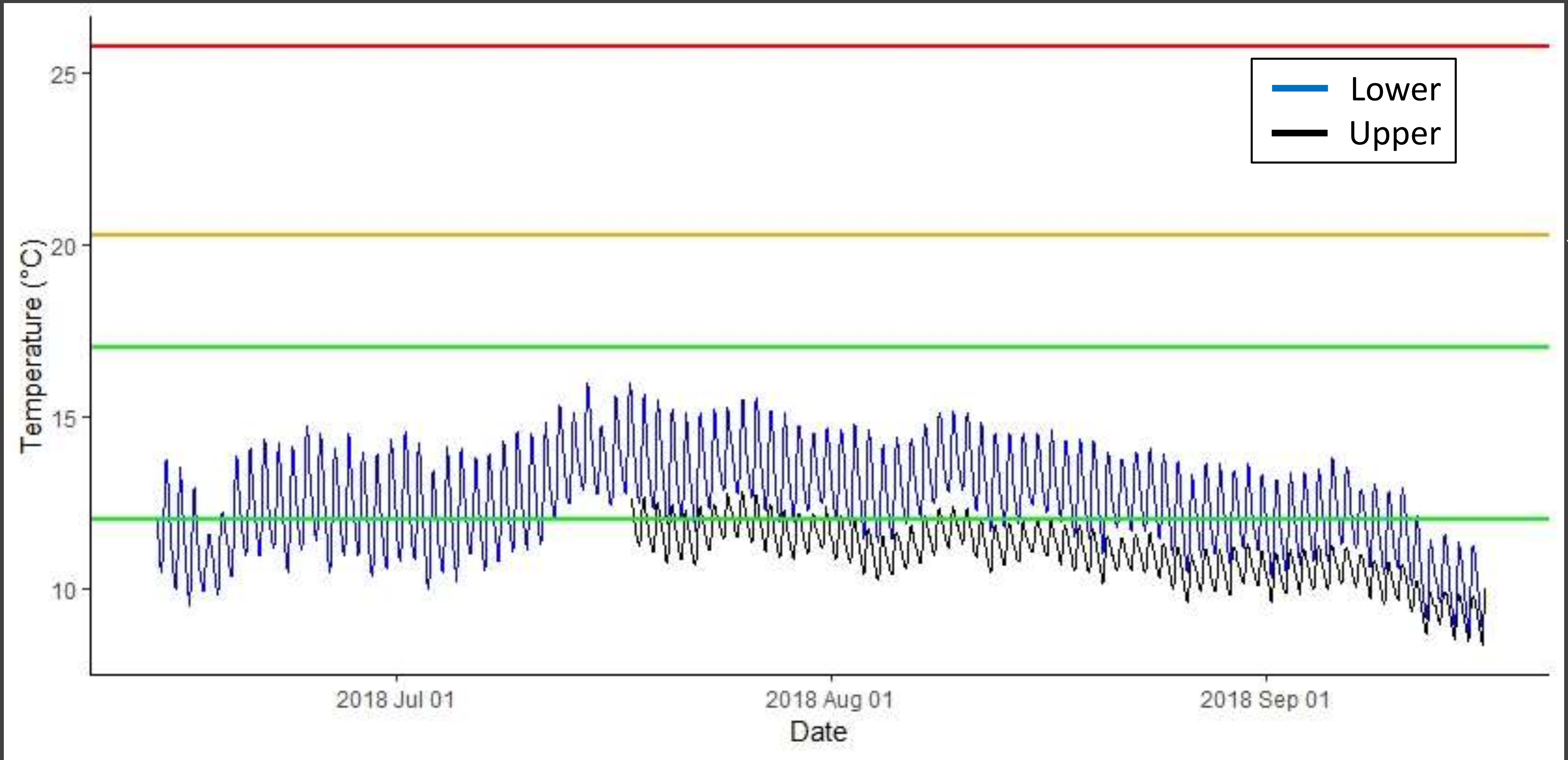
Upper Lethal Temperature (UTL) = 25.8 °C

Cessation of growth = 20.3 °C

Recommended range for juvenile coho rearing = 12 - 17 °C

*Thermal limits established by Richter et al. 2005

Shovel Creek



Upper Lethal Temperature (UTL) = 25.8 °C

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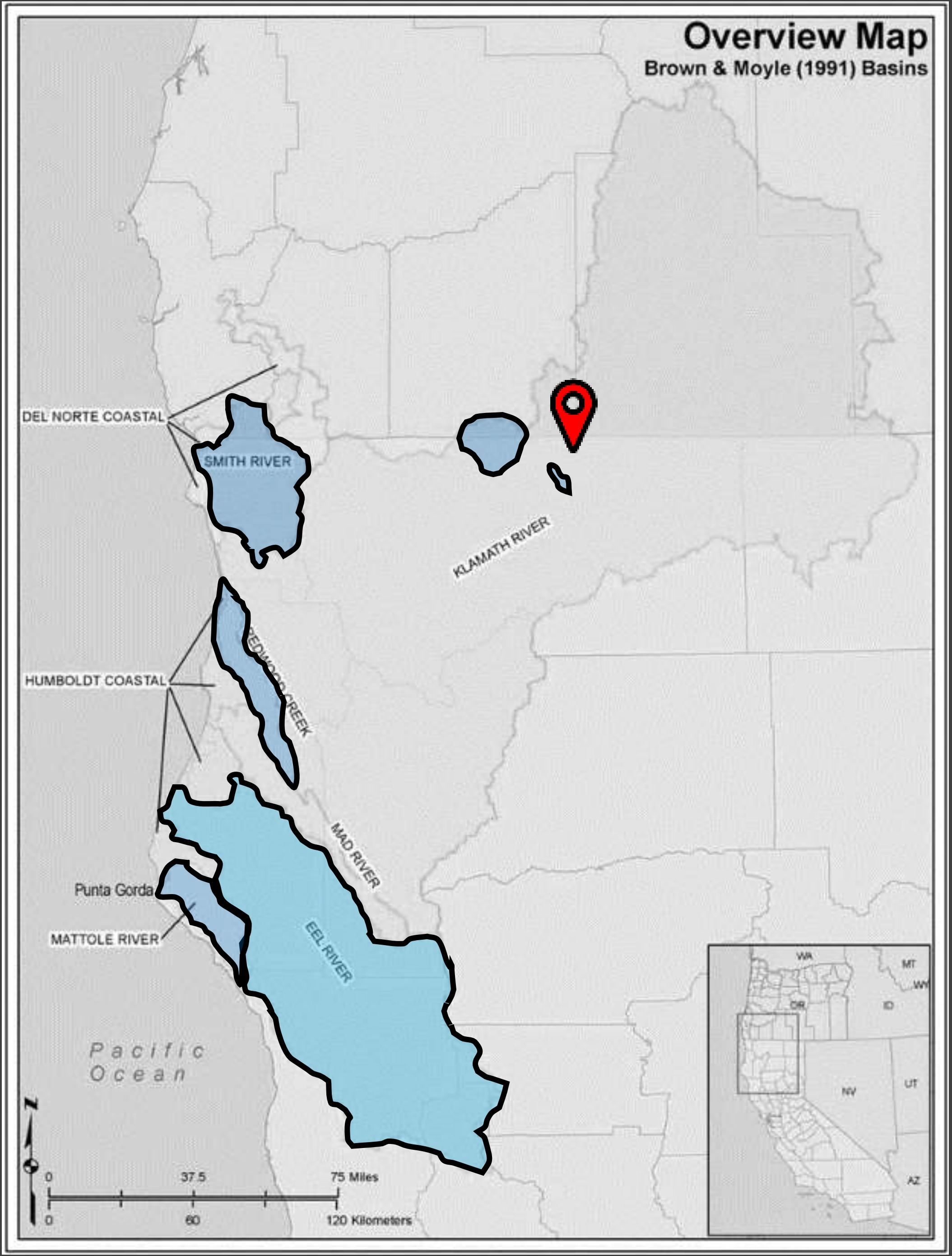

Overview Map
Brown & Moyle (1991) Basins
DEL NORTE COASTAL
SMITH RIVER
KLAMATH RIVER
REDWOOD CREEK
HUMBOLDT COASTAL
MAD RIVER
EEL RIVER
Punta Gorda
MATTOLE RIVER
Pacific Ocean
N
0
37.5
75 Miles
0
60
120 Kilometers
WA
MT
OR
ID
WY
NV
UT
AZ

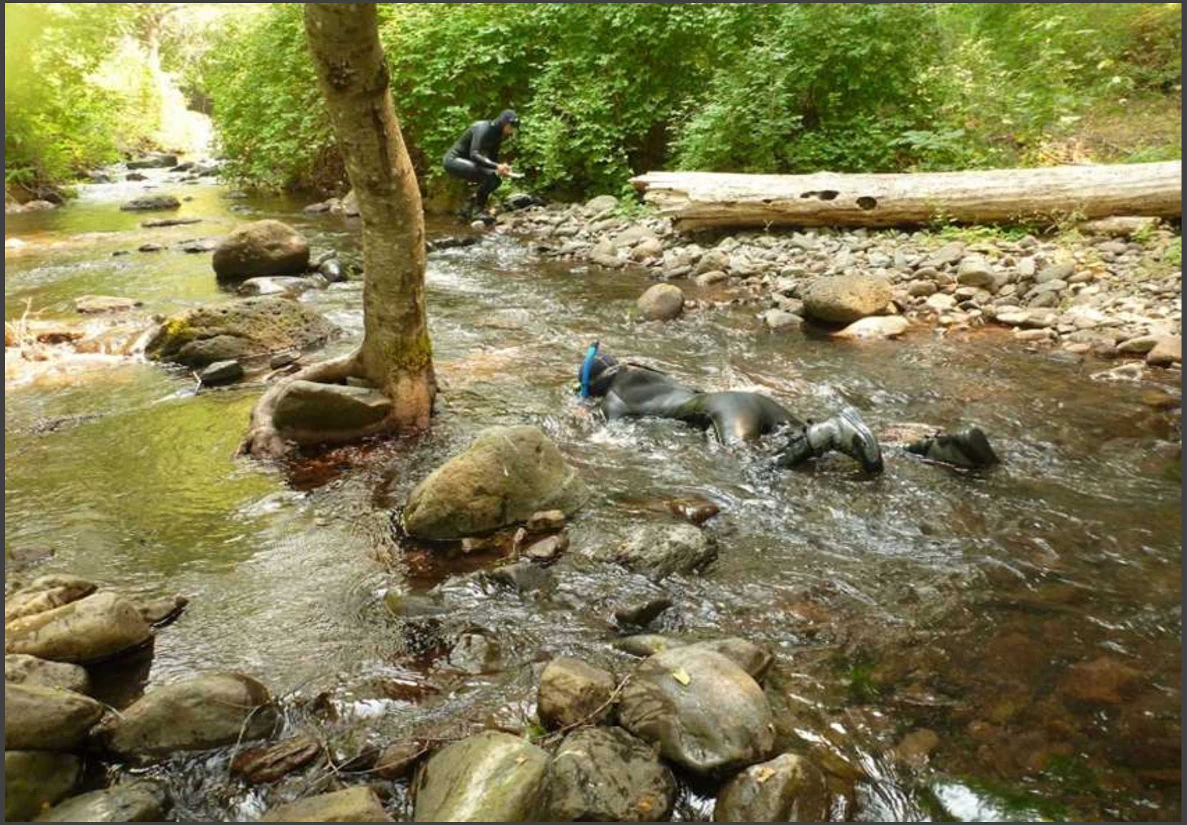
Single-Season Occupancy Model Structure

Covariates

1. Water temperature
2. Maximum pool depth
3. Gradient
4. Valley width
5. Instream cover
6. Pool area
7. Mean annual flow
8. Large woody debris

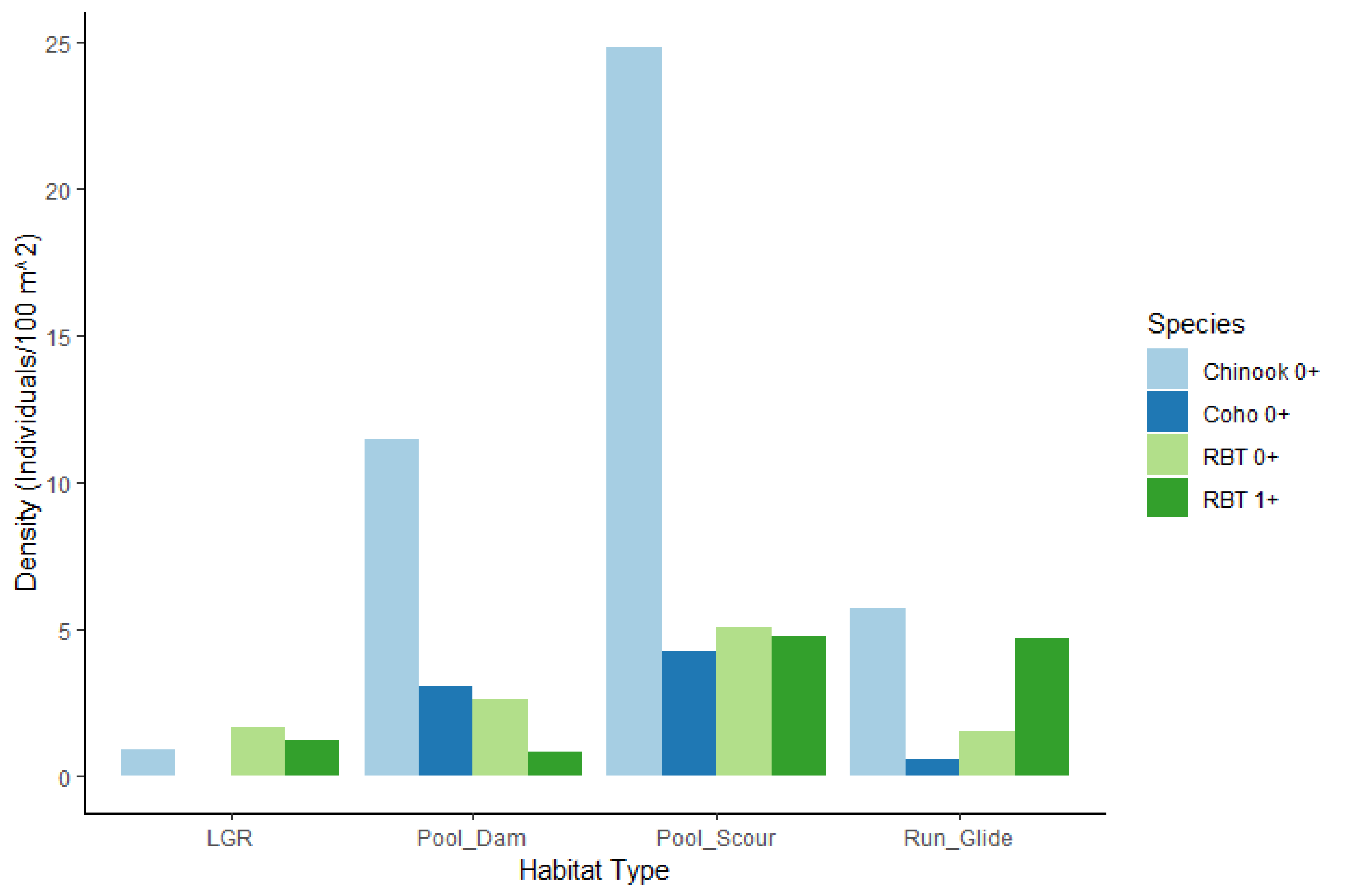
Response

- Juvenile coho salmon occupancy




Snorkel Surveys – Summer 2018

Beaver Creek



Conclusions

Model Ranking	Jenny Creek	Fall Creek	Shovel Creek
HLFM Ranking	1	3	2
IP Model Ranking	2	3	1

Factor	Jenny Creek	Fall Creek	Shovel Creek
Summertime Juvenile Rearing **Temperature**			
Barriers to Summertime **Juvenile Fish Passage**			
Barriers to **Adult Fish Passage**			

Planned Work - Summer 2019

1. Stable isotope sampling
   a. Macroinvertebrates
   b. Riparian arachnids
   c. Riparian vegetation
   d. Resident fishes

2. Resident fish sampling
   a. Snorkel surveys
   b. E-fishing

Future Research

Food Availability

Interspecific Competition

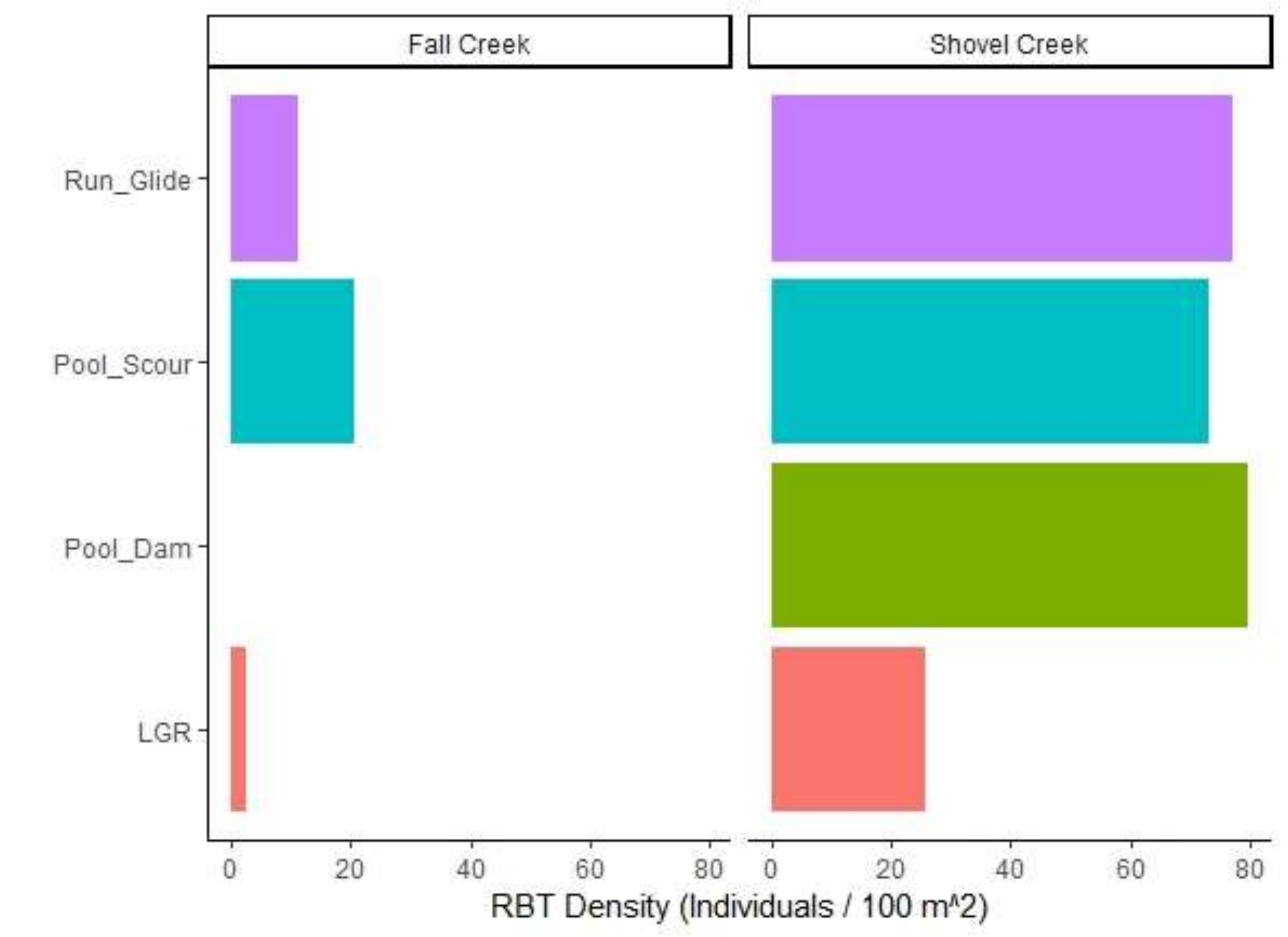
Terrestrial Predation and Piscivory

Future Research

Food Availability

Interspecific Competition

Terrestrial Predation and Piscivory


Fall Creek
Shovel Creek
Run_Glide
Pool_Scour
Pool_Dam
LGR
0
20
40
60
80
0
20
40
60
80
RBT Density (Individuals / 100 m^2)

Future Research

Food Availability

Interspecific Competition

Terrestrial Predation and Piscivory

Future Research

Food Availability

Interspecific Competition

Terrestrial Predation and Piscivory

Special Thanks To:

Justin Garwood, Morgan Knechtle & Seth Ricker - CDFW

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Mark Hampton & Tommy Williams - NOAA

Mark Hereford & William Tinniswood - ODFW

Demian Elbert - PacifiCorp

Nicholas Chischilly - rroulou’sik REU

Serena Doose - USFWS

EVIDENCE FOR THE GENETIC-BASIS AND EPISTATIC INTERACTIONS UNDERLYING OCEAN- AND RIVER-MATURING ECOTYPES OF PACIFIC LAMPREY (*ENTOSPHENUS TRIDENTATUS*) RETURNING TO THE KLAMATH RIVER, CALIFORNIA

Keith A. Parker, Humboldt State University and The Yurok Tribe

Graduate Research Fellowship Program

Co-authors: Jon E. Hess and Shawn R. Narum - CRITFC
Andrew P. Kinziger - Humboldt State Univ.

ROBERT & PATRICIA SWITZER FOUNDATION

Introduction

- The Yurok, Hupa, Karuk, Shasta, Modoc, Klamath, and Yahooskin: Native American Tribe’s located within the Klamath River basin. We depend on:

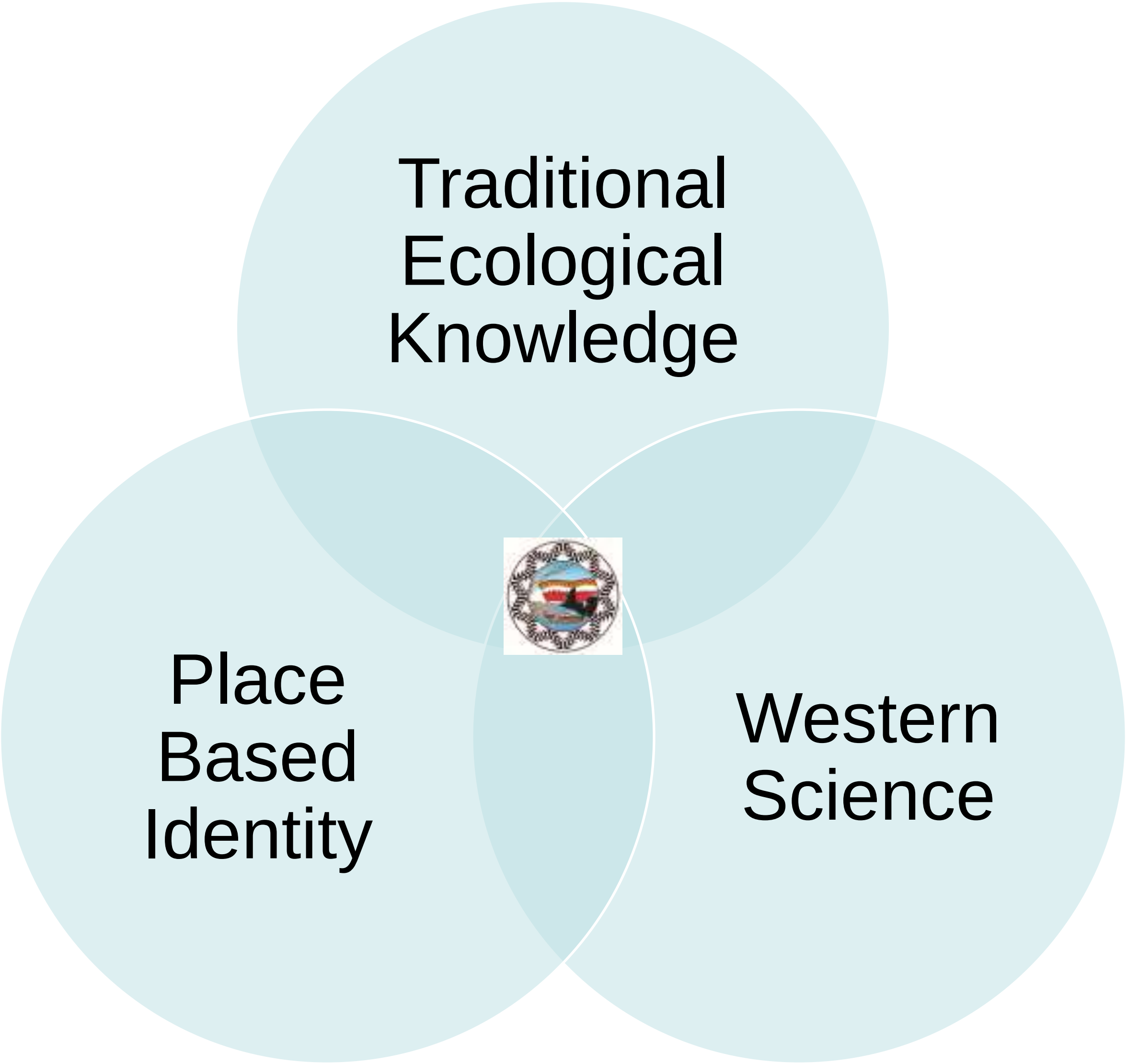
  - Chinook Salmon (*Onchorhynchus tshawytscha)*
  - Coho Salmon (*Onchorhynchus kisutch)*
  - Green sturgeon (*Acipenser medirostris)*
  - Steelhead (*Onchorhynchus mykiss)*
  - Pacific Lamprey “eel” (*Entosphenus tridentatus)*
  - Eulachon (*Thaleichthys pacificus)*

  for ceremonial, subsistence, and commercial purposes.

Food sovereignty - *“the right of a community to define its own diet and therefore shape its own food system with access to all the historical and traditional food.”*

Traditional Ecological Knowledge (TEK)

We can see the natural world as something to exploit (dams, mines, fracking)…


Traditional Ecological Knowledge
Place Based Identity
Western Science

Why are Pacific lamprey ecological important to the Klamath River Basin?

Klamath River Basin supports **highest number of lamprey species** in the world.

Historically, the Pacific lamprey total biomass is estimated as **the largest fish biomass of any species** residing in the Klamath River Basin.

Pacific lamprey **serve as a buffer species** to ESA protected migrating salmon in the Klamath River estuary.

Lamprey have significantly **higher lipid content than salmon** providing high caloric value per unit weight for predators.

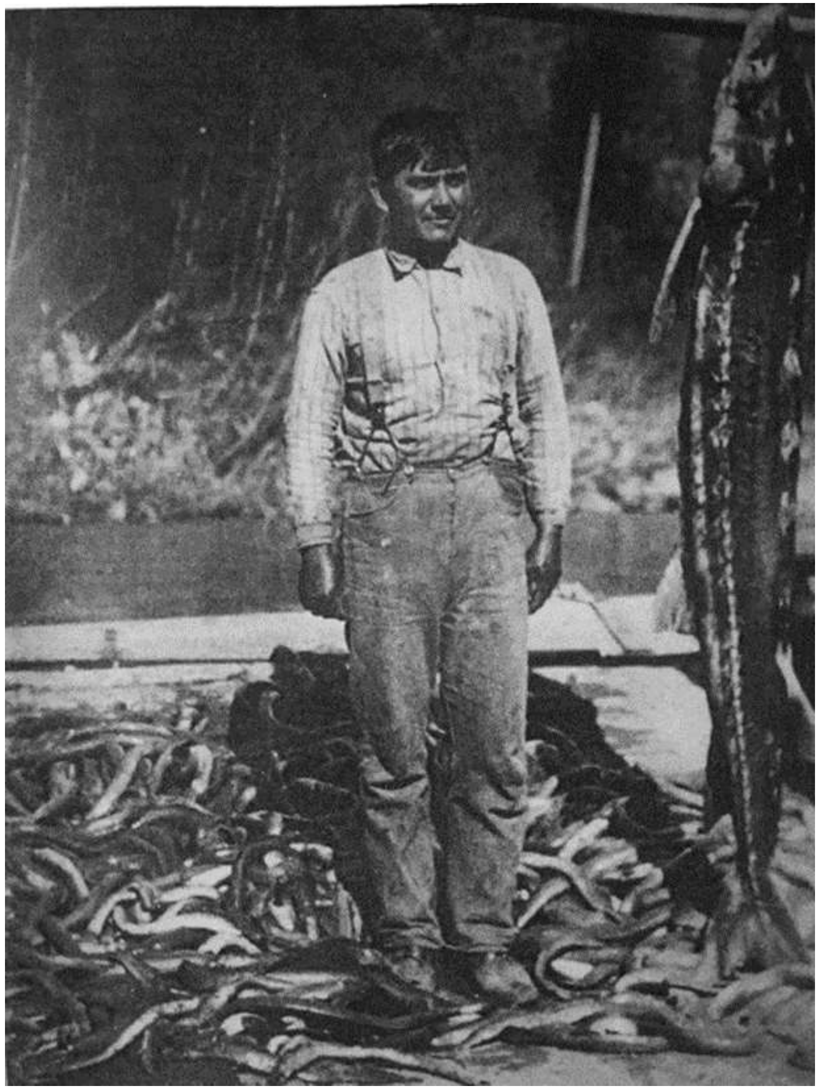
Spawned out lamprey **contribute essential biomass** of marine-derived nutrients and organic matter to the food web of headwater streams.

Food source for marine mammals, bear, blue heron, mink, fishers, river otters, hawks, eagles, osprey, cutthroat & rainbow trout, mergansers, kingfishers, seagulls, terns, and emerging spring salmon and lamprey ammocoetes.

Indicator species of ecosystem health as they live 4 to 7 years in sediment.

Larval lamprey burrowing and feeding tillage act as **ecosystem engineers** by softening and oxygenating stream sediment.

Why are Pacific lamprey culturally important to the Klamath River Basin?



Yurok with Klamath River Pacific lamprey "eels" and green sturgeon (circa 1920's).

Above: Hooking "eels" at the river mouth.

Left: Flattened lamprey ready for the smokehouse.

Cultural impacts

Awok Desmond “Merkie” Oliver displaying handmade eel hooks at his home at the mouth of the Klamath River.

Cultural impacts

Yakama tribal member cooking Pacific lamprey in Columbia River Basin.

Klamath River Basin Pacific lamprey freshwater habitat

Populations are at extinction risk due to passage barriers, habitat disturbance and loss, and are intermediate to intolerant of pollution.

What we did not know about Klamath River Pacific lamprey

Verification of ocean- and river-maturing ecotypes? Very limited amount of evidence.

The relationship between **ecotype diversity, relative run-timing and genetic stock structure** of Klamath River Pacific lamprey was not known.

No **abundance** estimates.

Likely due to:

(i) Large scale lamprey harvest typically only occurs in Native American subsistence fisheries,

(ii) not a priority for fisheries management, and

(iii) no commercial fishery exists.

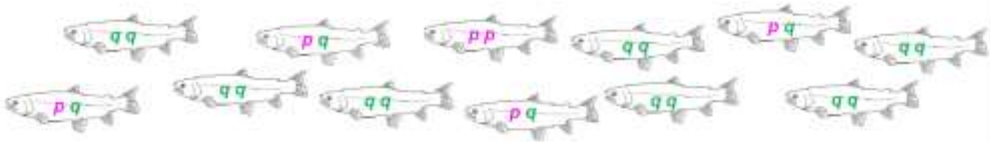
Objectives

My research encompassed three phases:

.

Field Methods

Laboratory and Molecular Methods



DNA extraction was accomplished using the **Chelex 100 method** (denaturing protocol).

Genotyping was conducted using the Genotyping-in-Thousands by sequencing (GT-seq) method (Campbell et al. 2015), allowing the **<u>simultaneous</u> genotyping of thousands of individual samples at hundreds of SNP loci** using **barcoding** and Illumina sequencers.

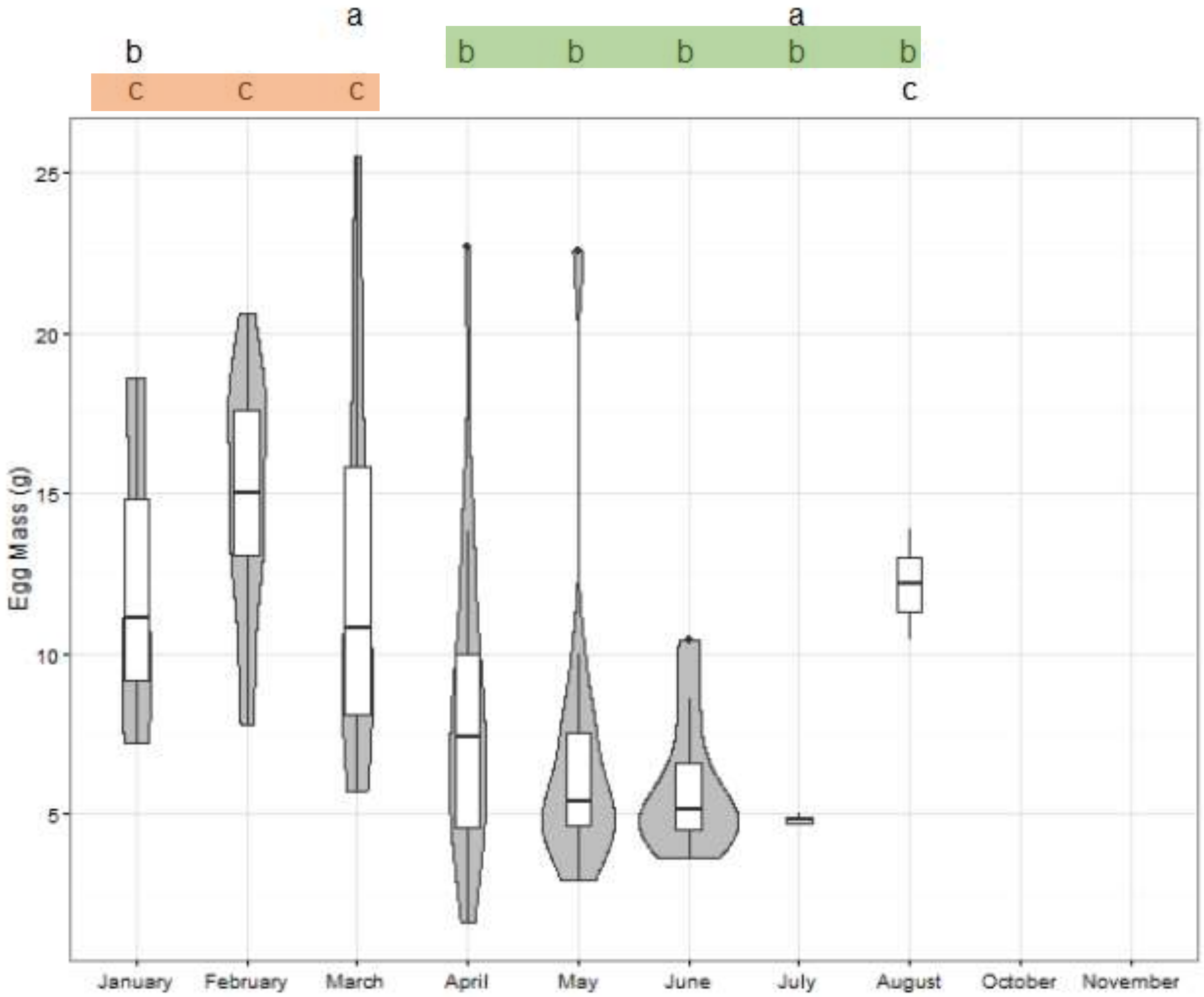
A SNP panel of 308 SNP loci was selected to be representative of neutral and adaptive genetic loci across the geographic range of Pacific lamprey.

Trait Results

Lamprey egg mass variation collected on same day (April 14, 2017), range 1.6 g (0.25% GSI) [third from left] to 22.7 g (5.62% GSI) [second from right], displaying a 1,400% variation in egg mass.

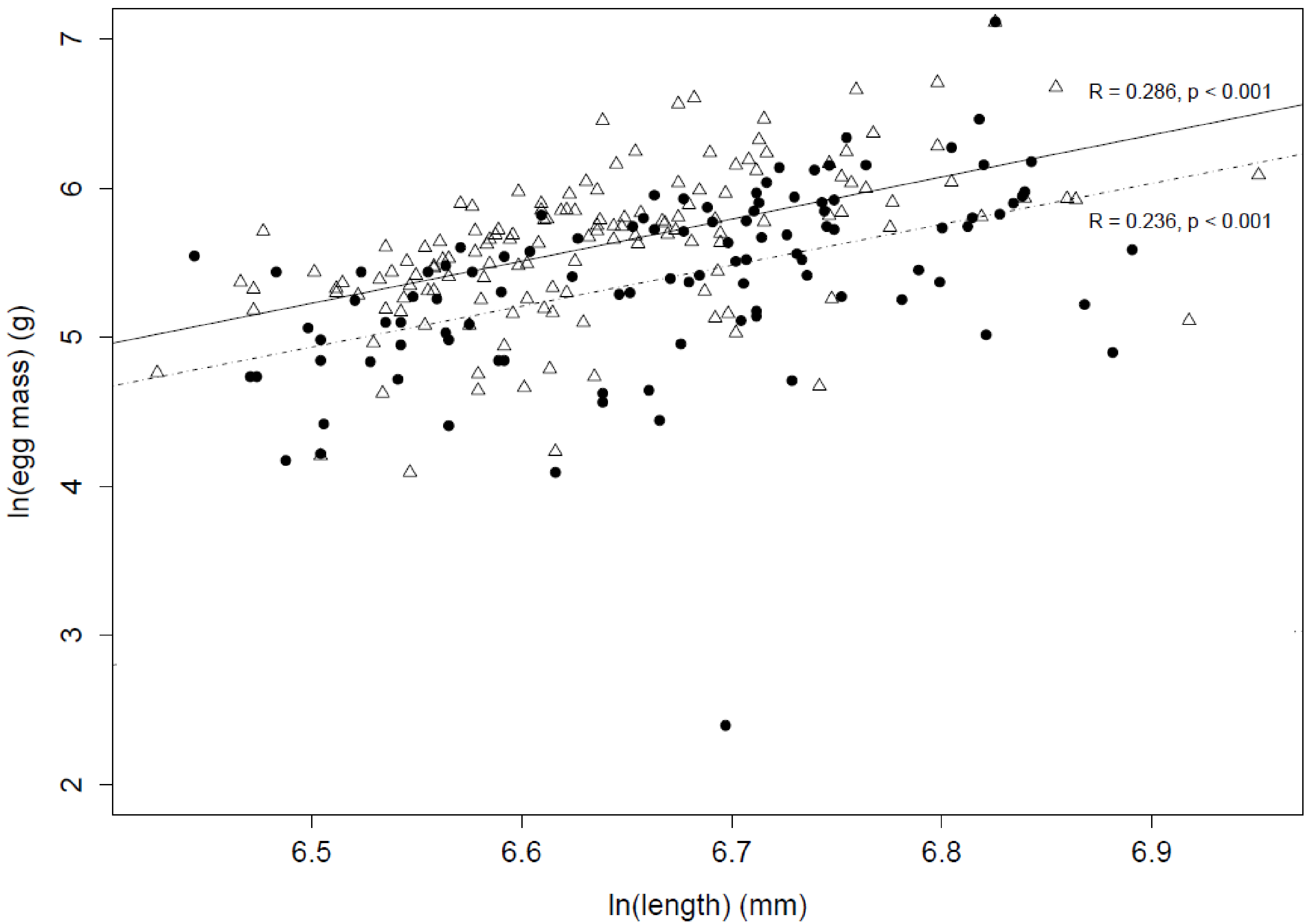
Female Pacific lamprey gut cavity prior to egg excision. The individual represents the largest egg mass of the study (25.5 g).

Initial observations



Mean egg mass (g) of Pacific lamprey at-entry to the Klamath River from June 2016 to May 2017. The width indicates the probability density, the horizontal bar is the median, the box 25% and 75% quantiles, and whiskers 5% and 95% quantiles. Months sharing the same letter were not significantly different (>0.05) for egg mass in post-hoc comparison using Tukey's HSD test.

The decoupling



Total length-egg mass relationships for at-entry Fall Klamath River Chinook Salmon, Aug-Oct 2009 (open triangles) showed a significant relationship , as did Aug-Oct 2010 salmon (solid circles, dot-dash regression line) , as compared to at-entry ocean-maturing Pacific lamprey (open diamonds, dashed regression line) displaying a decoupling of total length-egg mass relationship.

Genetic Results

GLM-MLM

General Linearized Model **p-values for associations between egg mass and each of the 308 SNP loci** genotyped, using the software TASSEL. P-values are ordered from smallest to largest. The horizontal dotted line indicates the critical value as determined using the false discovery rate procedure described by Benjamini and Yekutieli (2001) (**critical value = 0.006**).

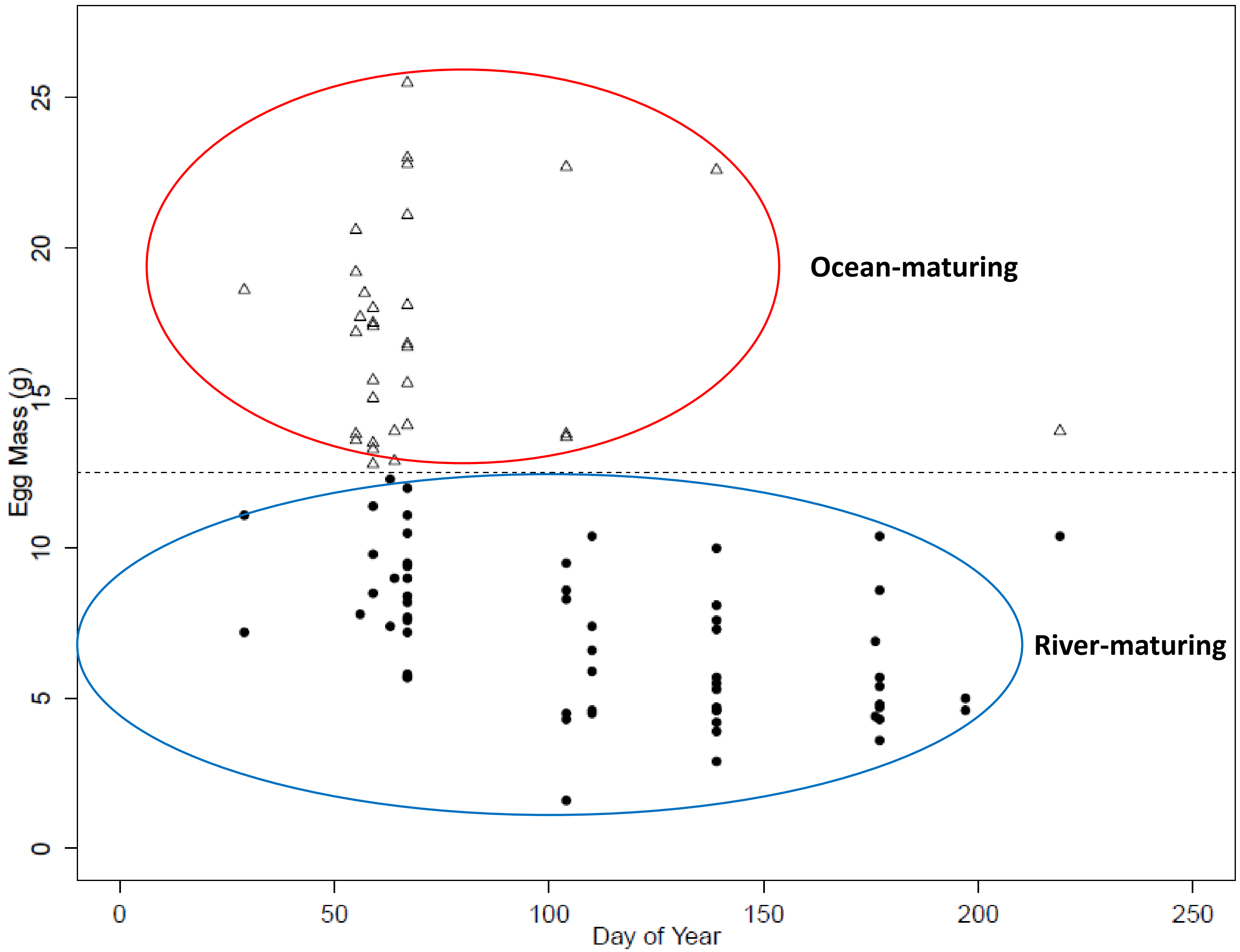
A pattern emerges

Lamprey egg mass segregated by ecotype, **based on genotype-phenotype egg mass association**, versus day of year.

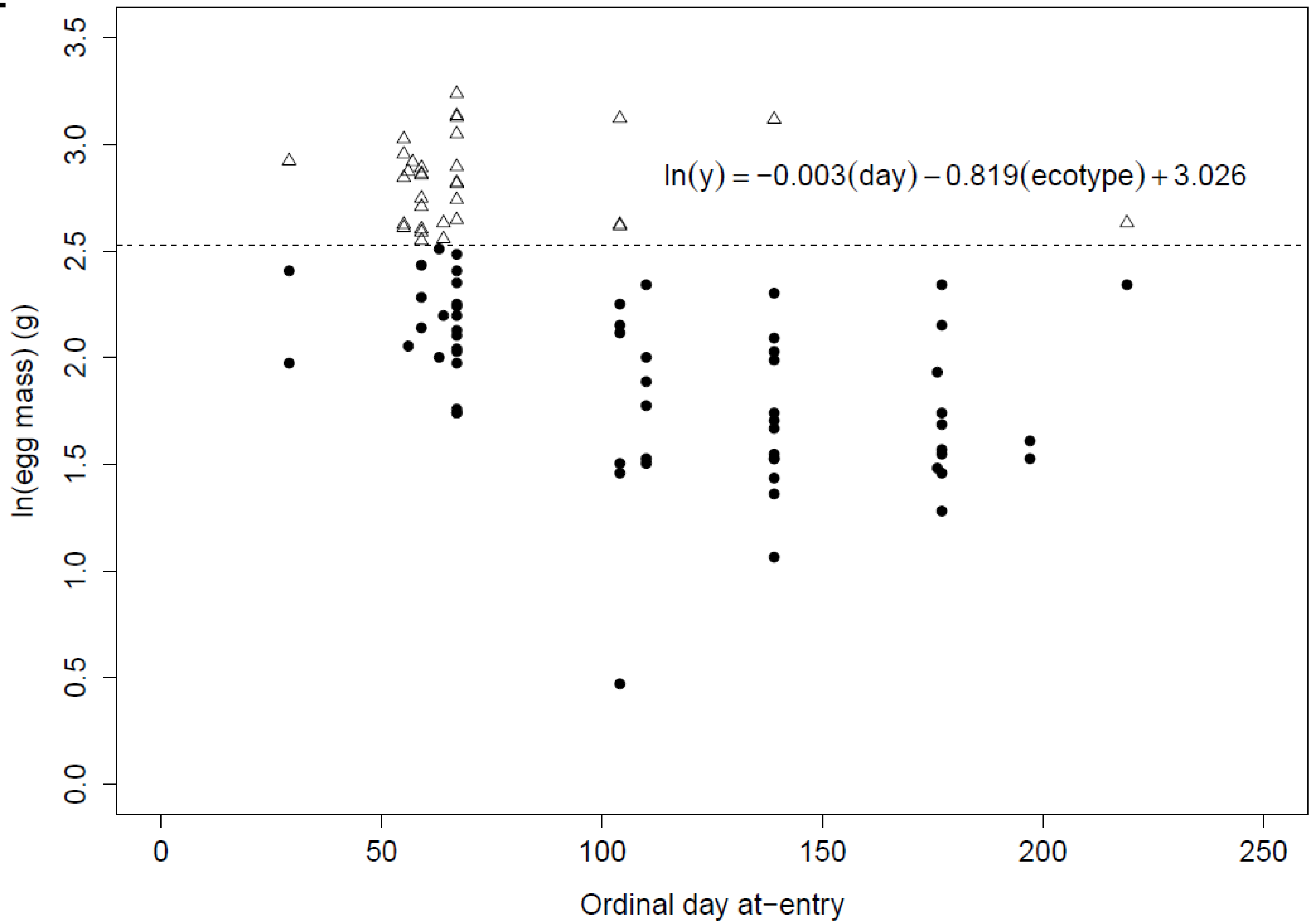
Dotted line = 12.5 g egg mass

Triangles = ocean-maturing ecotype

Filled circles = river-maturing ecotype

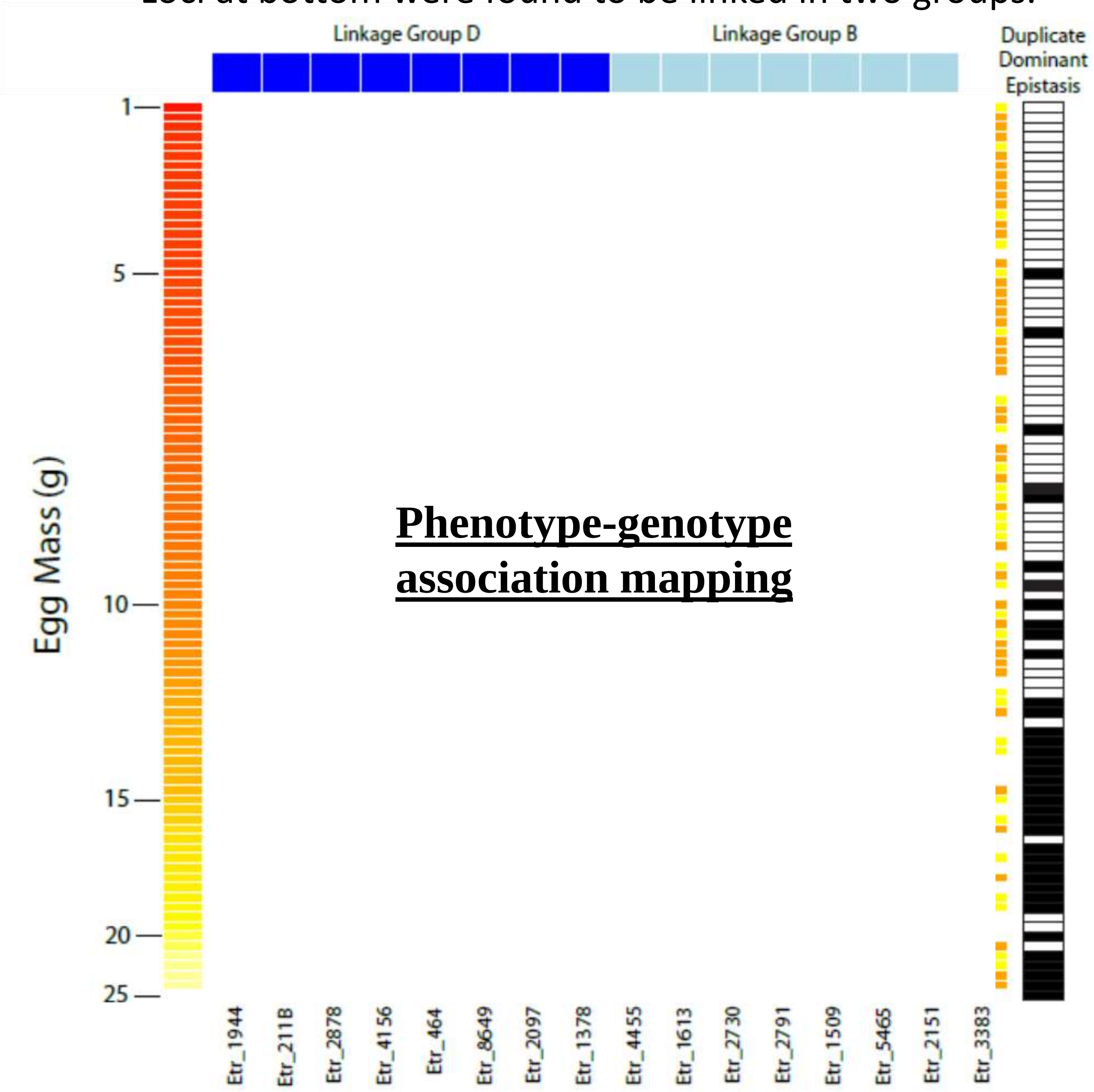


Regression analysis



Multiple linear regression fits for the best model (i.e., lowest AIC and BIC) that predicts ln(egg mass) for Pacific lamprey, based on at-entry day and ecotype ($r^2 = 0.683$, $p < 0.001$). River-maturing ecotypes represented with dark circles, and ocean-maturing ecotypes with open triangles.

Loci at bottom were found to be linked in two groups.



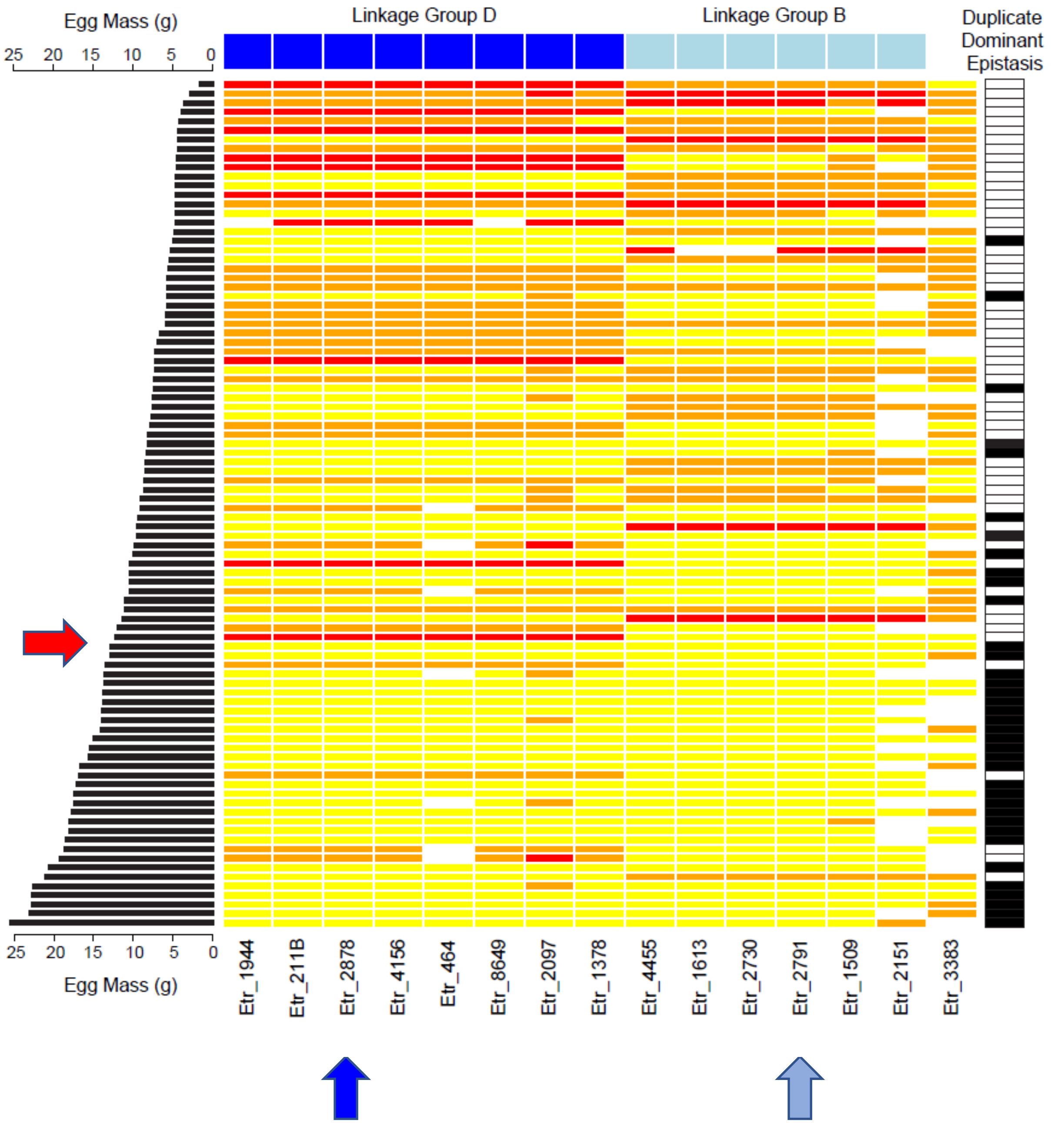
Phenotype-genotype association mapping

Epistasis refers to genetic interactions in which one gene locus masks or modifies the phenotypic effects of another gene locus.

Under duplicate dominant epistasis, a dominant allele at either of two loci can mask the expression of recessive alleles at the two loci.

A locus (plural loci) is a fixed location on a chromosome (e.g., position of a gene).

Phenotype-genotype association mapping identified **fifteen SNPs with significant associations to egg mass**, fourteen occurring on two linkage groups.



River-maturing is considered dominant and develops when genes in both linkage groups are **homozygous dominant (red) or heterozygous (orange)**.

Ocean-maturing is considered recessive and only develops when genes in linkage group B and D are **homozygous recessive (yellow)**.

Assignments are based upon one locus from linkage group D (Etr_2878) and one locus from linkage group B (Etr_2791).

Inheritance model support

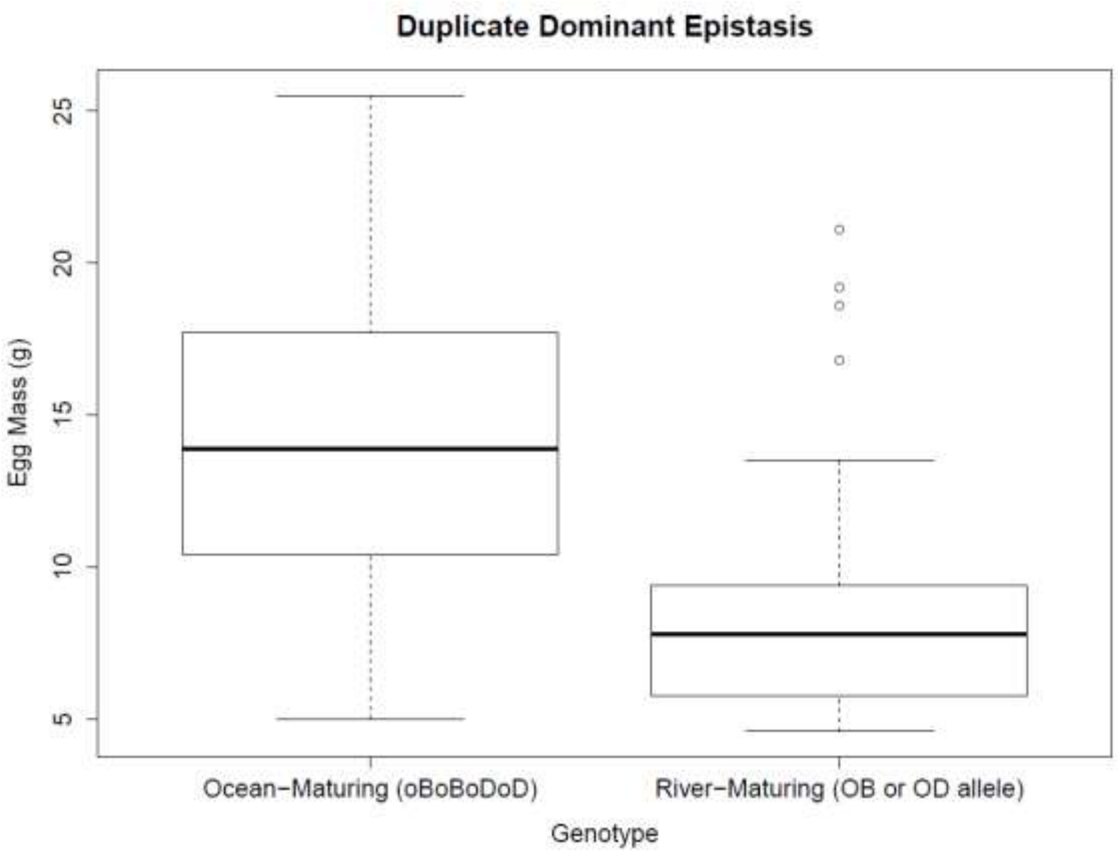
1). Egg mass associated loci **only explained about 39% of the variation** in egg mass, indicating limited support for a model of additive genetic variation.

(iii) Duplicate Dominant Epistasis (Etr_2791, Linkage Group B and Etr_2878, Linkage Group D)

Phenotype	$o_B o_B o_D o_D$	One river allele (O_B or O_D)
Ocean-maturing	26	5
River-maturing	11	50

Proportion correctly classified: 0.83

Duplicate dominant epistasis



The difference in egg mass means is not chance, but is likely due to an epistatic difference [$t(65.64) = 6.90$, $p < 0.001$].

Ocean-maturing	30	1
River-maturing	31	30

Proportion correctly classified: 0.65

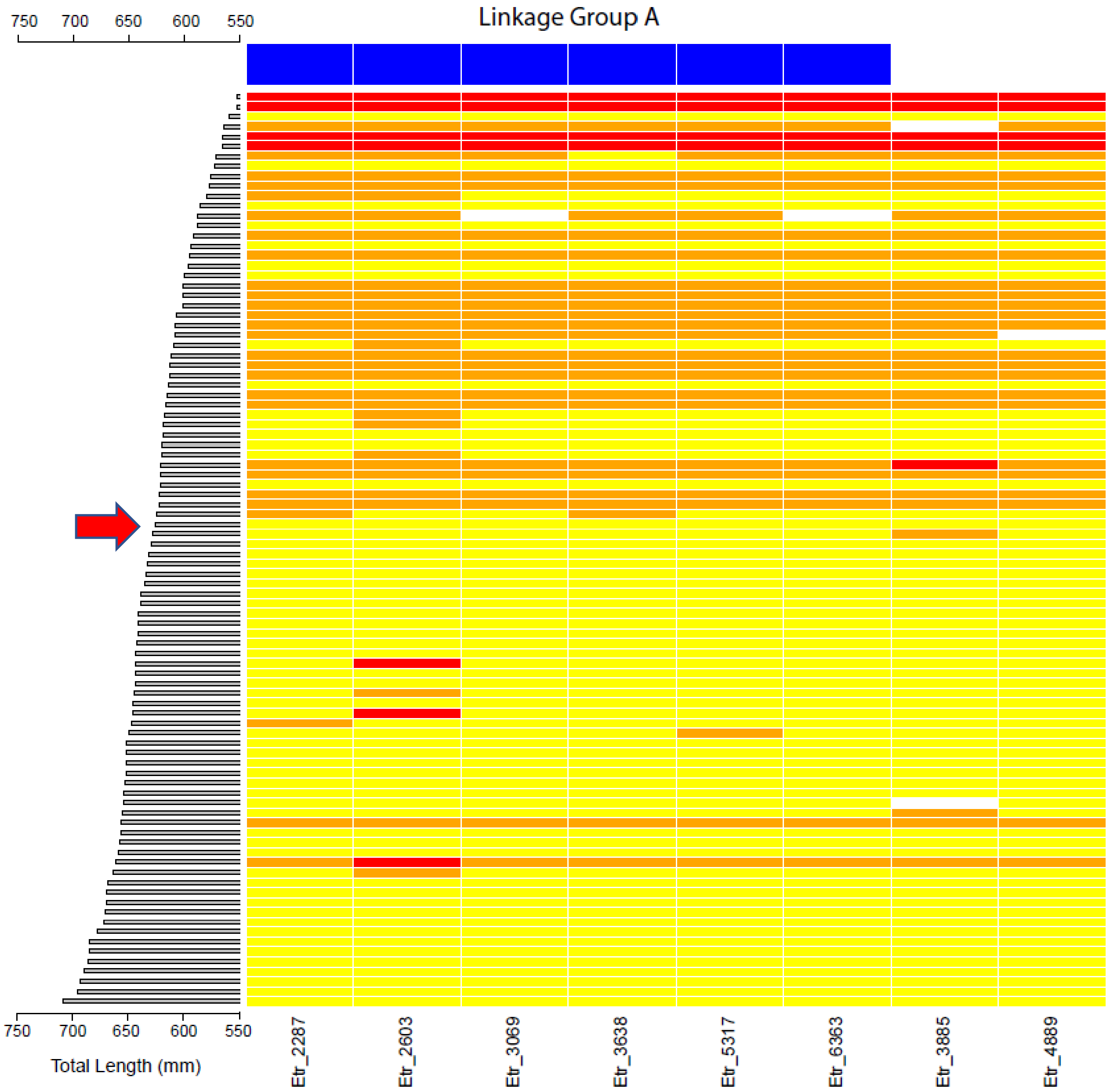
(iii) Duplicate Dominant Epistasis (Etr_2791, Linkage Group B and Etr_2878, Linkage Group D)

Phenotype	$o_Bo_Bo_Do_D$	One river allele (O_B or O_D)
Ocean-maturing	26	5
River-maturing	11	50

Proportion correctly classified: 0.83

Phenotype-genotype association mapping - Part II

Significant associations between **total length and eight loci**, including six loci occurring on linkage group A.



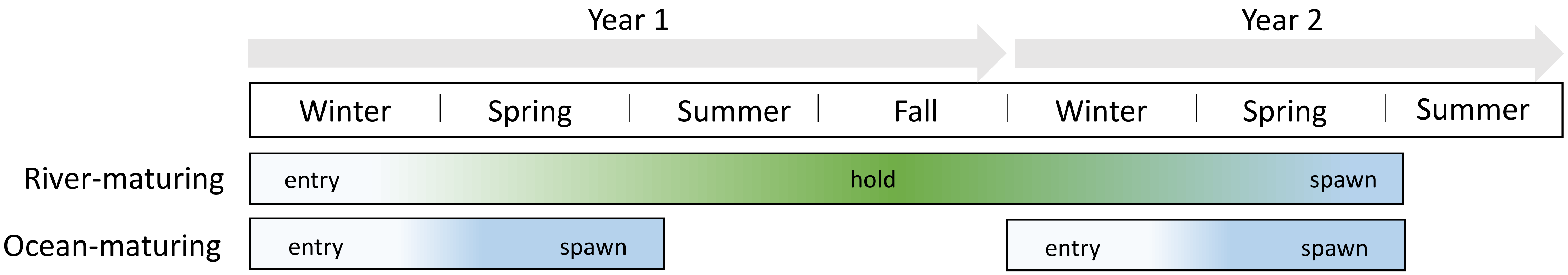
Conclusions

(1) We **identified the genetic basis of maturation ecotypes as polygenic**, involving two unlinked gene regions (linkage groups B and D), and further found that the effects of the two gene regions **did not appear to be additive but instead had complex interactive or epistatic relationship**.

(2) We found that Klamath River Pacific lamprey are **panmictic at neutral loci** indicating that maturation **ecotypic diversity exists within a single population**, **presumably caused by interbreeding** between hold-over river-maturing and current year and ocean-maturing ecotypes.

(3) Our analysis indicates **river- and ocean-maturing ecotypes initiate freshwater migration simultaneously** with each other and co-occur at-entry on a nearly year around basis, with **peaks in abundance from late-winter to early-spring**.

Hypothesized ecotype strategies



** We found that Klamath River Pacific lamprey are **panmictic at neutral loci** indicating that maturation ecotypic diversity exists within a single population**, presumably caused by interbreeding between hold-over river-maturing and current year and ocean-maturing ecotypes.**

Management implications

(1). For conservation planning, the findings indicate that the **river-maturing ecotype carries standing genetic variation capable of producing both ecotypes** (e.g., both dominant and recessive alleles), while the ocean-maturing ecotype carries a single allele (e.g., recessive only).

(2). Therefore, when assessing stream restoration projects for lamprey, the **river-maturing ecotypes could perhaps be prioritized** as they contain the genetic diversity capable of producing both ecotypes (i.e., heterozygosity), whereas the ocean-maturing ecotypes do not.

(3). The Klamath River Pacific lamprey appear distinctive, both genotypically and phenotypically. I recommend distinguishing the river-maturing and ocean-maturing ecotypes of Pacific lamprey by **adopting the names ke'ween and tewol**, respectively, using terms from the Yurok language, in recognition of the importance of Pacific lamprey to Pacific Northwest fishing tribes.

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Developing a Comprehensive Restoration Plan for the Scott River – Klamath Basin

Erich Yokel

Scott River Watershed Council

SCOTT RIVER WATERSHED COUNCIL

NATIONAL FISH AND WILDLIFE FOUNDATION NFWF

Klamath River Coho Enhancement Fund

Scott River Westside Planning Project Team:

- Scott River Watershed Council (SRWC) - Erich Yokel, Charnna Gilmore & Betsy Stapleton
- Fiori GeoSciences – Rocco Fiori, PG
- Cascade Stream Solutions – Joey Howard, PE
- National Oceanic and Atmosphere Administration (NOAA) – Michael Pollock, PhD & Brian Cluer, PhD

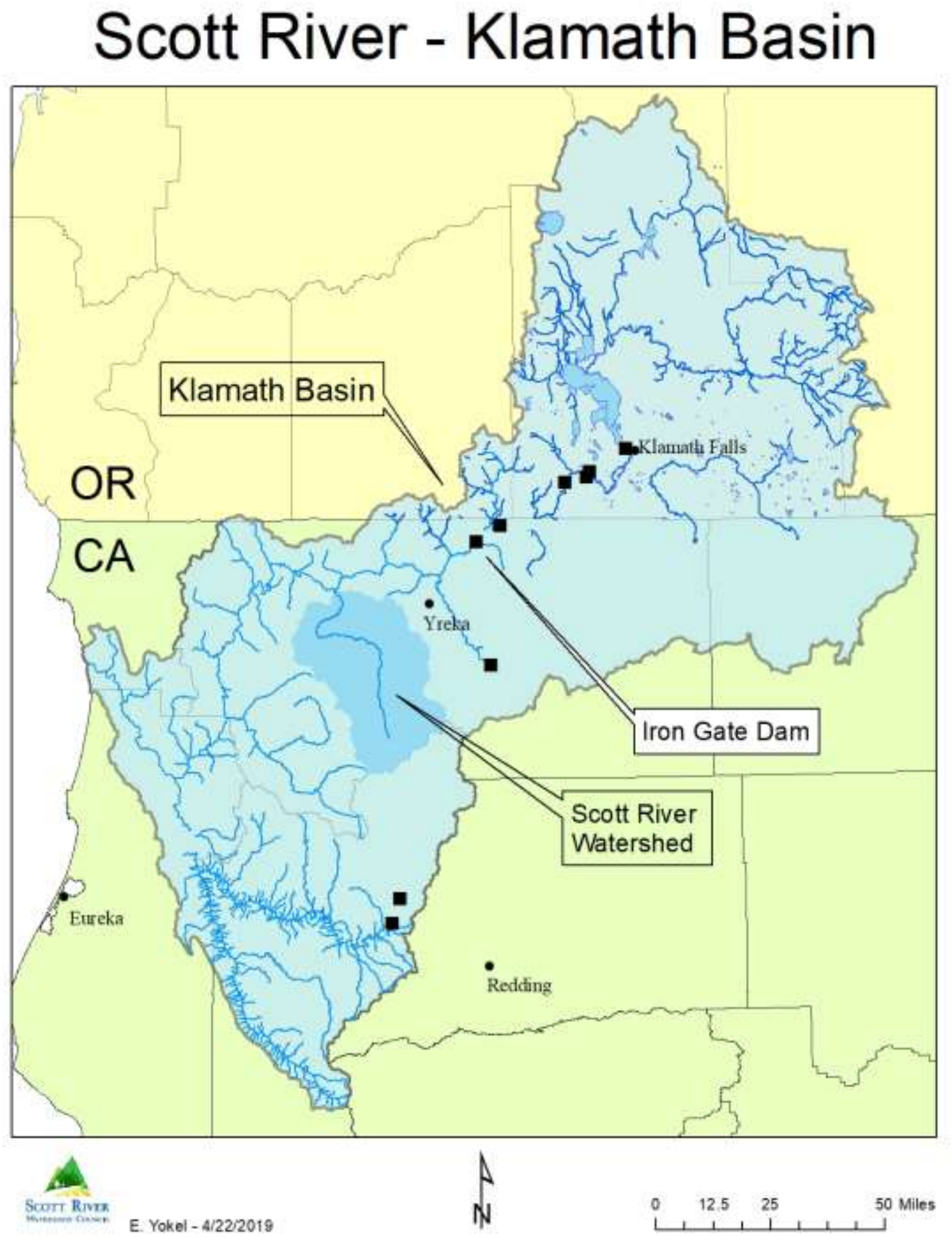
Technical Advisory Committee (TAC):

- Lorrie Bundy, PE, Natural Resource Conservation Services (NRCS)
- Eli Scott, North Coast Regional Water Quality Control Board (NCRWQCB)
- Jennifer Bull, California Department of Fish and Wildlife (CDFW)
- Bob Pagliuco, National Oceanic and Atmosphere Administration (NOAA)

Funding Provide By:

- Coho Enhancement Fund – PacifiCorp Funds (Administered by the National Fish and Wildlife National)
- Bella Vista Foundation
- United States Fish and Wildlife Service

Project Goal: Restoration of critical habitats for year round juvenile coho salmon (*O. kisutch*) rearing in the Scott River Watershed



Scott River Watershed:

- 813 square miles
- Contributes 5% of Klamath runoff
- 63% Private Land and 37% Federally Managed Land

Scott River Supports a significant population of wild SONCC coho salmon in the Klamath Basin

Project Objectives:

- Prioritize tributaries and reaches for restoration planning
- Identify discrete sites with high restoration potential

Restoration Objectives:

- Increase surface water and groundwater elevation
- Restore floodplain connectivity
- Enhance stream complexity

Scott River Landowner and Community Outreach Efforts

Majority of critical habitat for coho salmon is located on private property

Successful restoration requires community buy in

- TAC meetings – 14 meetings
- Webinars – 5 webinars
- Landowner letters – 104 letters
- Stakeholder meeting – 2 meeting by invitation
- SRWC Community Meeting – 2 presentation
- SRWC presentation at Scott Watershed Informational Forum
- Individual landowner meetings

Historic Legacy Effects Have Significantly Reduced Stream Complexity and Floodplain Connectivity

- Beaver harvest for fur trade
- Gold mining – placer, hydraulic and dredging
- Development of land for agriculture
- Stream channelization, straightening and clearing for flood control
- Upslope road building and timber harvest

Results of Historic Legacy Effects

- Loss of historic wetlands and floodplains
- Reduction in condition of the riparian forest ecosystem
- Incision of stream channels
- Reduction in occurrence of floodplain inundation
- Reduction in occurrence and volume of pool habitat
- Altered hydrologic regime

Collect Existing Data

- State and Federal Coho Recovery Plans
- Historic aerial images
- Water quality and physical habitat data
- Coho salmon distribution data

Recovery Plan for SONCC Coho Salmon -Highest Priority Recovery Actions

- Increase beaver abundance
- **Construct off channel-ponds, alcoves, backwater habitat, and old stream oxbows**
- **Restore natural channel form and function**
- Remove, setback, or reconfigure levees and dikes
- Increase instream flows
- Improve irrigation practices

NOAA, 2014

Key Streams and Rivers – CDFG Recovery Strategy & Tributaries with high Intrinsic Potential – NMFS Recovery Plan

Key Streams and Rivers (CDFG, 2004)

Key Populations to Maintain or Improve	Sites to Establish Populations
Mill Creek (near Scott Bar)	Tompkins Creek
Wooliver Creek	Kidder Creek
Kelsey Creek	Boulder Creek
Canyon Creek	
Shackleford Creek	
Mill Creek	
Patterson Creek	
Etna Creek	
French Creek	
Miners Creek	
Sugar Creek	
South Fork Scott River	
East Fork Scott River	
Big Mill Creek	

Tributaries with high IP reaches (IP > 0.66) (NMFS, 2014)

Shackleford Creek	Boulder Creek
Mill Creek	Kidder Creek
French Creek	Noyes Valley Creek
South Fork Scott River	Moffett Creek
Sugar Creek	Canyon Creek
Big Mill Creek	Kelsey Creek
East Fork Scott River	Mill Creek (near Scott Bar)
Patterson Creek	Tompkins Creek
Wildcat Creek	Wooliver Creek
Etna Creek	

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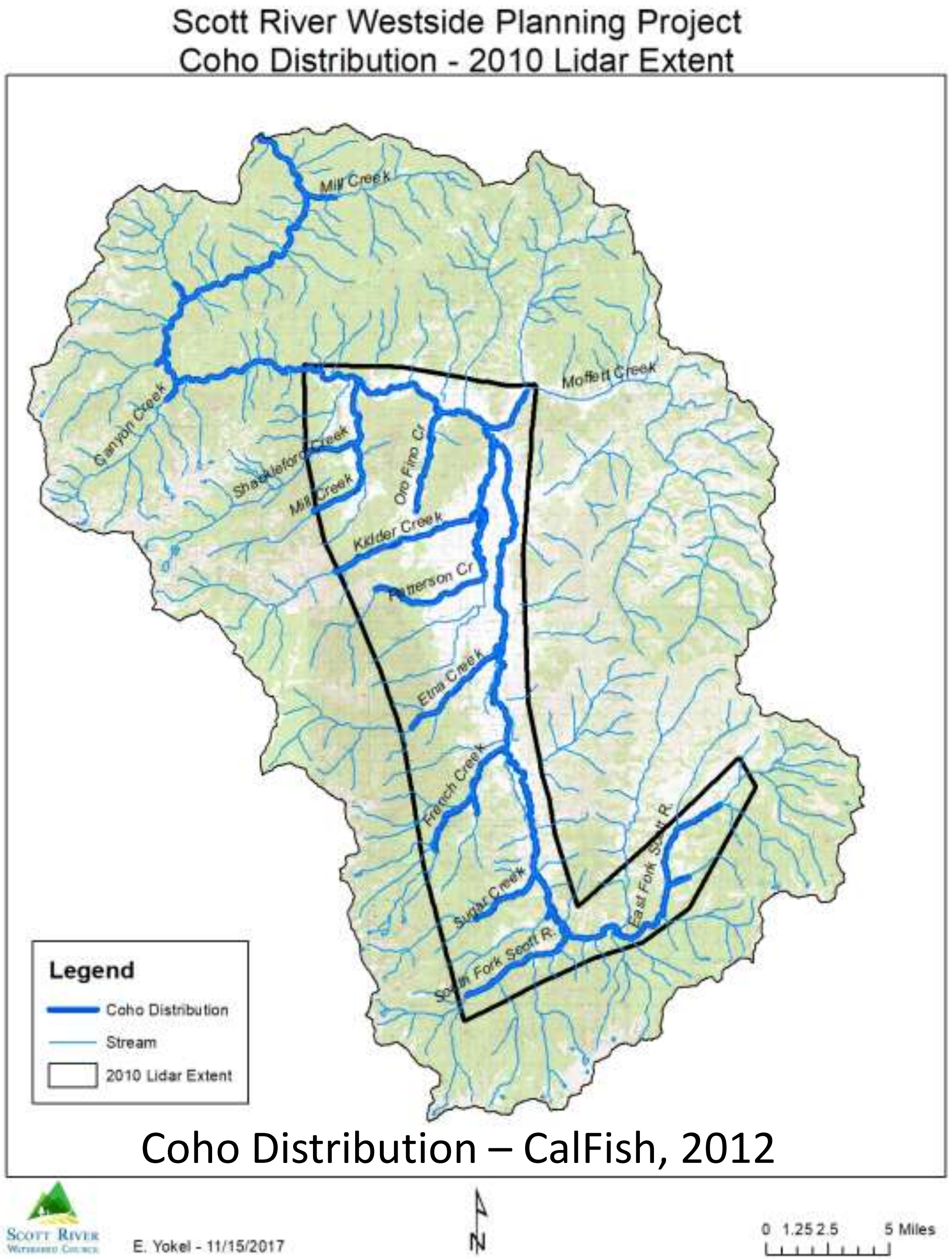


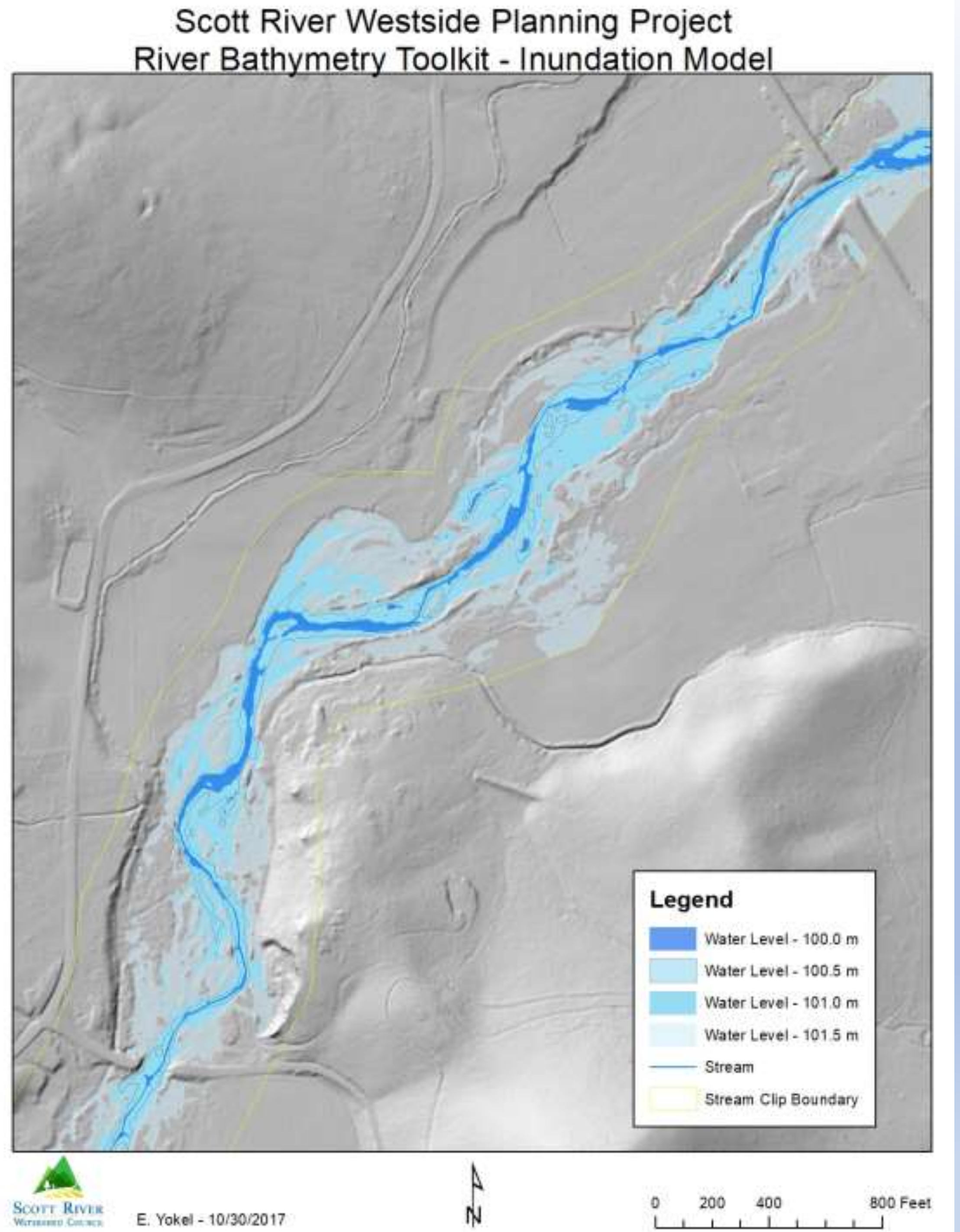
Coho Distribution – CalFish, 2012

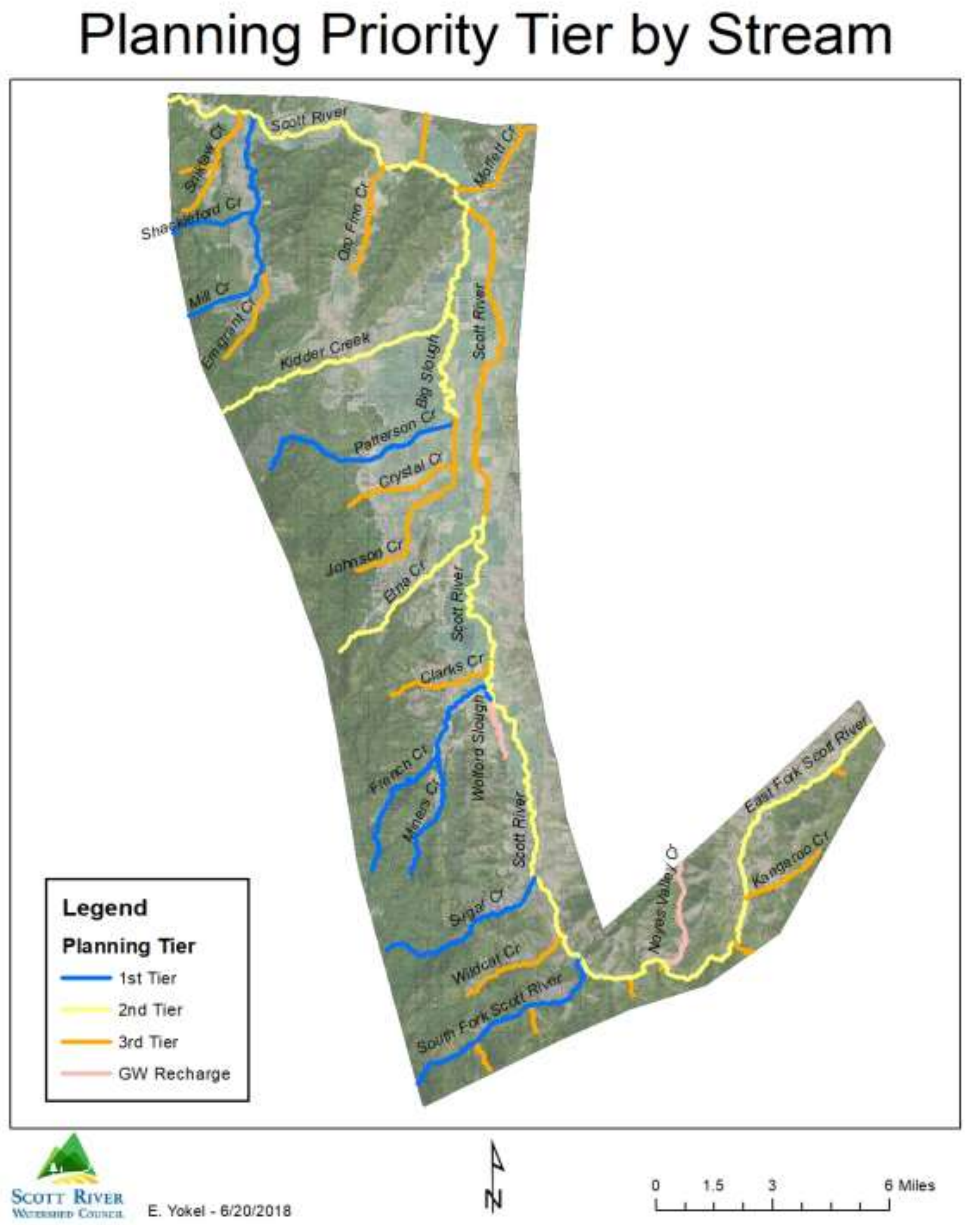
Utilize 2010 LIDAR DEM in ArcGIS to develop products for analysis:

- Digitize stream layer - 32 Streams in study area
- Use RBT to create inundation layers
- Generate riparian canopy height DSM

These geospatial products were used to characterize the stream and riparian condition leading to scoring and ranking of individual reaches.

- River Bathymetry Toolkit (RBT) used in ArcGIS 10.1 to create detrended DEM from 2010 Lidar bare earth DEM
- RBT used to determine inundation area for various water levels (0 m and 0.5 m – 2.5 m)





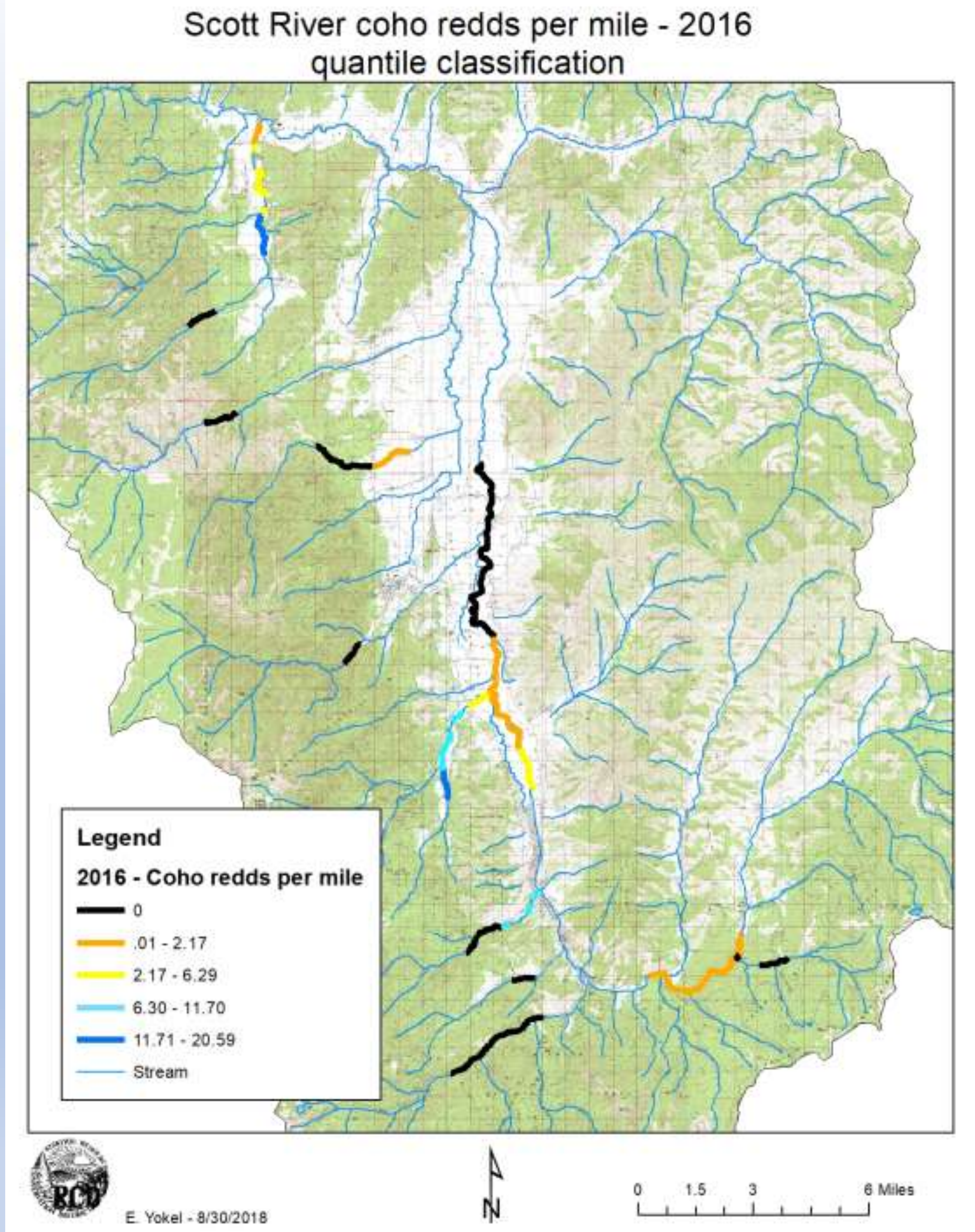
Stream Reach Prioritization

- Thirty Two(32) streams in Study Area
- Parsed into 257 reaches
- Seven (7) Tier 1 Streams and Six (6) Tier 2 Streams
- The Thirteen (13) Tier 1 and Tier 2 streams contain 158 reaches

For Each Tier 1 and 2 Stream Reach
Determine:

Coho salmon utilization – Adult Spawner Density
Stream Gradient

Connectivity during base flow of average water year
Riparian Canopy Height and Density Score
Stream Confinement Score

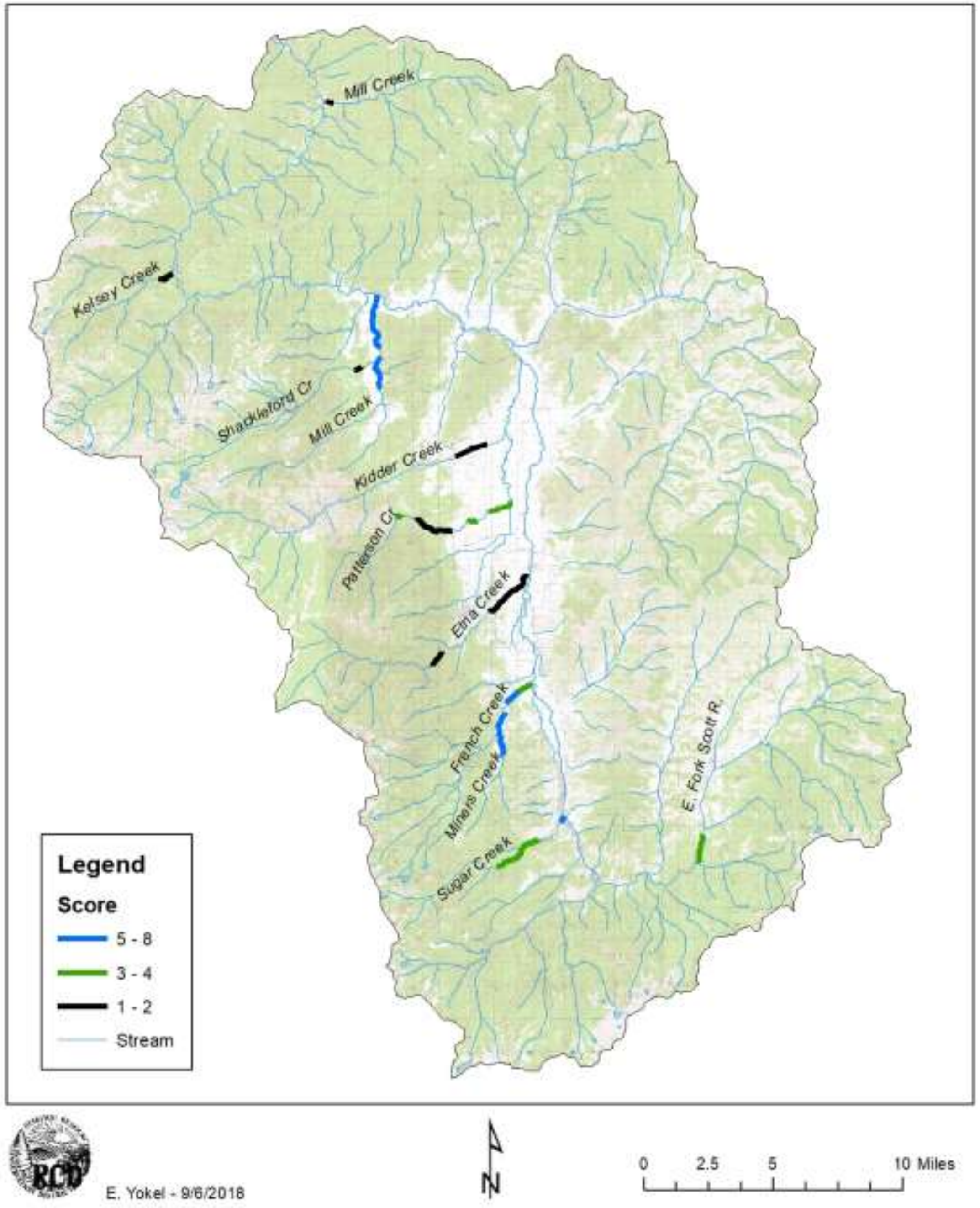


Adult coho salmon spawning ground surveys 2001 - 2016

Magranet, Lindsay and Yokel, Erich. 2017. Scott River Adult Coho Spawning Ground Surveys – 2016 – 2017 Season. Prepared by the Siskiyou Resource Conservation District for the United States Fish and Wildlife Service.

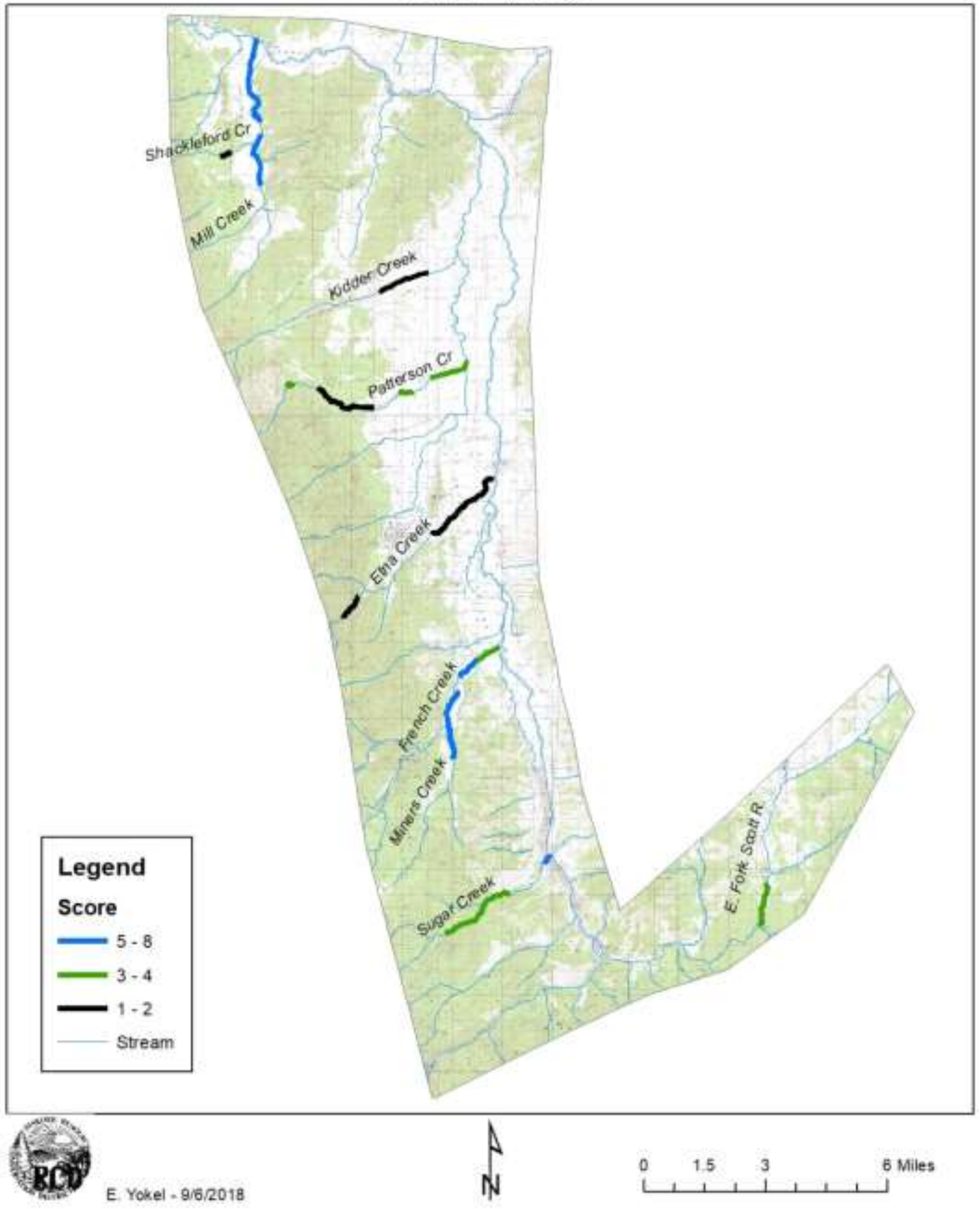
	2004	2007	2010	2016
1st Quantile	Lower Mill Creek (Shackleford)	Lower Mill Creek (Shackleford)	Lower Mill Creek (Shackleford)	Lower Mill Creek (Shackleford)
	Lower Miners Creek	Shackleford-Mill Creek	Shackleford-Mill Creek	Lower Miners Creek
	Lower Sugar Creek	Mid French Creek	Mid French Creek	
	Lower Patterson Creek	East Fork above Grouse Creek	Mid Sugar Creek	
	Lower Kidder Creek	Lower French Creek		
	Lower Mill Creek (Scott Bar)	Upper Patterson Creek		
		Mid Patterson Creek		
2nd Quantile	Shackleford-Mill Creek	Lower Sugar Creek	Lower Sugar Creek	Lower Sugar Creek
	Mid French Creek	Lower Miners Creek	East Fork above Grouse Creek	Mid Sugar Creek
	East Fork above Grouse Creek	Shackleford Creek	Lower Kelsey Creek	Mid French Creek
	Lower French Creek	Lower Patterson Creek	Etna Creek below Diversion Dam	
	Upper Patterson Creek	Etna Creek below Diversion Dam		
	Lower Etna Creek			

Scott River - Surveyed Reaches with Highest Coho Redd Density
2004 - 2016

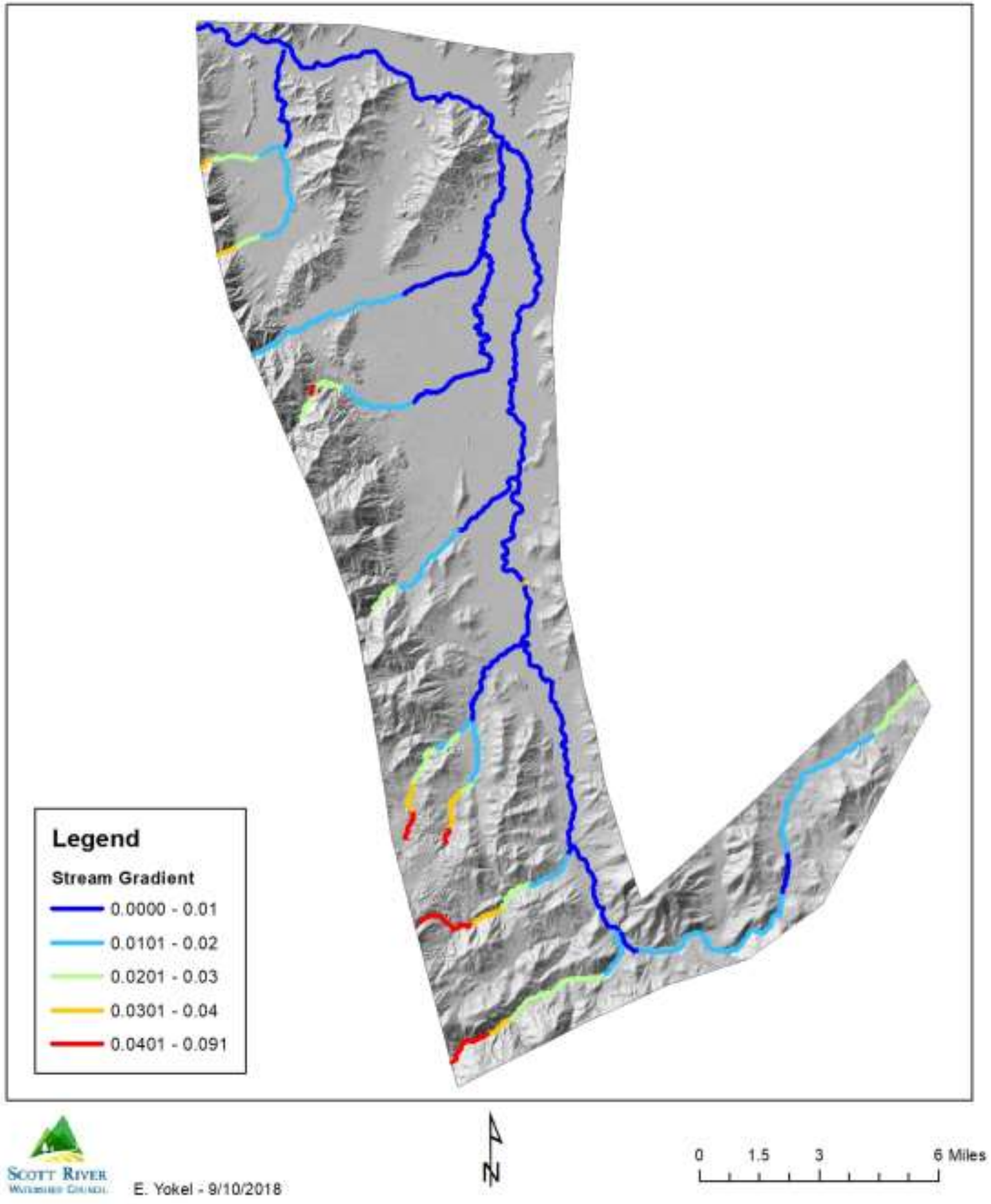


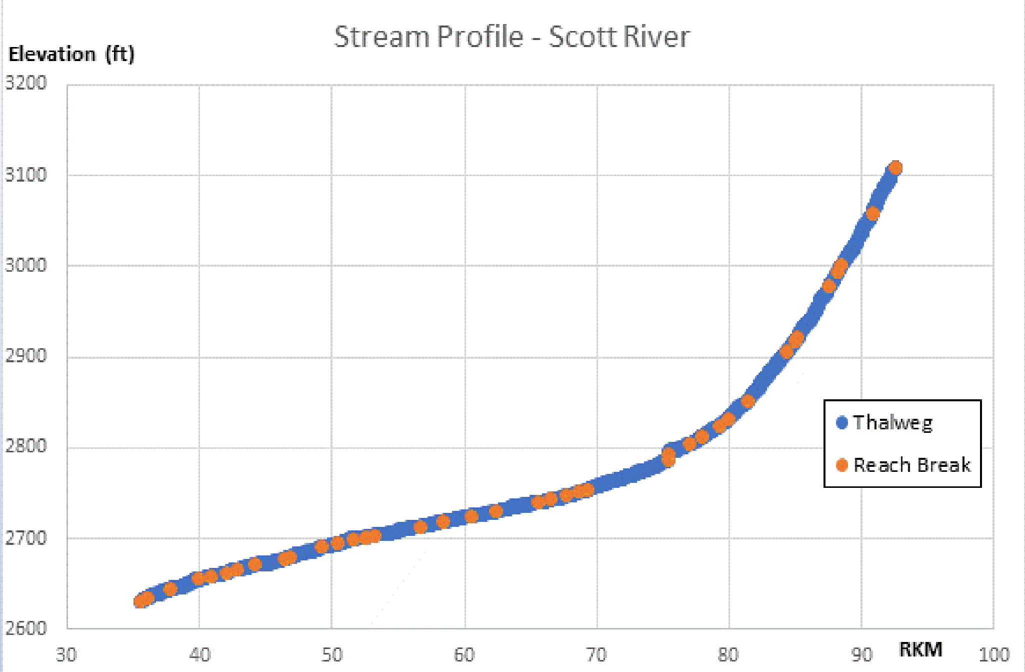
Reach	Total Points
Lower Mill Creek (Shackleford)	8
Mid French Creek	6
Lower Miners Creek	5
Lower Sugar Creek	5
Shackleford-Mill Creek	5
East Fork above Grouse Creek	4
Lower French Creek	3
Lower Patterson Creek	3
Mid Sugar Creek	3
Upper Patterson Creek	3
Etna Creek below Diversion Dam	2
Lower Kidder Creek	2
Lower Mill Creek (Scott Bar)	2
Mid Patterson Creek	2
Lower Etna Creek	1
Lower Kelsey Creek	1
Shackleford Creek	1

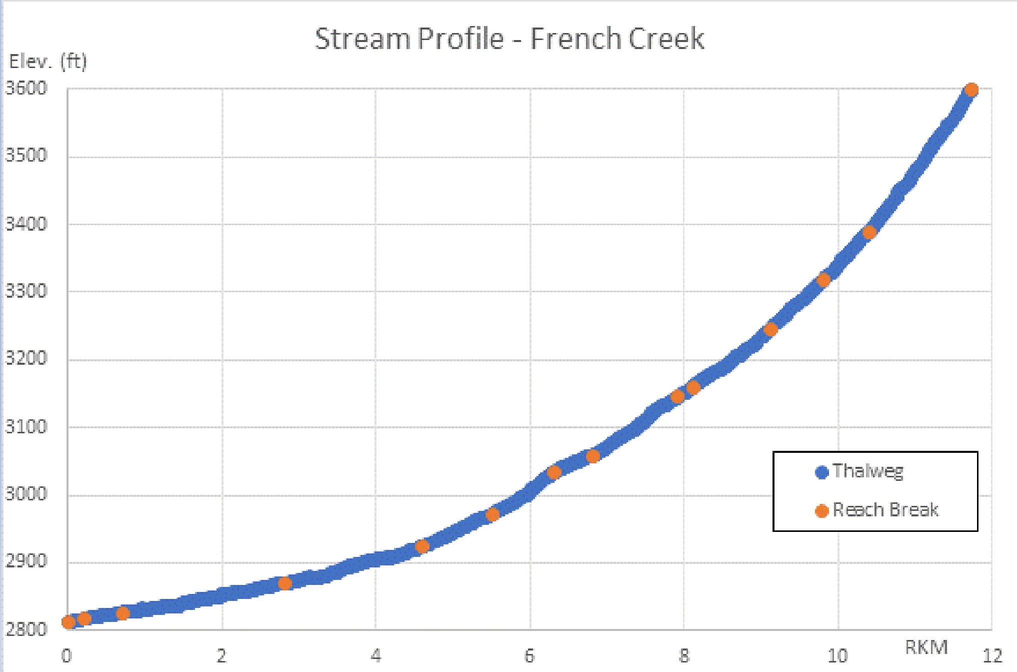
Scott River - Surveyed Reaches with Highest Coho Redd Density 2004 - 2016



Stream Gradient

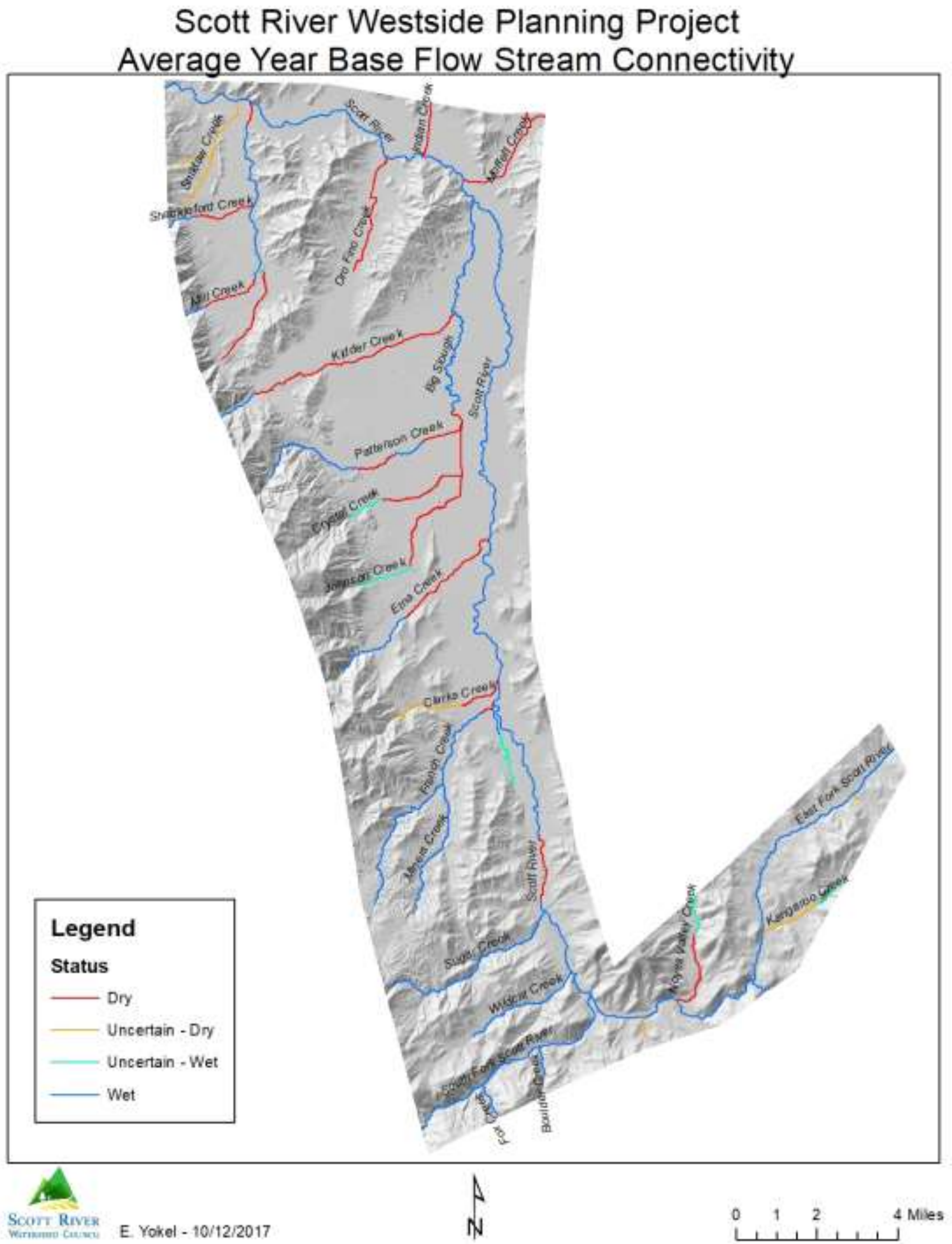






Stream Connectivity During the Base Flow Period of an Average Water Year

Disconnected reaches identified by aerial images and ground truthed

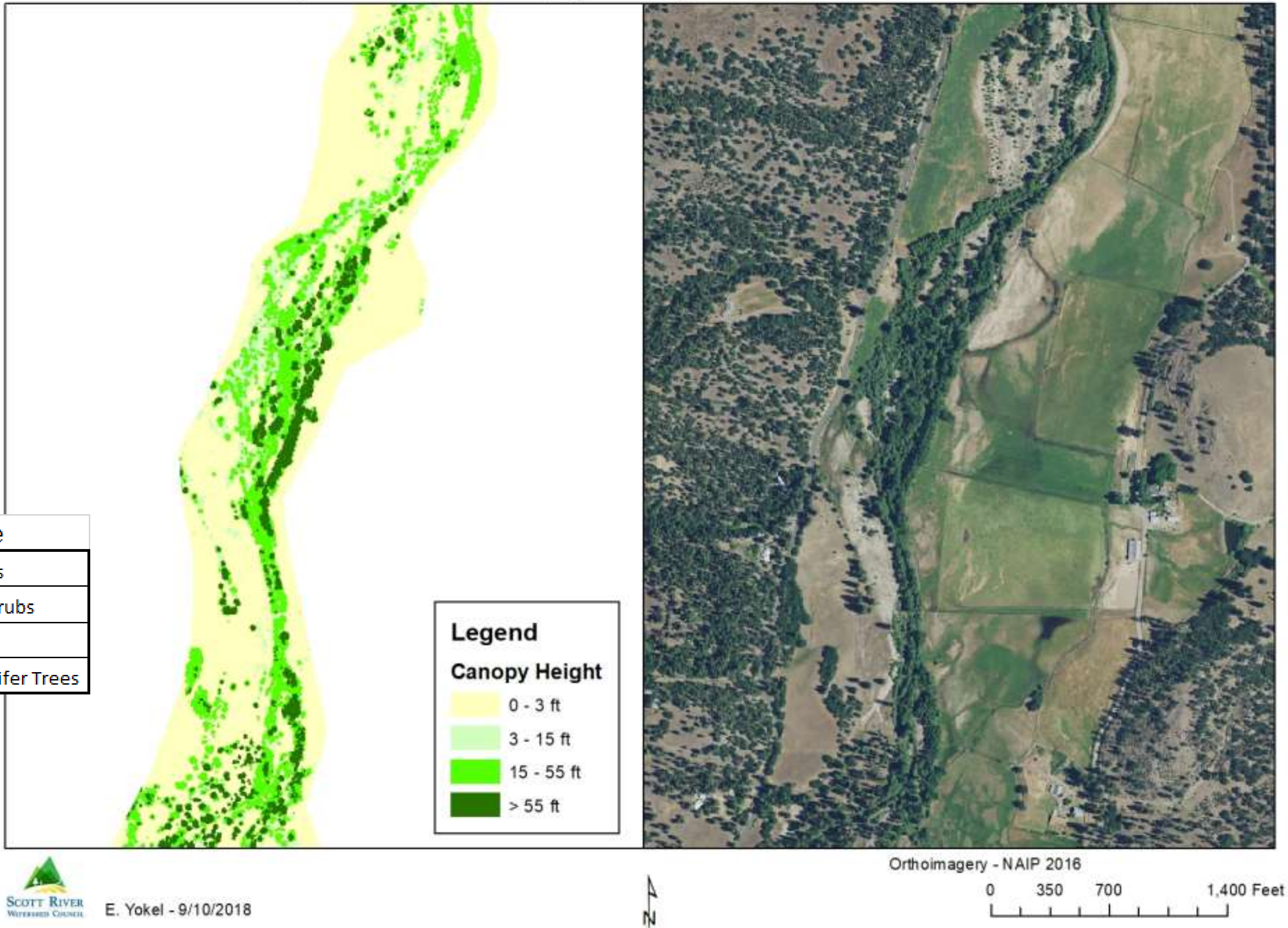


Raster math used to calculate riparian height using the LIDAR bare earth DEM and first return DSM

Canopy Height Class	Vegetation Type
0-3 ft	Grass - Small Shrubs
3-15 ft	Small Shrubs - Large Shrubs
15-55 ft	Deciduous Trees
> 55 ft	Large Deciduous Trees - Conifer Trees

Classify Canopy Heights

Riparian Canopy Height Classification

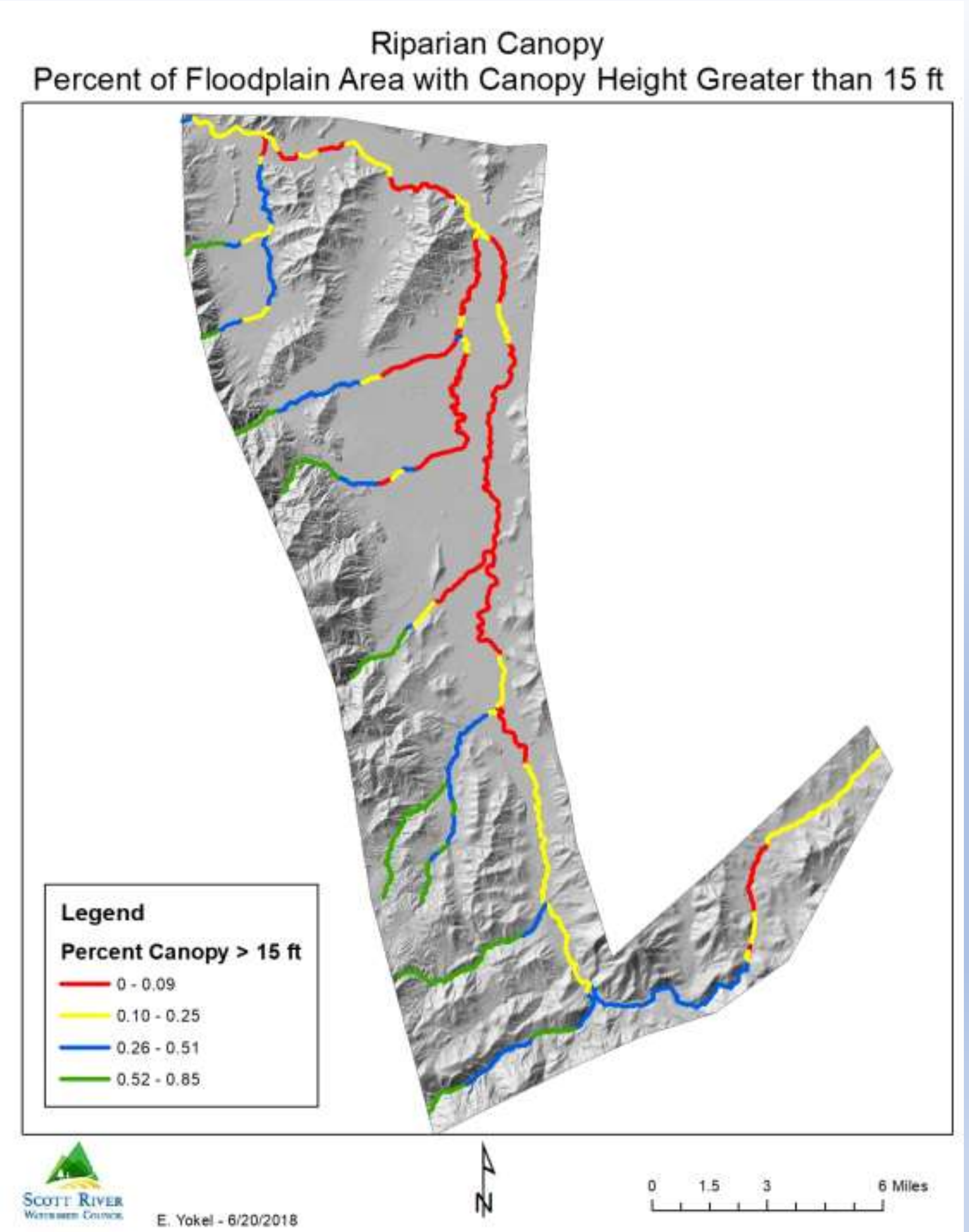


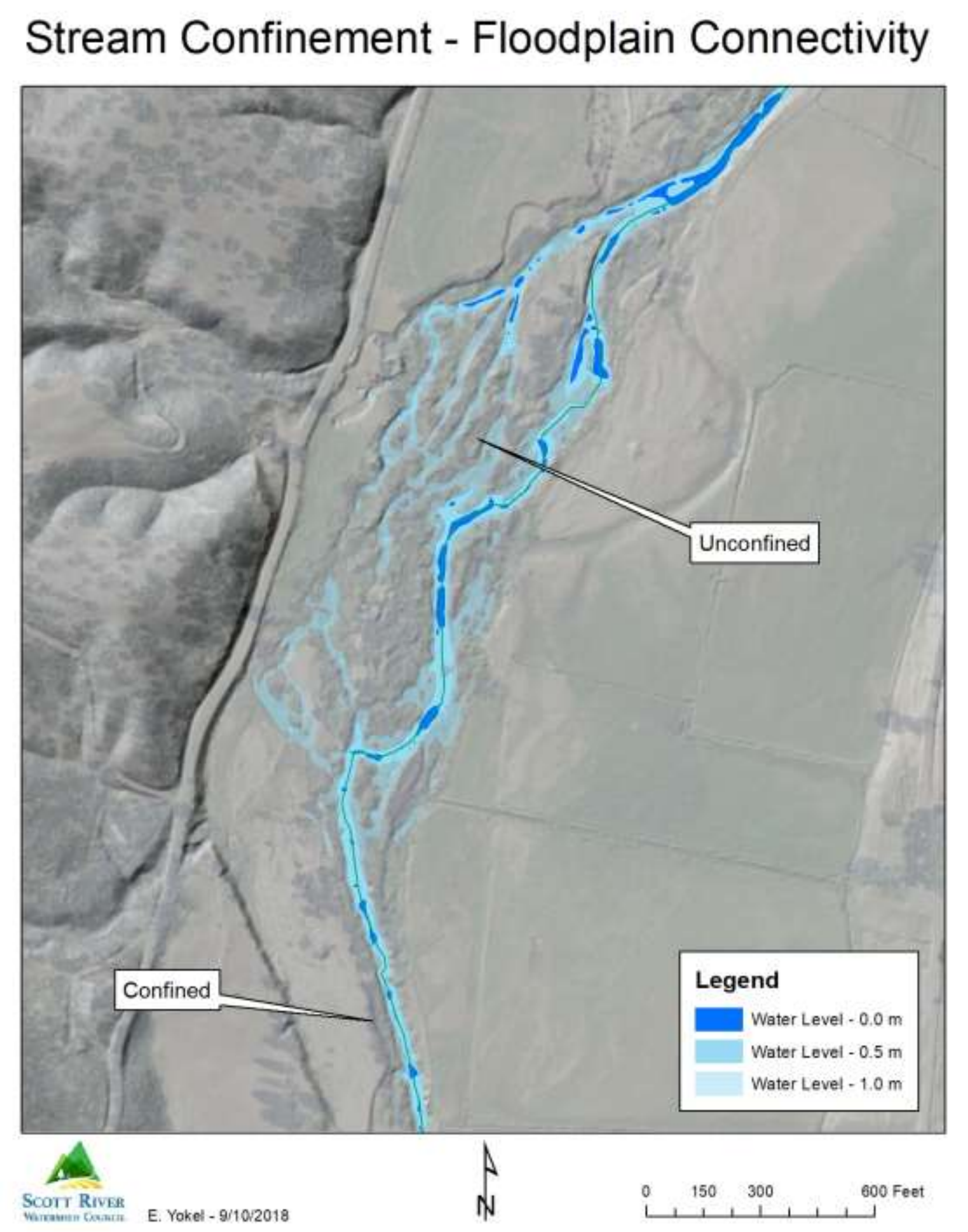
Riparian Canopy Scoring

For each reach the percent of the area with canopy height greater than 15 ft was calculated

The values where classified and scored

Canopy > 15 ft	Riparian Score
0.52 - 0.85	1
0.26 - 0.51	2
0.10 - 0.25	3
0.0 - 0.09	4





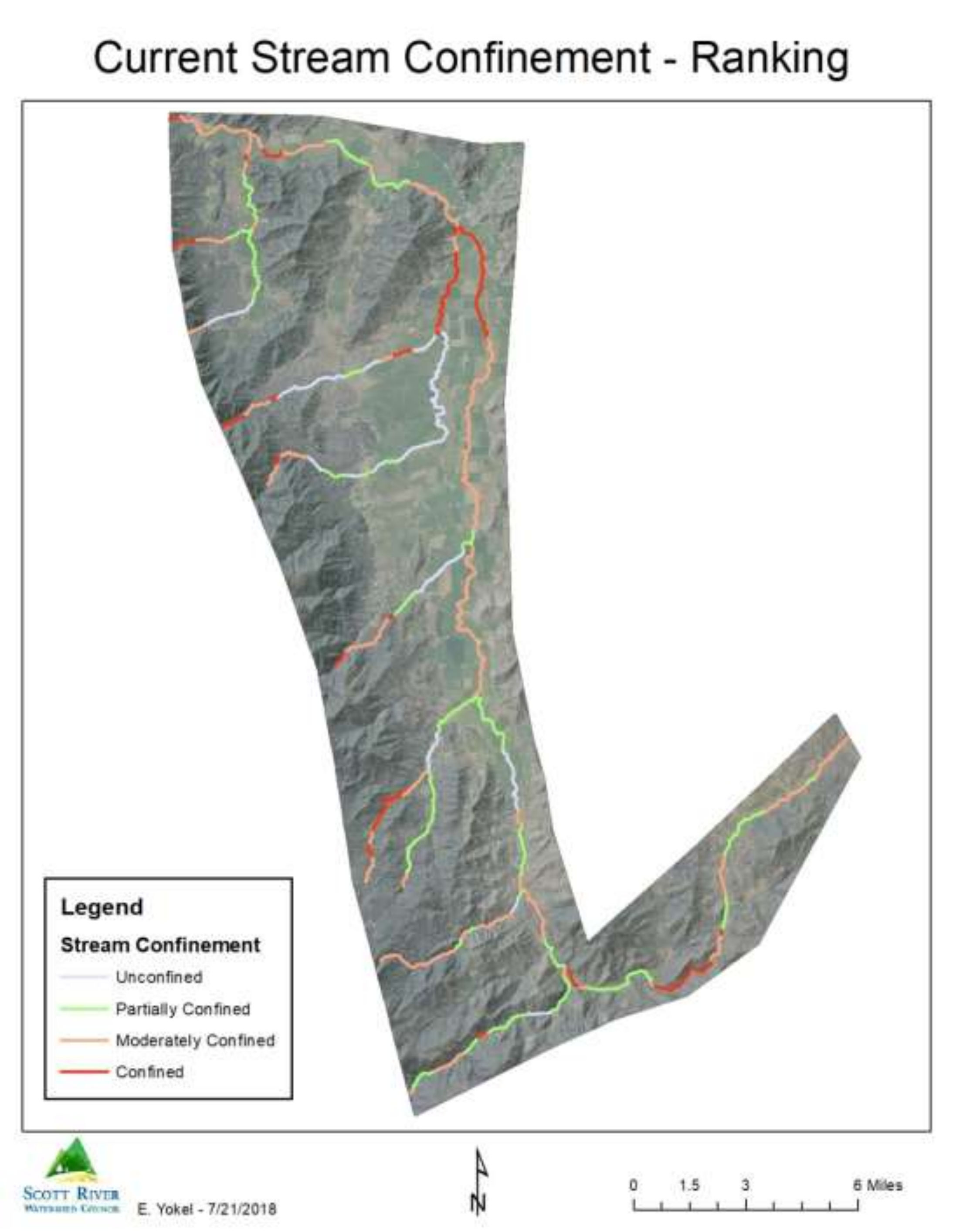
Determination of Stream Confinement

Determine width of Water Level 0.0 m for stream

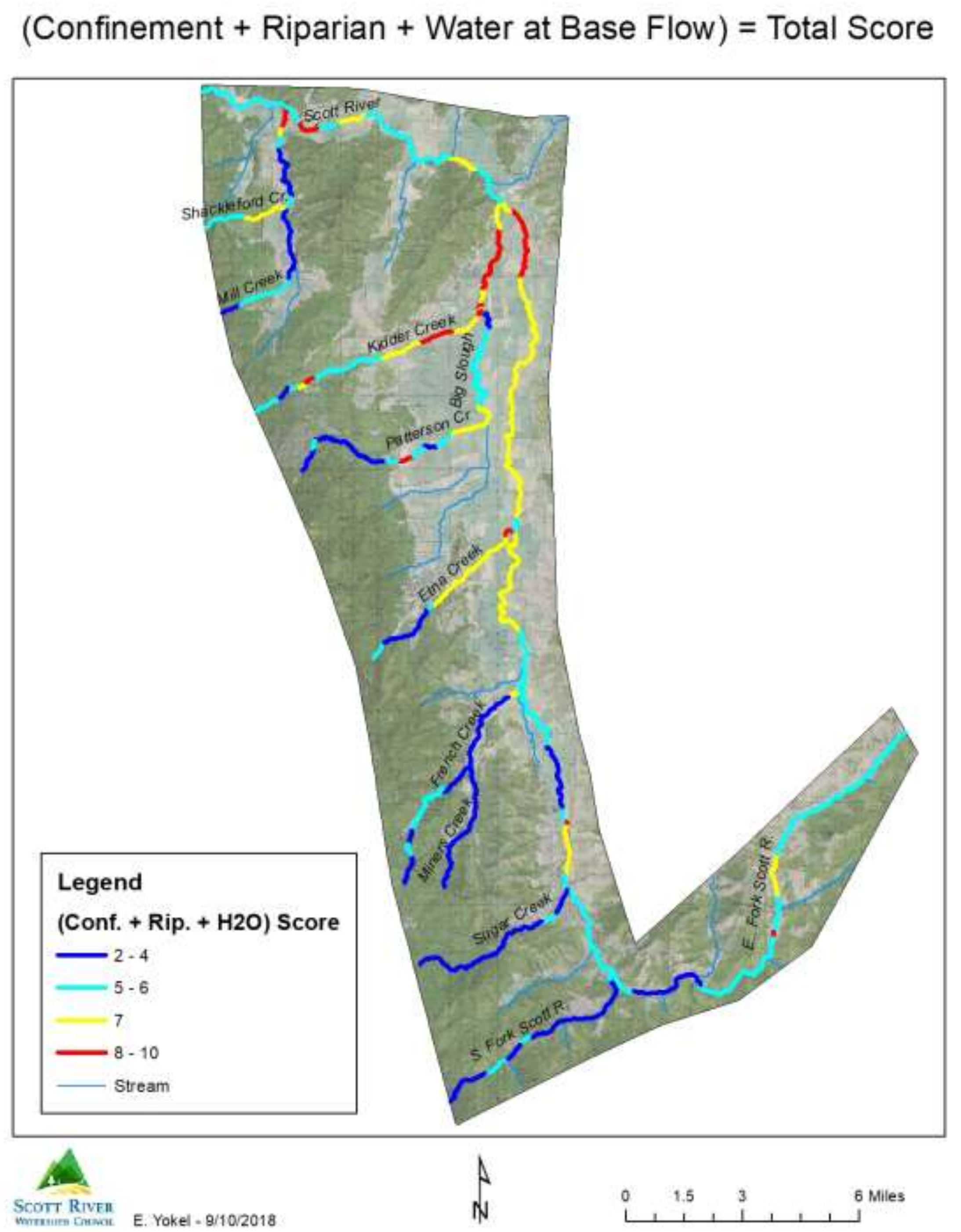
Determine width of Water Level 1.0 m for reach

Calculate ratio of 1.0 m width to 0.0 m width for reach

1.0 m/ 0.0 m width	Status	Score
>10	Unconfined	1
10 - 5.01	Partially Confined	2
5 - 2.01	Moderately Confined	3
2 - 1	Confined	4



Stream Confinement	Score
Unconfined	1
Partially Confined	2
Moderately Confined	3
Confined	4



Water Present at Base Flow	Score
Yes	**0**
No	**2**

Highest Possible Score – 2
Lowest Possible Score - 10

Concept:

It is potentially easier and more cost effective to increase the stream's water surface elevation and/or connectivity to existing low lying areas of the floodplain than it is to decrease the ground elevation of the floodplain.

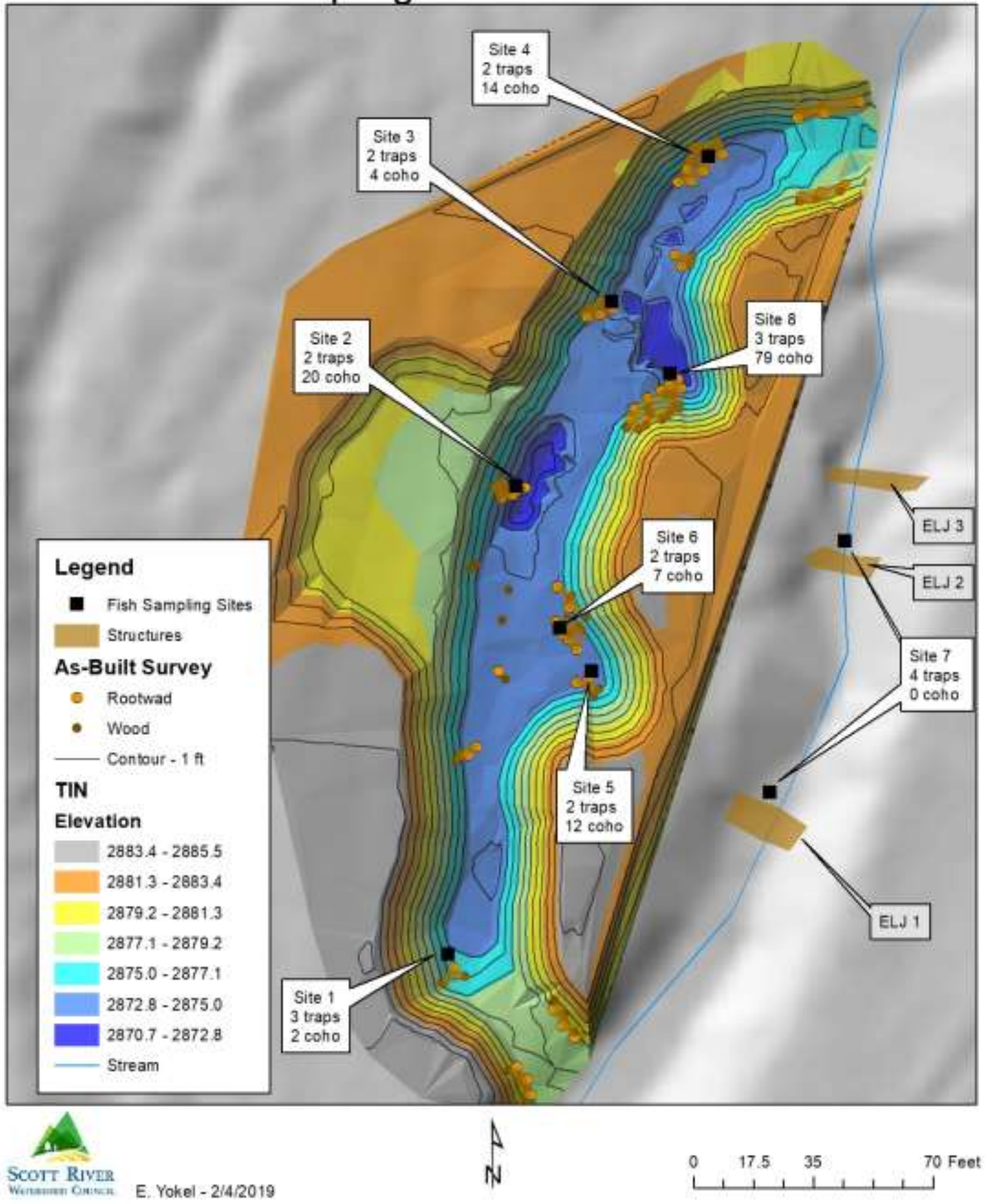
Potential Restoration Approaches

- Increase water surface elevation with instream structures – e.g. Beaver Dam Analogue
- Excavate and grade floodplain to connect existing off channel features or create feature
- Promote floodplain connectivity and stream aggradation by increasing in channel roughness – e.g. Large Woody Debris loading

NATIONAL FISH AND WILDLIFE FOUNDATION NFWF

U.S. FISH & WILDLIFE SERVICE

Mid French Creek - FRGP Side Channel Fish Sampling Locations - 1/31/2019



CALIFORNIA
DEPARTMENT OF
FISH & WILDLIFE

Engineered Log Jams – French Creek

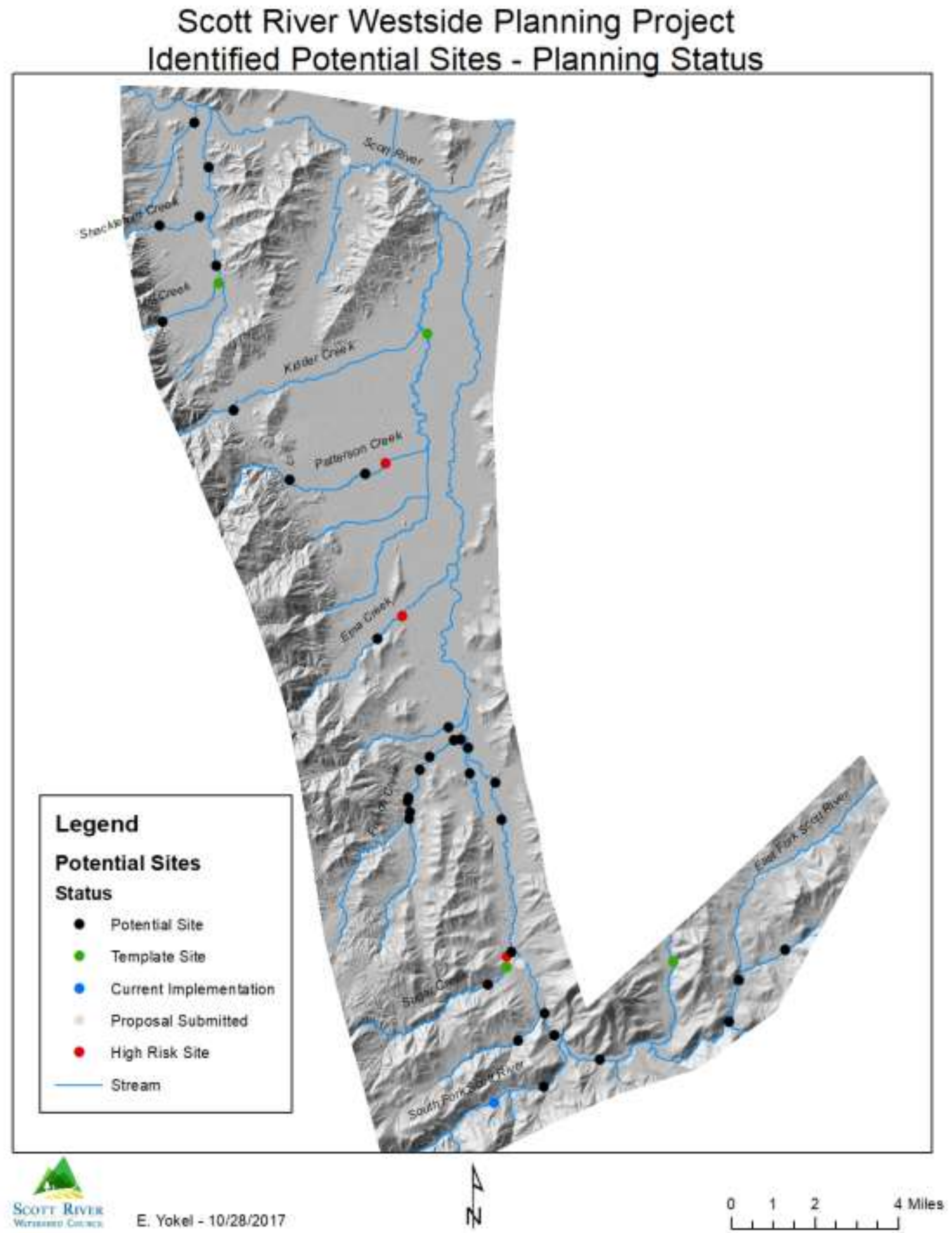
Accelerated Wood Recruitment – Patterson Creek

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

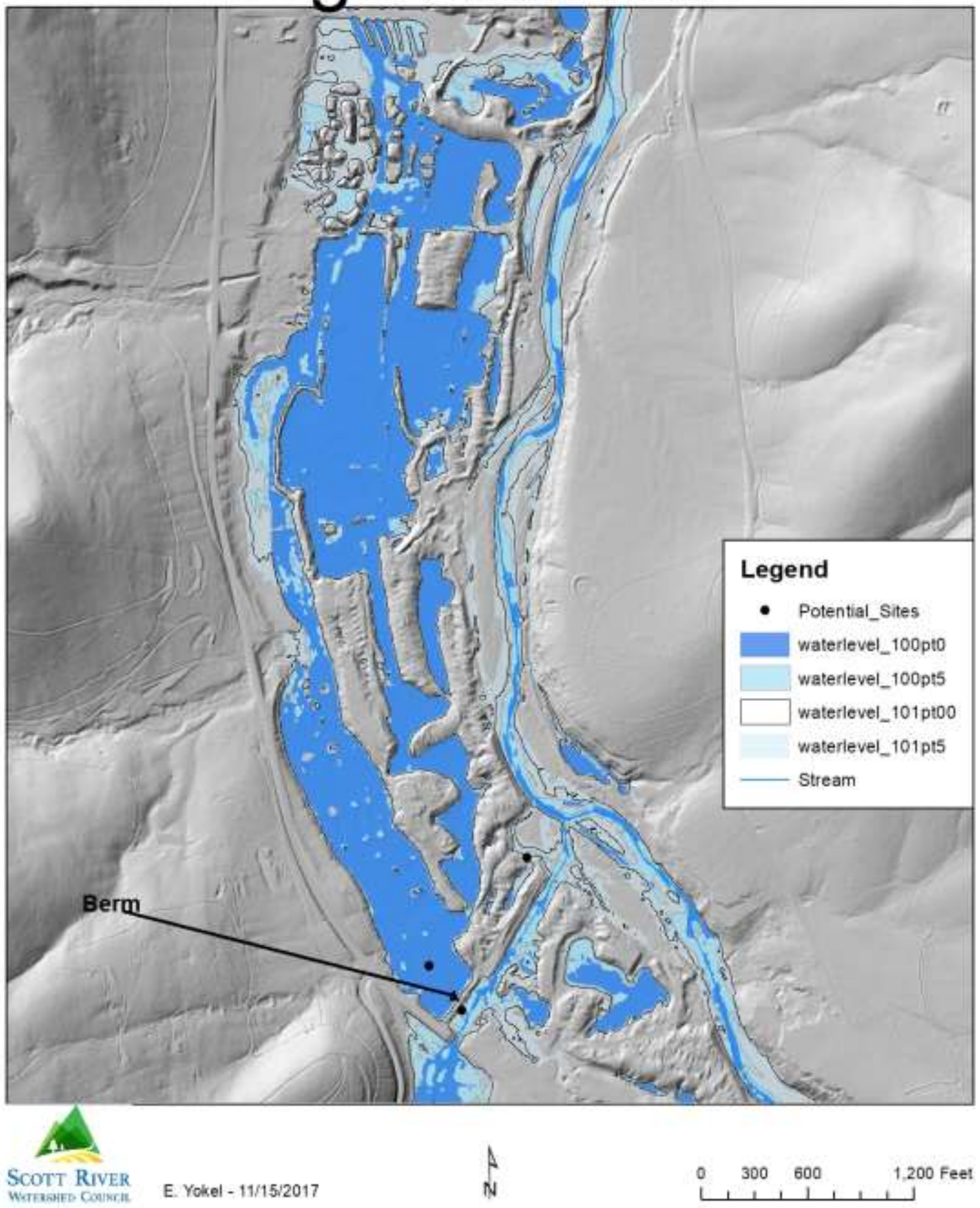
U.S. FISH & WILDLIFE SERVICE DEPARTMENT OF THE INTERIOR

CALIFORNIA CONSERVATION CORPS CCC EST. 1976

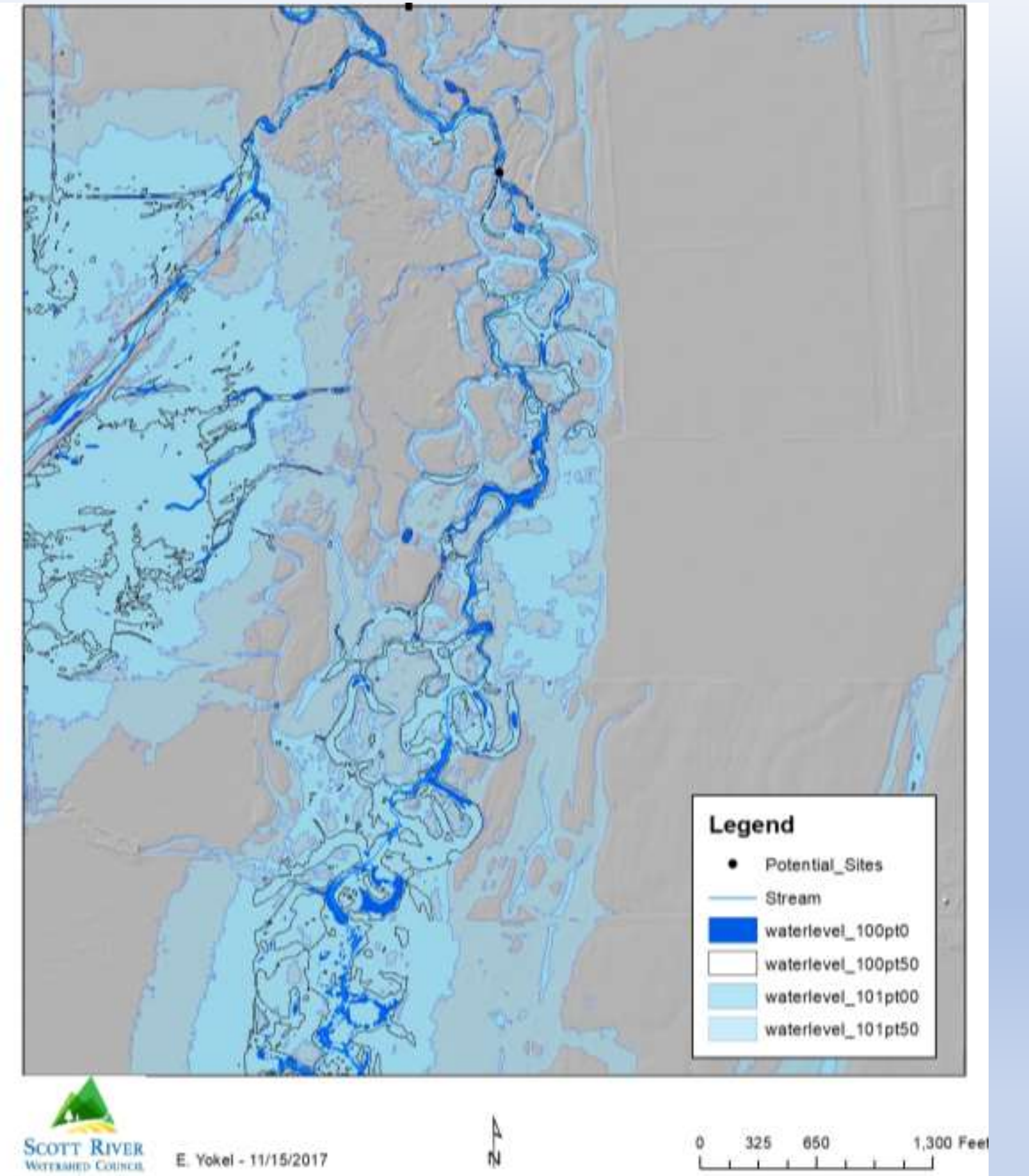
Total Number of sites = 46
High Risk Sites = 3
Reference Sites = 4
Ongoing Implementation = 1
Funding Proposal Submitted = 5
Potential Sites for Planning = 33



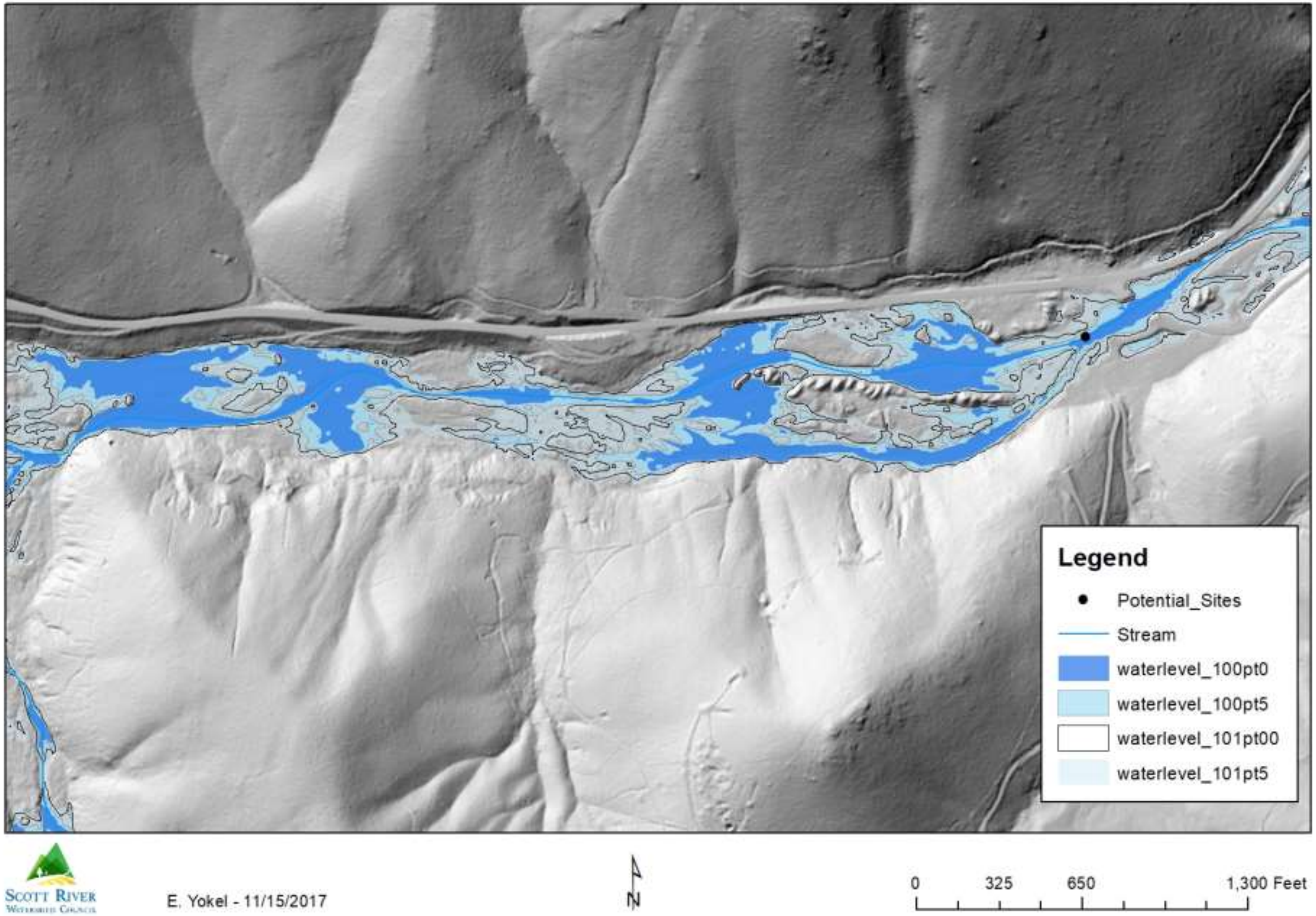
High Risk Site



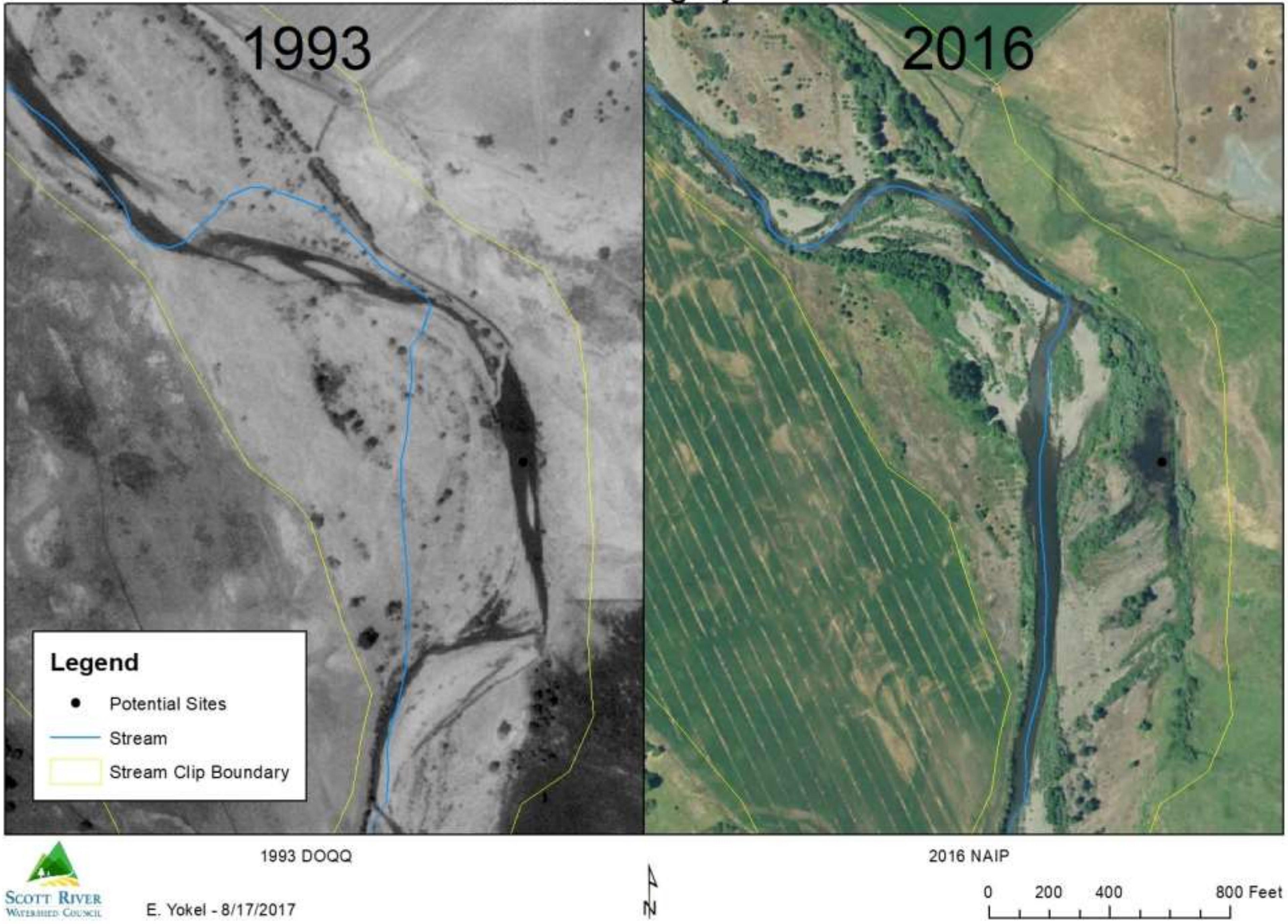
Reference Site



Potential Site



Historic Imagery



Scott River Watershed Council

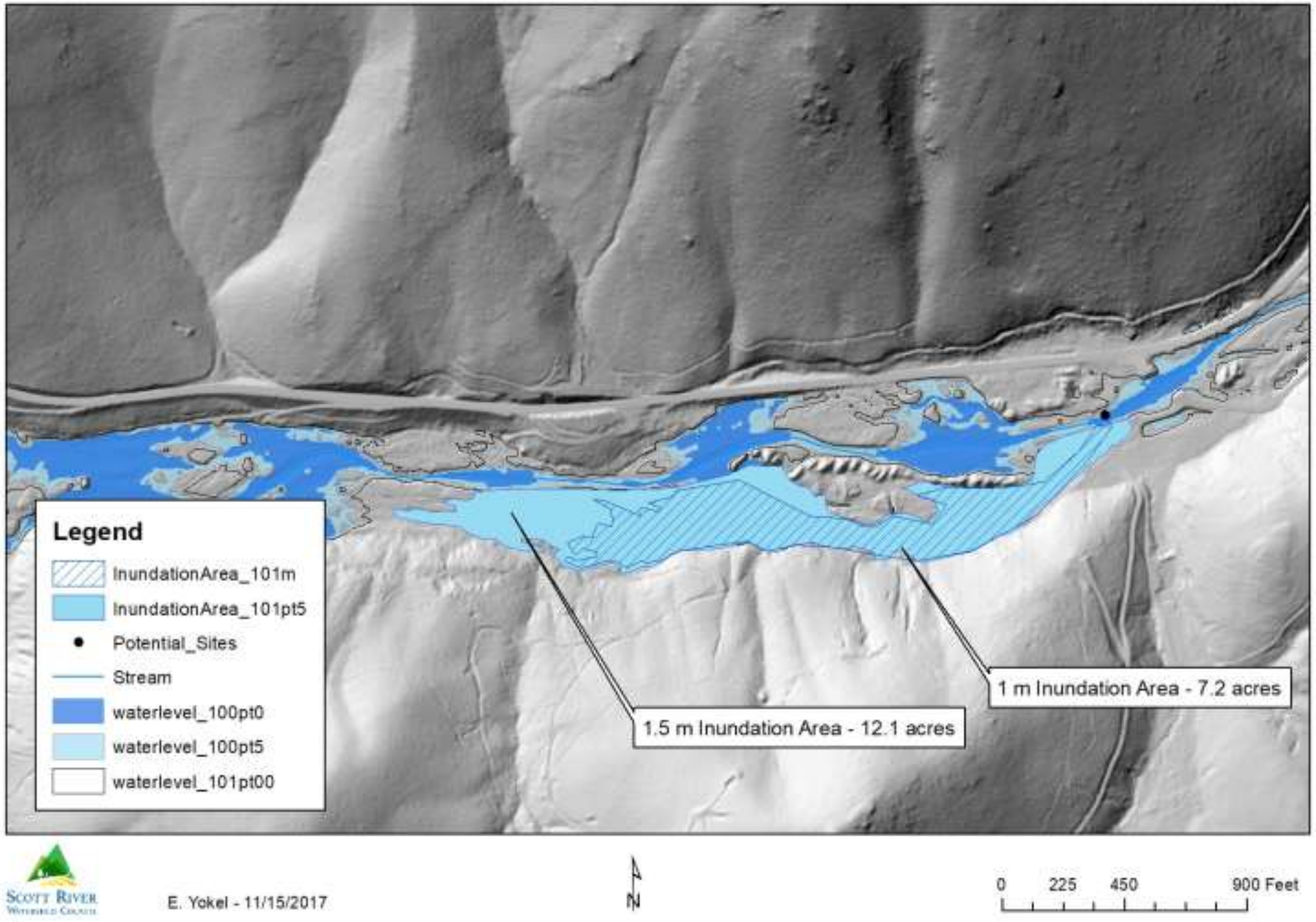
E. Yokel - 8/17/2017

Initial Scoring of Identified Potential Sites

Four Parameters Scored:

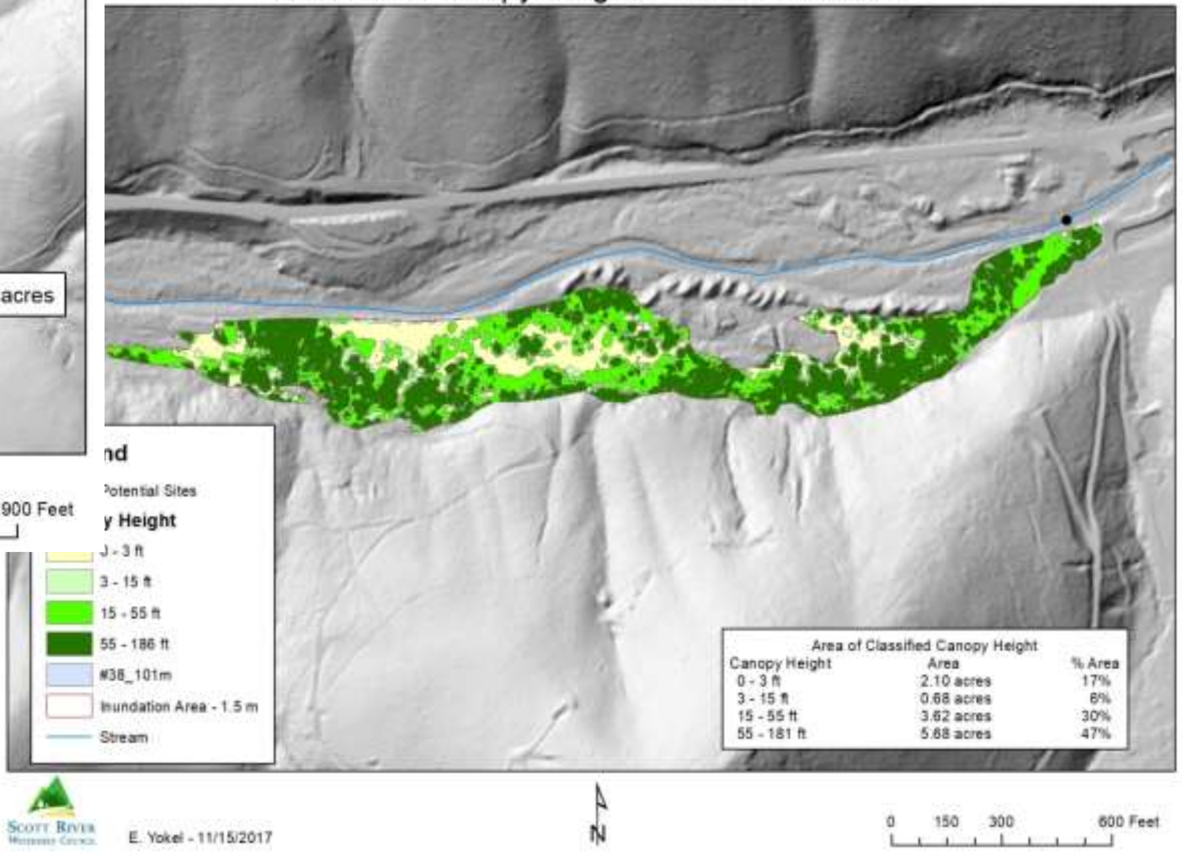
1) Water Presence during base flow period of summer
2) Coho Presence
3) Potential Site Inundation Area
4) Riparian Condition and Density

Inundation Area - 1m and 1.5 m



Determine inundation area and canopy height for all identified potential sites

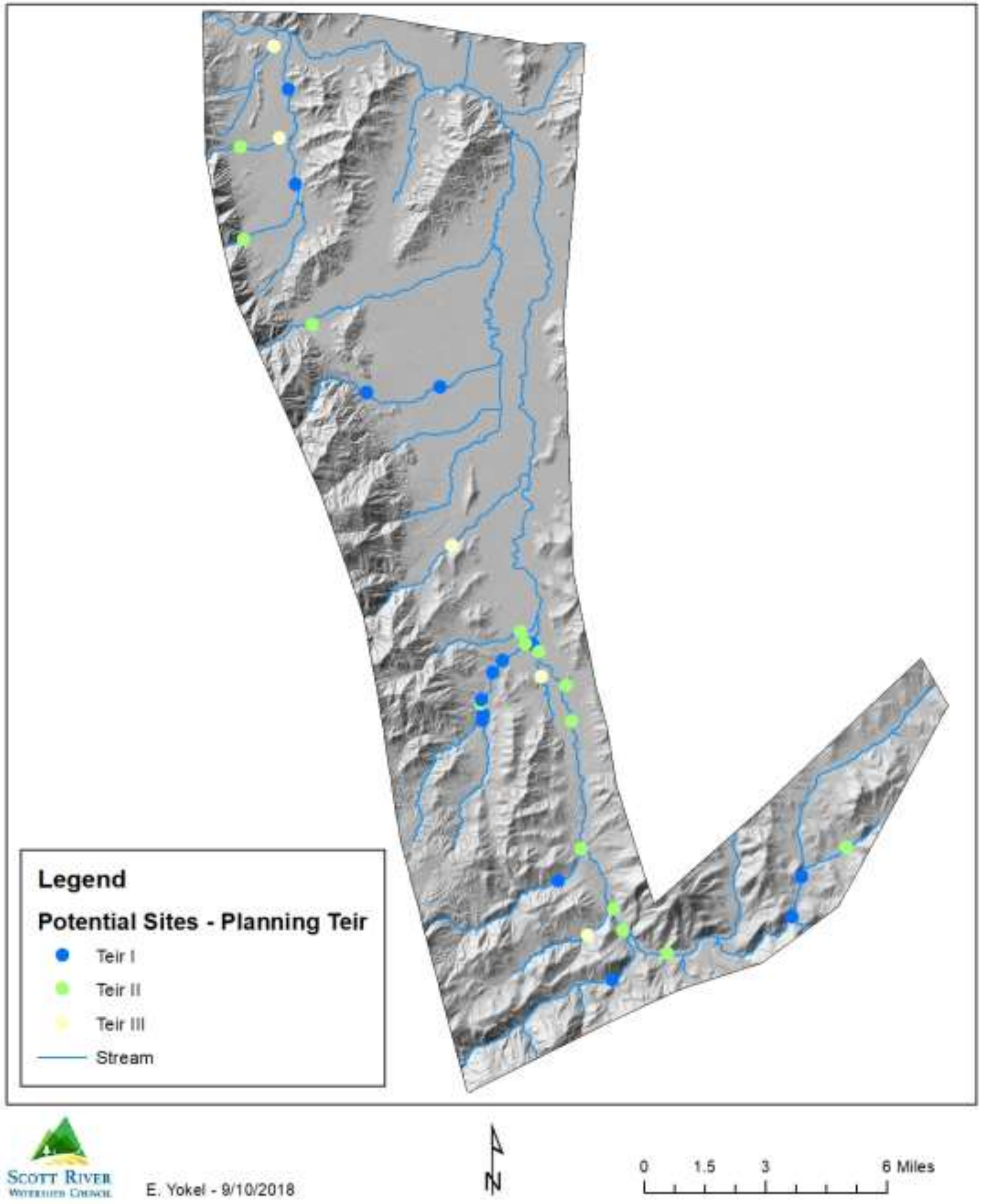
Scott River Westside Planning Project
Classified Canopy Height - 1.5 m Inundation

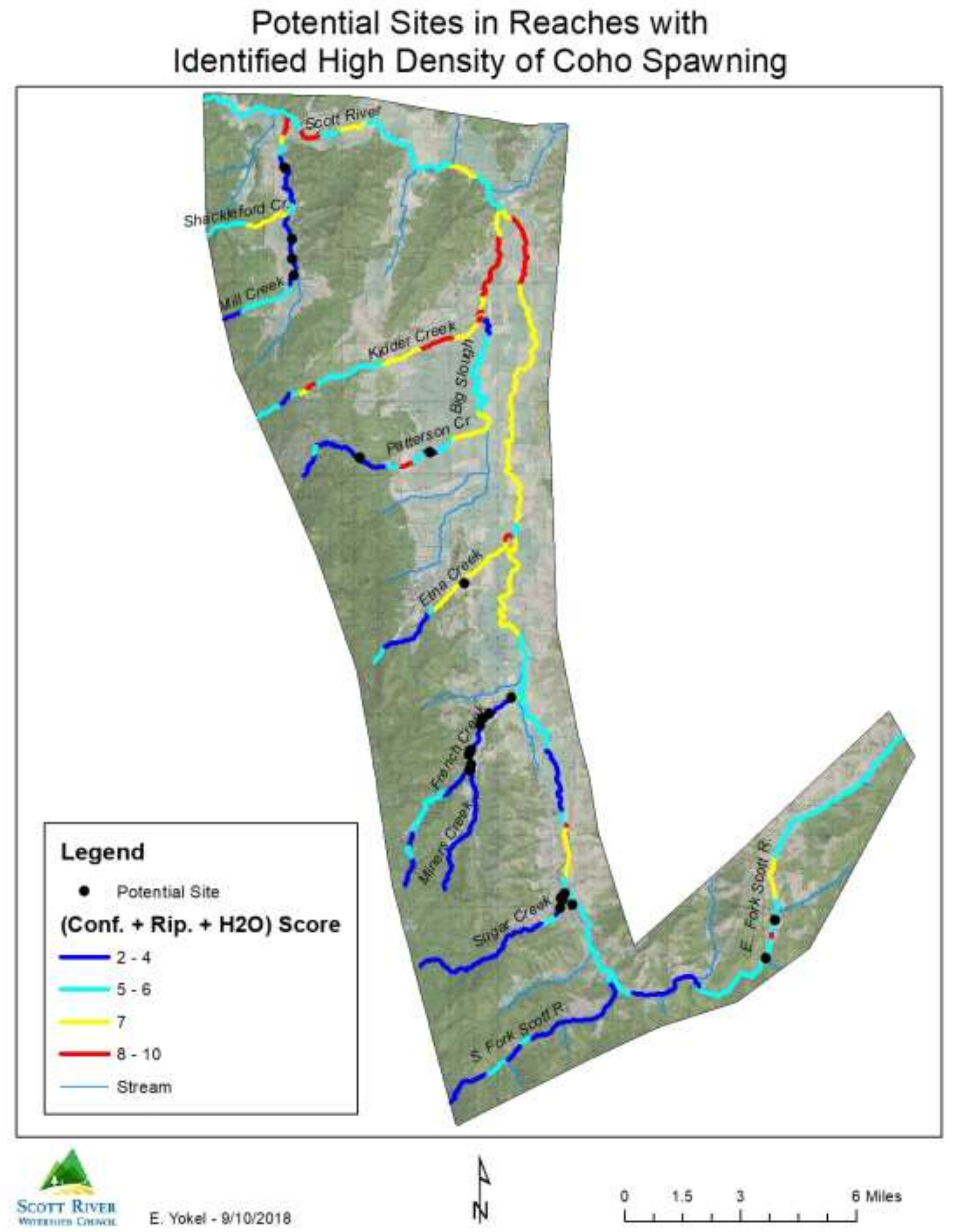


Area of Classified Canopy Height

Canopy Height	Area	% Area
0 - 3 ft	2.10 acres	17%
3 - 15 ft	0.68 acres	6%
15 - 55 ft	3.62 acres	30%
55 - 181 ft	5.68 acres	47%

Potential Sites - Planning Teir





Twenty Four Potential Sites

are located in Reaches with Documented Historic High Density Coho Spawning

Tributaries w/ Potential Sites in Reaches of Historic High Density Coho Spawning

Shackleford Creek
Mill Creek
Patterson Creek
Etna Creek
French Creek
Miners Creek
East Fork Scott River

Potential application to Klamath tributaries behind the dams

- Collate existing water quality/physical habitat and biological data
- Utilize existing LIDAR DEMs (Oregon) and/or acquire LIDAR DEM to develop inundation model and geospatial products
- Utilize LIDAR DEMs to determine stream gradient and confinement and riparian condition
- Classify, score and rank

Dave Hering – National Park Service

For Full Report see www.scottriverwatershedcouncil.com

Thank You!