# Salmon and Climate Change: Advancing a Recovery Approach for Pacific Salmon

A Concurrent Session at the 42nd Annual Salmonid Restoration Conference
Santa Cruz, California, April 29 - May 2, 2025

**Session Coordinators: Shaara Ainsley,** Long Live the Kings, and **Sherri Norris**, California Indian Environmental Alliance (CIEA)

Robust and resilient Pacific salmon populations that support thriving ecosystems, Indigenous rights and cultures, local economies, and recreation require effective and ongoing stewardship. However, rapid climate change is making this salmon recovery goal more difficult to achieve and calls into question the viability of salmon runs and fisheries along the coast and watersheds of western North America. Climate change is adding to existing stressors, causing complex, interacting processes that drive mass mortality events and changes in phenology, range shifts, and extirpations. A future in which resilient salmon can flourish and salmon populations can support harvest in the face of climate change depends on a recognition of social – ecological systems and diverse knowledge sources, innovative science and policy, dramatically increased funding, well-informed climate resiliency planning, and significantly greater information-sharing across a wide geographic range. Salmon-reliant communities are working hard, but we need new approaches to achieve recovery and support salmon resiliency. This requires a rapid paradigm shift with an unprecedented expansion of collaborative engagement and a braiding together of Indigenous and Western knowledge systems. To advance this paradigm shift, presenters in this session will share innovative and collaborative approaches to supporting tribal climate resilience planning and climate resilience of Pacific salmon populations.

# Presentations


- **Developing Collaborative Solutions to Address and Plan for Climate Impacts on Pacific Salmon**
  Shaara Ainsley, Long Live the Kings and Sherri Norris, California Indian Environmental Alliance (Co-presenters)…………………………… Slide 4

- **Reorienting to Recovery: Stretching into the Whole,** Natalie Stauffer-Olsen, Trout Unlimited…………………… Slide 47

- **Cool Corridors: How Identifying and Indexing Riparian Climate Refugia Contributes to The Future Protection and Restoration of Anadromous Fish Habitat in Northern California,** Christine Davis M.S., California Trout, Farrah Tyler B.S., CalPoly Humboldt, and James Graham Ph.D., CalPoly Humboldt …………………… Slide 87

- **Rapid Evolution In The Face Of A Changing Climate: Can Salmonids Keep Up With Rising Temperatures?**
  Paige Gardner, UC Santa Cruz…………………………… Slide 120

- **Spawning Distributions Through Space And Time: Assessing Resilience Of An Endangered Coho Salmon Population Complex In A Coastal California Watershed,**
  Rachael Ryan, Ph.D., University of California Davis…………………………… Slide 151

- **A Model-Based Investigation Of Early Marine Growth And Survival For California Chinook Salmon,**
  Kelly Vasbinder, Ph.D., University of California Santa Cruz…………………………… Slide 172

# Salmon and **Climate Change**

*Advancing a climate-resilient recovery approach for Pacific salmon*

# Salmon and Climate Initiative

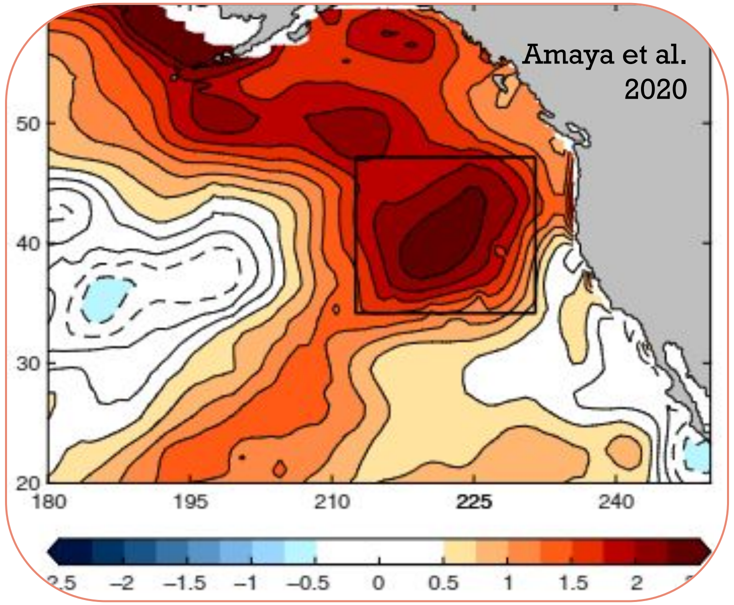
Advancing a climate-resilient recovery approach for Pacific salmon throughout their North American range

**Shaara Ainsley, Long Live the Kings**

April 2025

# What we stand to lose

Salmon are crucial to the environmental, cultural, and economic health of the North America


# Salmon-Human Ecosystems

Effective salmon stewardship

- Thriving ecosystems
- Indigenous rights and cultures
- Local economies that depend on salmon

# Allocated resources are inadequate

Gross Domestic Product of Pacific Coast States and British Columbia

**$4.9 trillion (2021)**

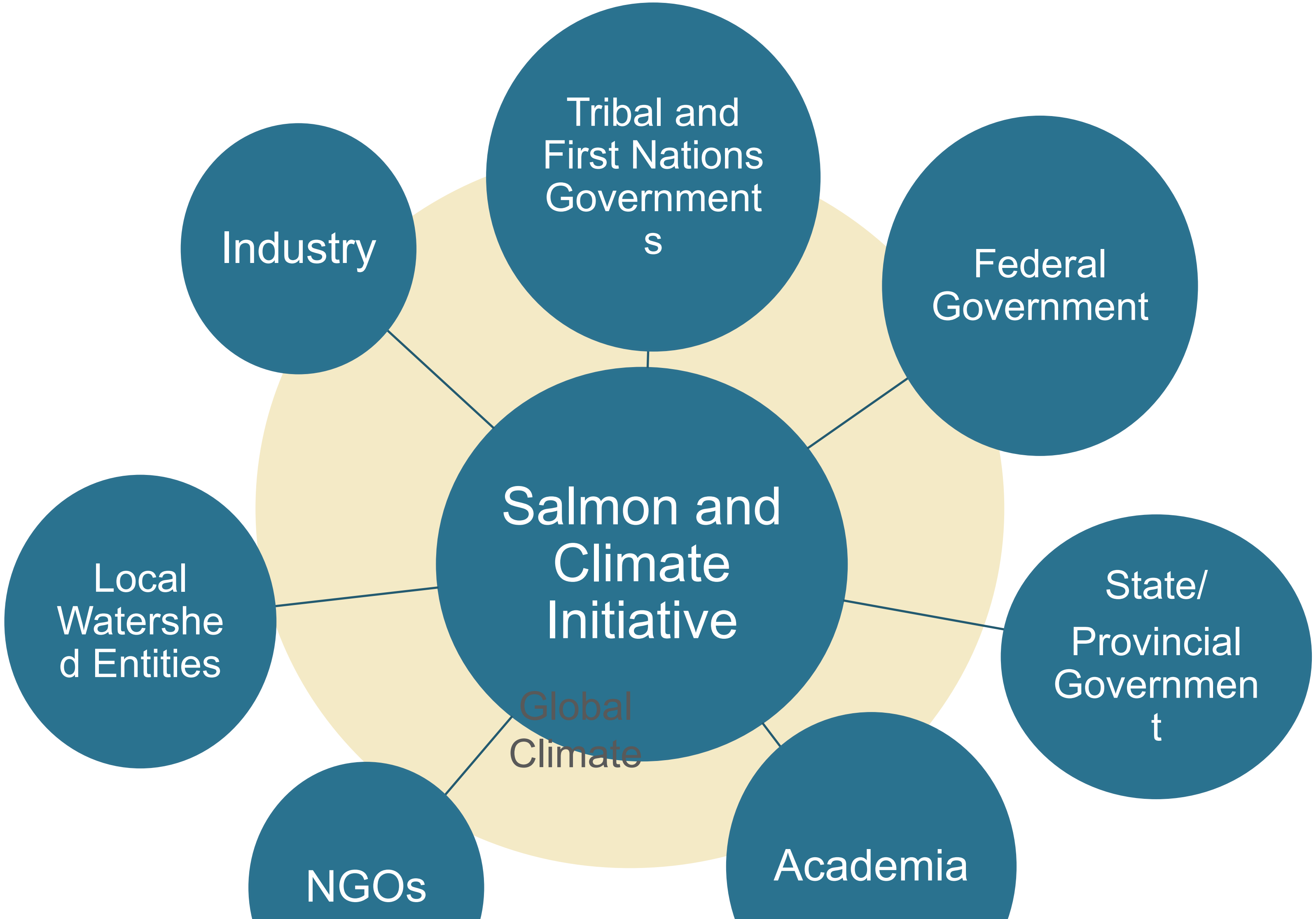
Yearly Pacific Coastal Salmon Recovery Fund (PCSRF) Spending

**$65 million (2021 enacted)**

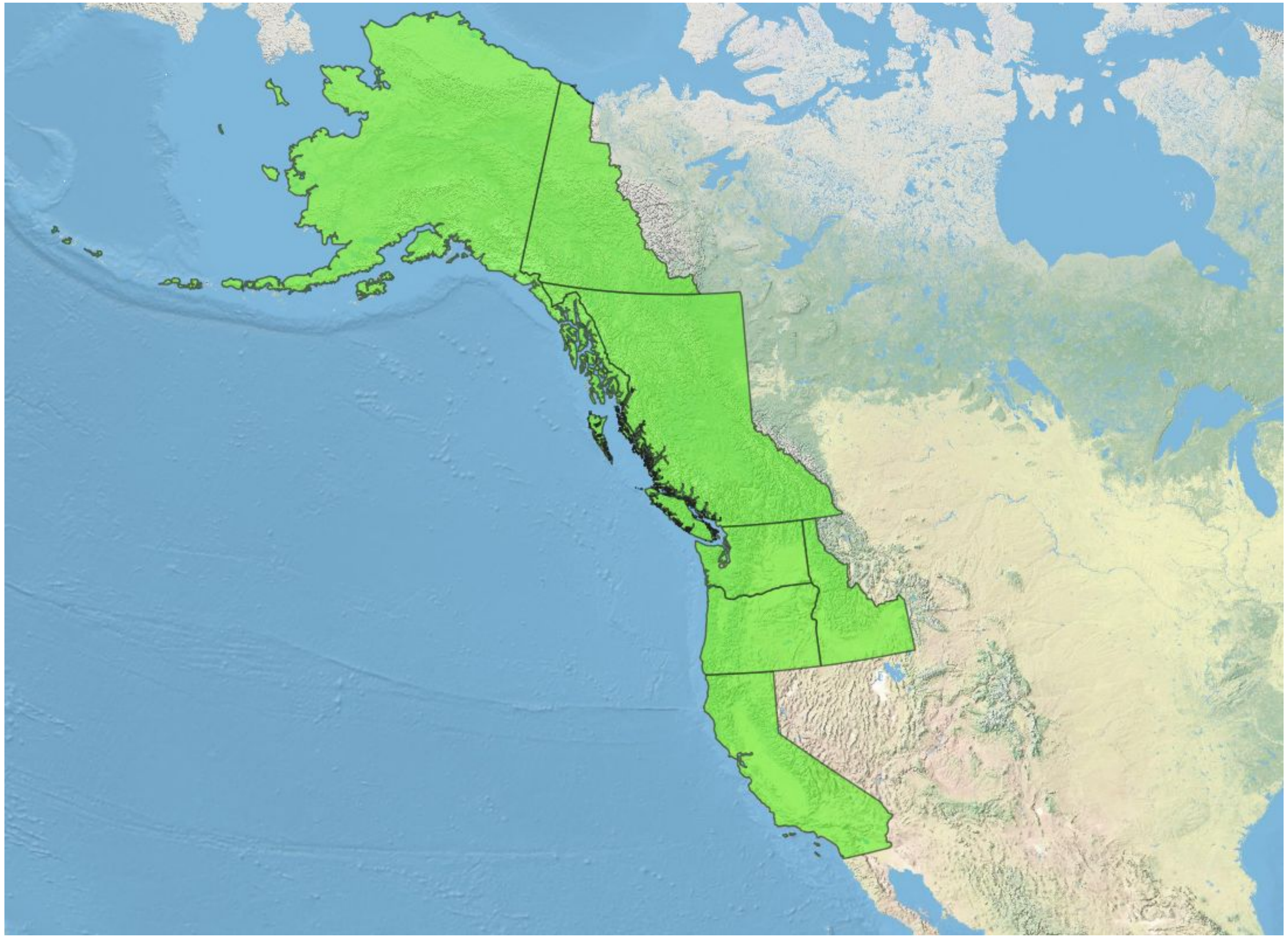
PCSRF x 100? **$6.5 billion**

# We are at a crossroads

# We need to think BIG



# We Need to think BROADLY

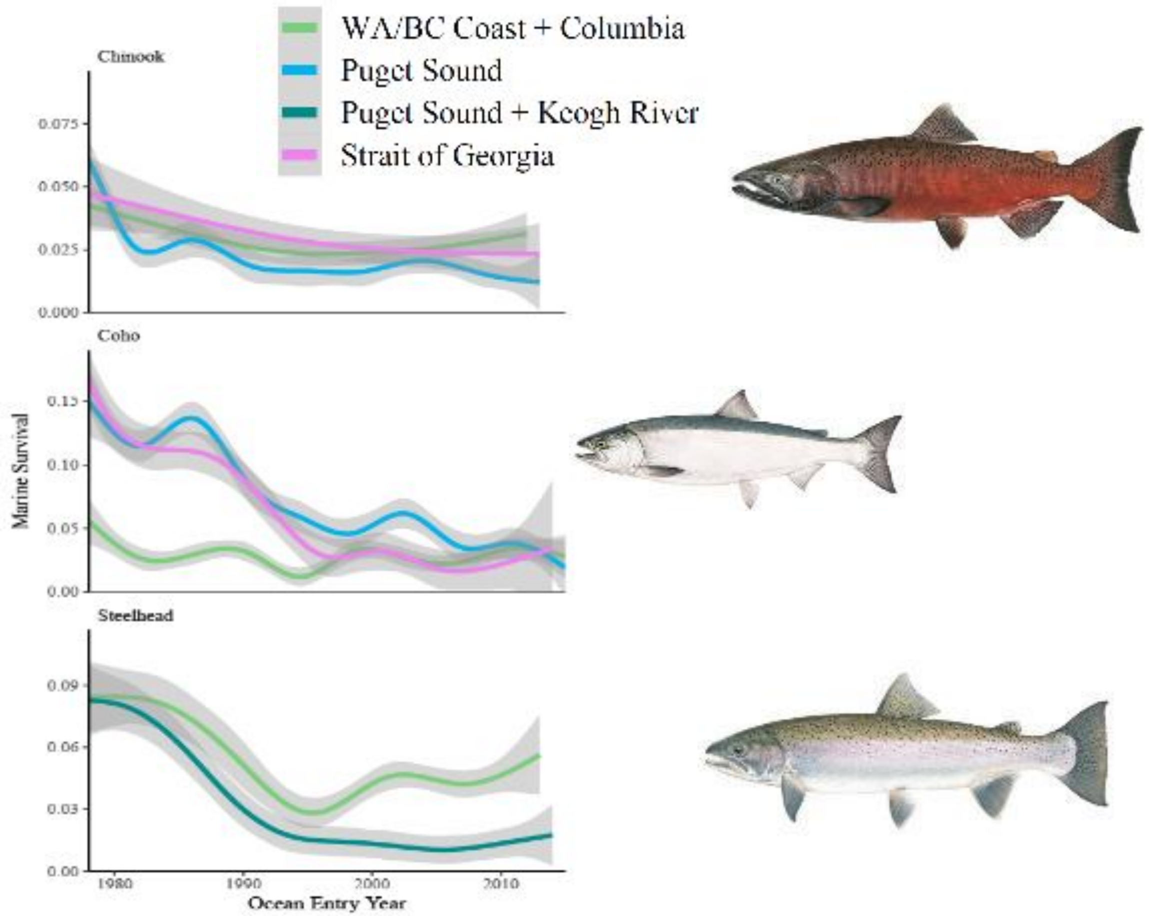


# Collaboration is Hopeful


## Climate Emotions Wheel

https://www.climatementalhealth.net

# Collaborative Precedent




- **Salish Sea Marine Survival Project:** 2014-2019
- **Question:** What are primary factors affecting juvenile salmon survival in the Salish Sea marine environment?
- **Approach:** 200+ people, 60+ organizations, 90+ studies across the Salish Sea

# Solution

**Collaborative Framework** → **Multi-Year Initiative** → **Outcomes**

Prioritize, fund & implement big projects

Test novel approaches

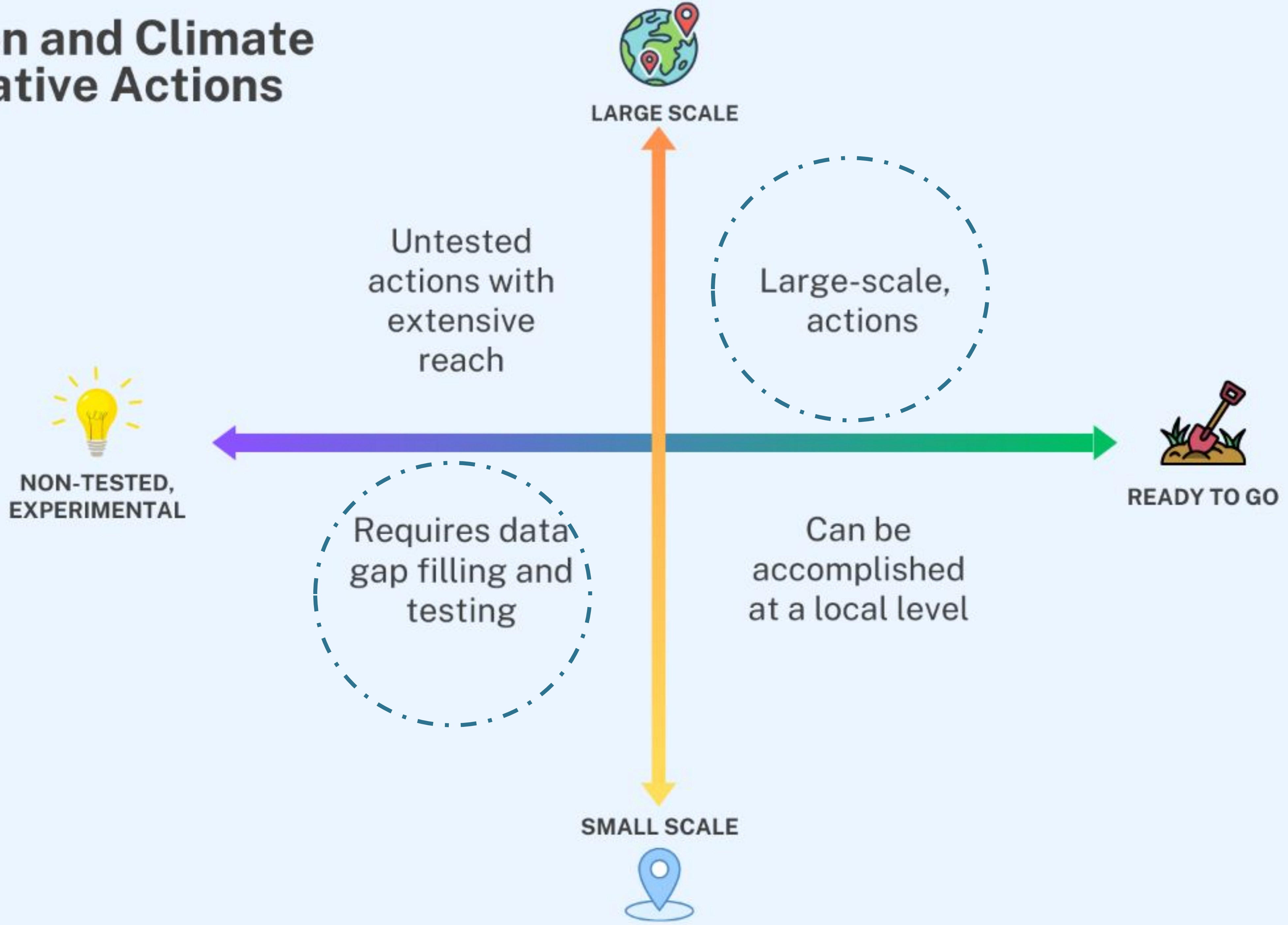
Fill strategic knowledge gaps

Make a case for funding

Inform local & regional planning and management

Build capacity & resilience in impacted communities

# Salmon and Climate Initiative Actions



# 2023 Planning Meeting

# 2023 Scoping Workshop

# A few ideas…

- Build a common understanding
- Leverage our collective outreach with a 'Salmon PR Campaign'
- Bring in diverse holders of knowledge on climate change and human thinking
- Create a database of life history and genomic diversity portfolios

# SCI Strategic Plan will include…

# SCI Values

The values are beliefs that will guide our decision making as an initiative:

- Honor sovereignty
- Respect multiple ways of knowing and build on that knowledge
- Be inclusive and transparent
- Be salmon-centered and action-oriented

DRAFT

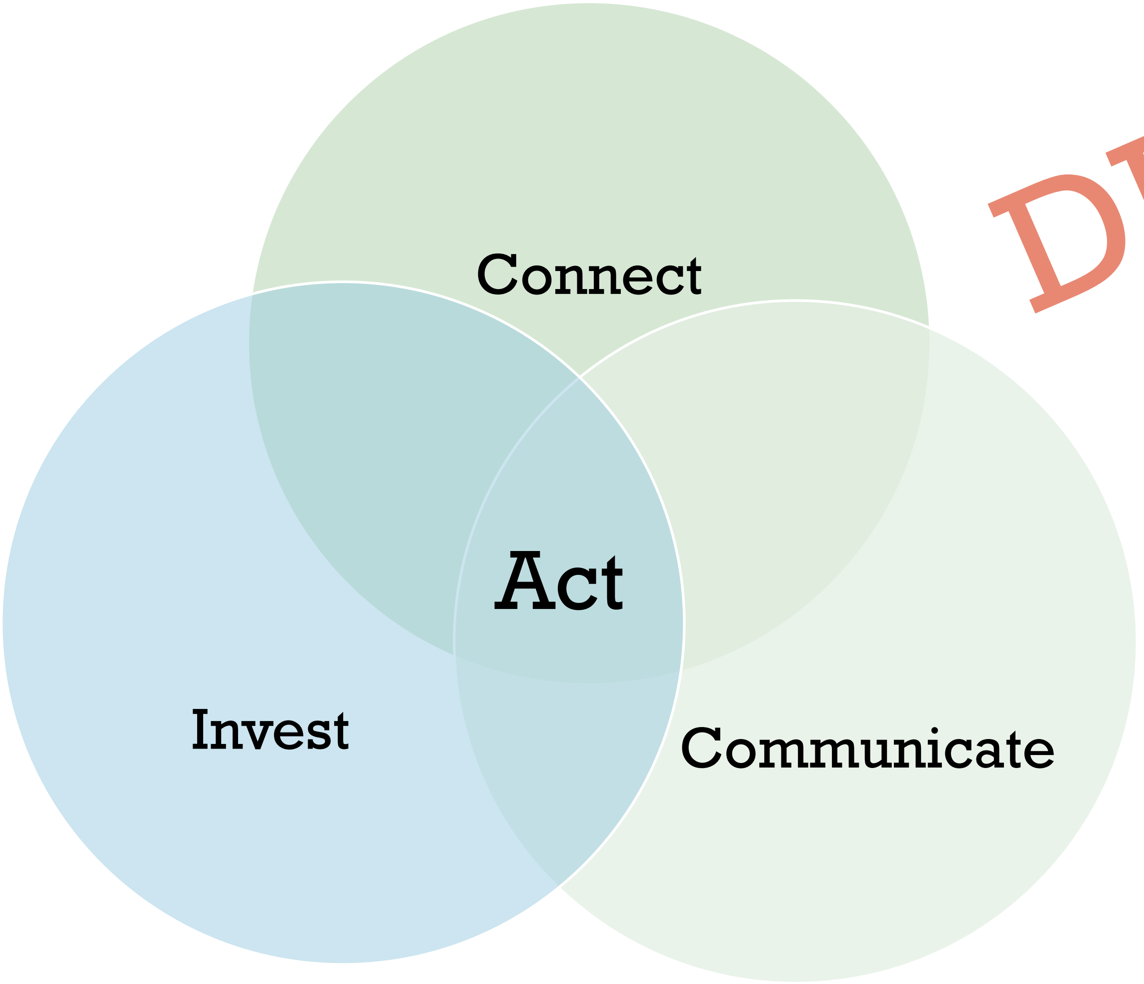
# SCI Strategic Goals by 'Stream'

DRAFT

- Connect
- Communicate
- Invest
- Act

- Strategic Goals (Long-term)
  - Immediate Objectives (2 Years)
  - Mid-range Objectives (5 Years)
  - Advanced Objectives (10+ years)

# SCI Strategic Goals by 'Stream'

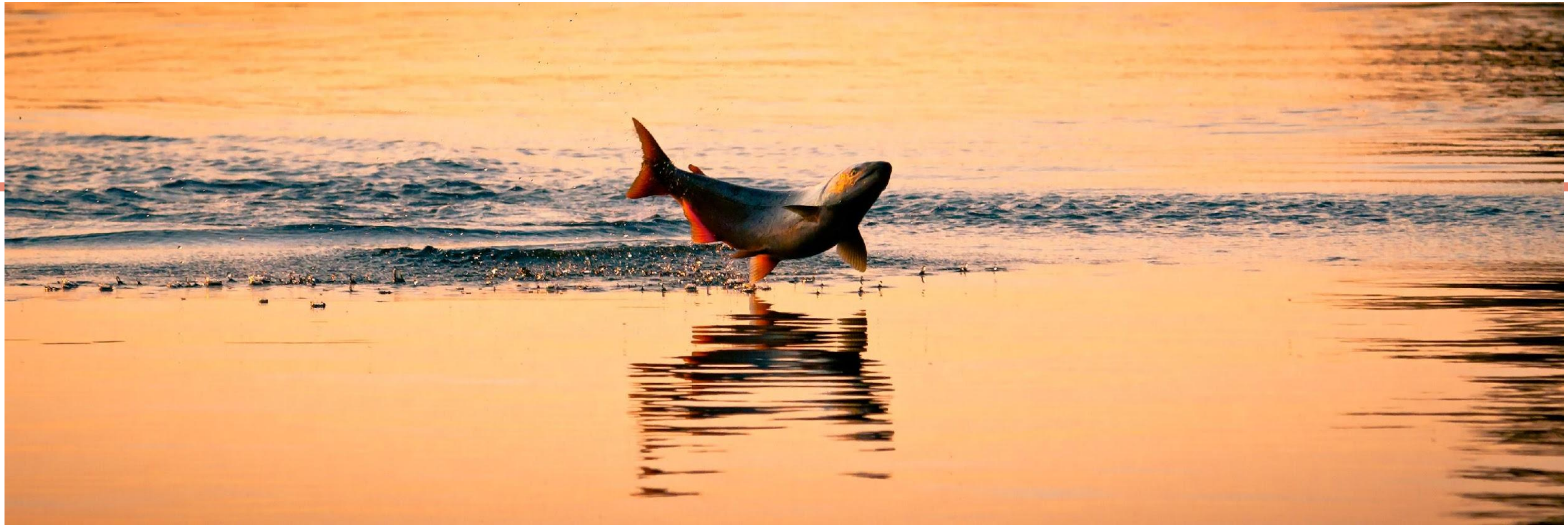



DRAFT

- Strategic Goals (Long-term)
  - Immediate Objectives (2 Years)
  - Mid-range Objectives (5 Years)
  - Advanced Objectives (10+ years)

# How can SCI benefit your work?

- Provide a compelling case for **additional funding**
- Provide a **cooperative environment** to coordinate efforts
- Unify regional efforts by sharing data and approaches, and **supporting coordinated analyses and reporting**



"Salmon recovery is about us. All of us. And it's going to take all of us and all we can do to make it happen."
~ Billy Frank Jr.

# Thank you!

**Shaara Ainsley**
Associate Director of Projects
Long Live the Kings
sainsley@lltk.org

LONG LIVE THE KINGS

PACIFIC SALMON FOUNDATION

Salmon Defense

## CORE TEAM

**Jen Bayer**, U.S. Geological Survey

**Peggen Frank**, Salmon Defense

**Ben Harrison,** Port Gamble S'Klallam Tribe

**Jason Hwang**, Pacific Salmon Foundation

**Kerry Naish,** University of Washington

**Erik Neatherlin,** WA Governor's Salmon Recovery Office

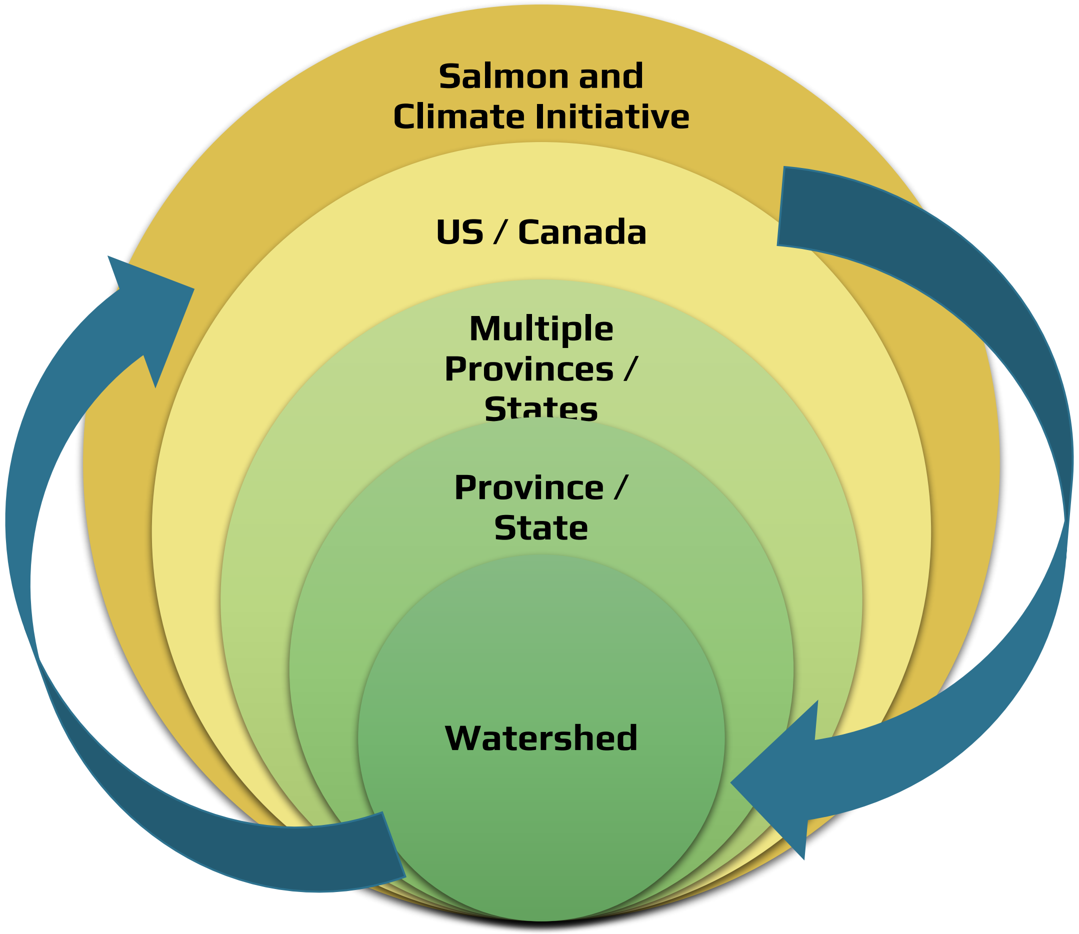
**Lisa Seeb,** University of Washington

**Jacques White**, Long Live the Kings

# SCI Value Proposition

**Bottom-up:**

SCI can gather watershed- and basin-level priority actions, advance regionally-relevant actions at the national level, and amplify successes




**Top-down:**

Collectively, SCI can provide regional support to direct more resources to the watershed level

# The Problem

Existing Pressures

- Rapid human population growth
- Intensive land and water use
- Depleted salmon populations
- Inadequate response

+

Climate Impacts

- Variable snowpack
- Extreme wildfires
- Elevated river temperatures
- Lower flows
- Warming and acidifying oceans
- Altered food webs

=

**Increased Salmon and steelhead vulnerably**

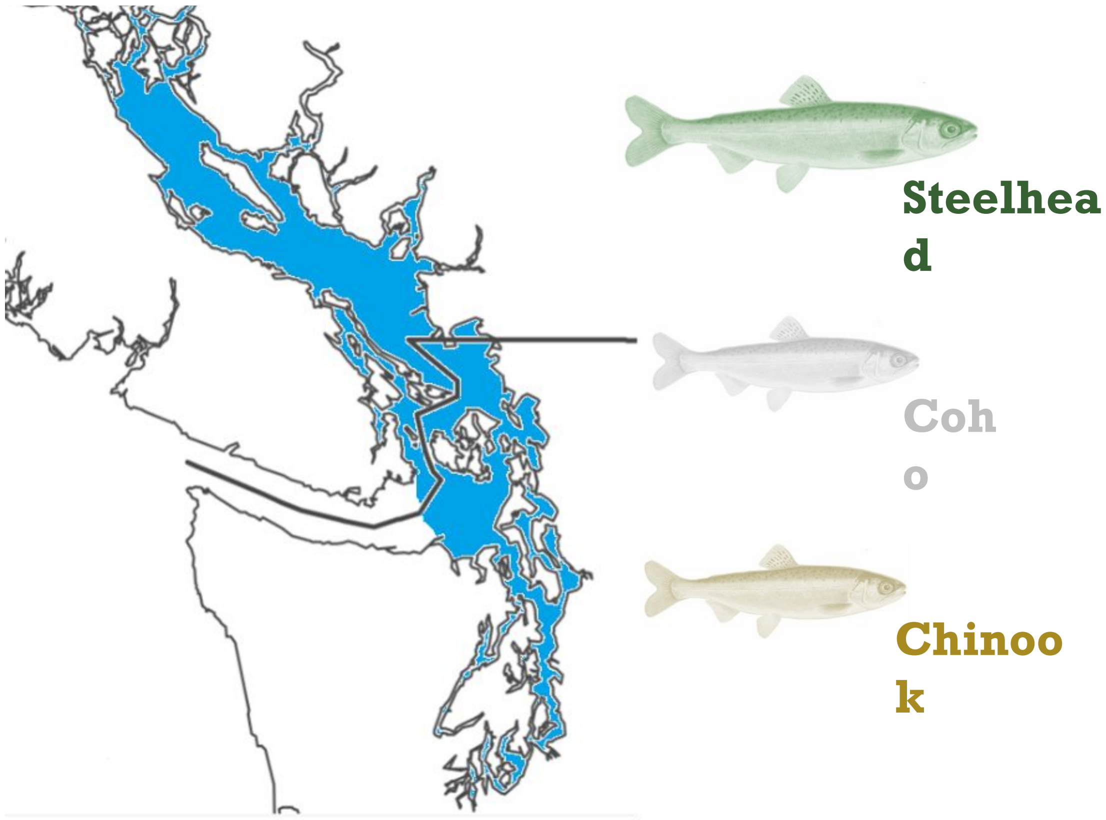
# We need to think CREATIVELY

"Key opportunities include expanding beyond preservationist approaches by including those that enable and facilitate ecological change."

**Getting ahead of climate change for ecological adaptation and resilience**

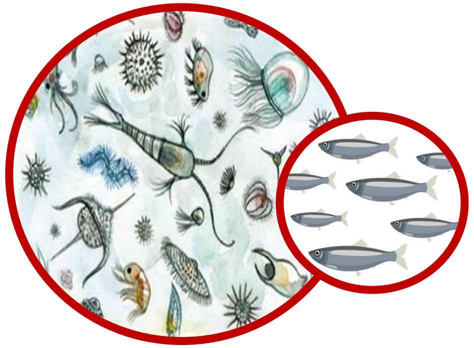
Jonathan W Moore[1], Daniel E Schindler[2] Science. 2022 Jun 24;376(6600):1421-1426.

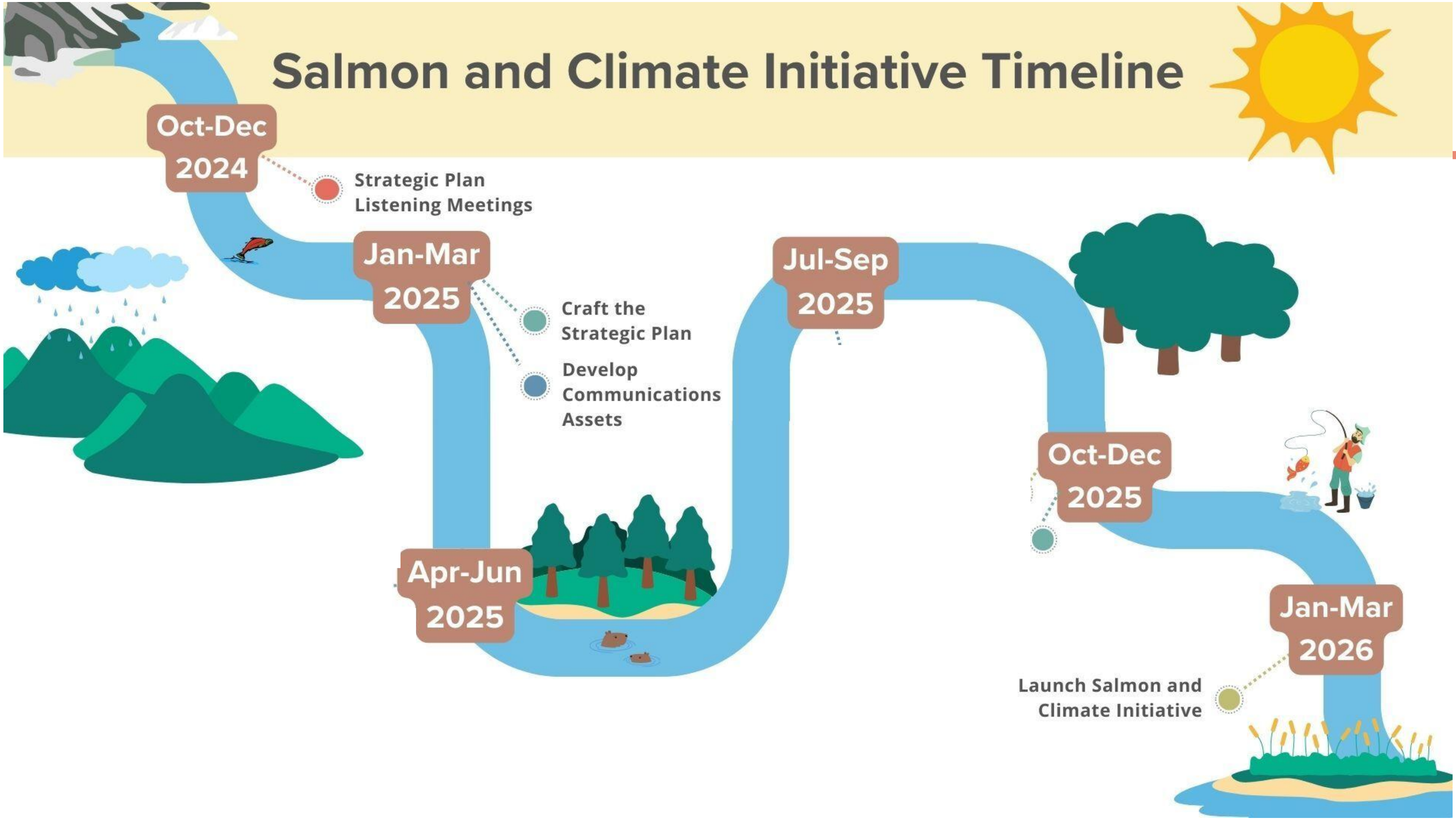
# Primary Factors in the Salish Sea




More predators: more salmon and steelhead consumed

Less food available when young salmon need it most




Salmon and Climate Initiative Timeline
Oct-Dec 2024
Strategic Plan Listening Meetings
Jan-Mar 2025
Craft the Strategic Plan
Develop Communications Assets
Apr-Jun 2025
Jul-Sep 2025
Oct-Dec 2025
Jan-Mar 2026
Launch Salmon and Climate Initiative

# Initiative and Scoping Workshop Sponsors

HORIZONS FOUNDATION OF WASHINGTON

**Alida and Christopher Latham**

LONG LIVE THE KINGS

**MJF Foundation**

PACIFIC SALMON FOUNDATION

PUGETSOUND PARTNERSHIP

**Duke's Damsel on a Train Foundation**

Sea Grant Washington

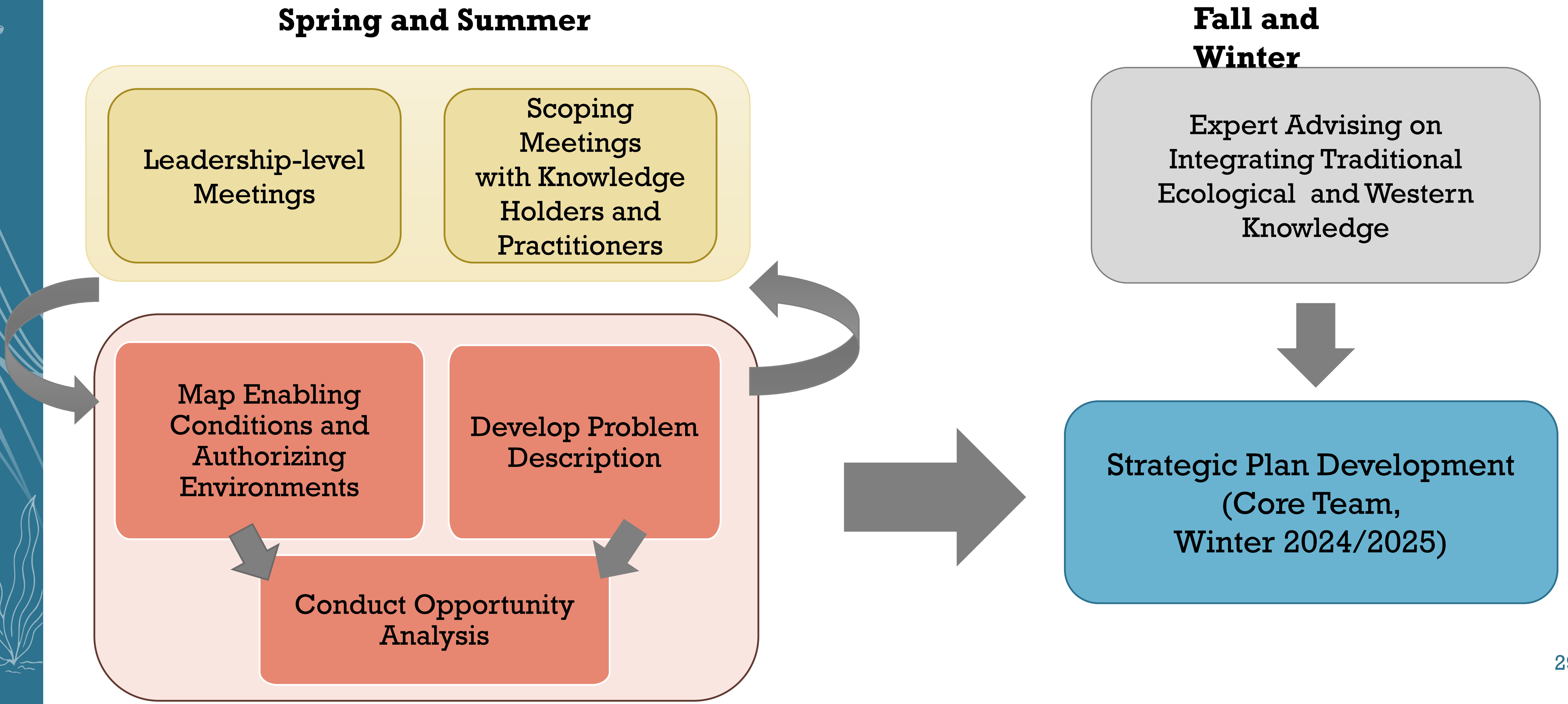
Squaxin Island Tribe
*People of the Water*

THE SUQUAMISH TRIBE

Satterberg foundation

**The Norcliffe Foundation**

# Next Steps: Additional Scoping



# Northern California Tribal Consortium for Climate Resiliency (NCTCCR)

**42nd Annual Salmonid Restoration Conference**

Santa Cruz

April 29 - May 2, 2025

# Northern California Tribal Consortium for Climate Resiliency (NCTCCR)

**NCTCC partners:**

- Project Lead: Dry Creek Rancheria
- Amah-Mutsun Tribal Band
- Blue Lake Rancheria
- Kashia Band of Pomo Indians of Stewarts Point Rancheria
- Robinson Rancheria
- California Indian Environmental Alliance

# NCTCC Outputs

To create clearing house of tools and resources to create Vulnerability Assessments and actionable Climate Resiliency Workplans.

Workplans, points of contacts multiple Tribal experts

- Data collection preparation
- Resource research
- Tool development: Framework, Tools, Resources
- NCTCC Portal
- ArcGIS hands on trainings
- Partners chose which tools and resources each would pilot

# NCTCC Portal

- Climate Action Resilience Plan Framework
- Targeted Surveys & Support tools
- Resource Library
- Trainings & Species Resiliency


www.catribalclimateresiliencyresourceportal.com

# CLIMATE ACTION RESILIENCE PLAN FRAMEWORK

- CARP outlines step-by-step process to create Vulnerability Assessments and actionable Climate Adaptation Plans
- Review and integrate new and emerging climate planning tools and methodology

I. **Understand Exposure & Community Concerns:** Exposures, hazards, impacts and vulnerabilities with traditional territories.

**1. Community Participatory Research**

**Surveys** - Staff, Leadership and Community

- COMMUNITY SURVEY
- STAFF AND COUNCIL SURVEY
- CLIMATE CHANGE RATED CONCERN SURVEY

**2. Analyze, Interpret & Receive Feedback**

- Analyze data
- Pair Assets and Hazards
- Identify Assets and Hazards

**3. Create Risk Matrix**

**II. Draft Vulnerability Assessment** - Directs Climate Resiliency Plan Development

- Review Peer Vulnerability Assessments
- Integrate and Draft Vulnerability Assessment
- Community Truth-Check Meetings

**III. Investigate Options for Climate Resiliency Plan**

- Review Solutions
- Align with Existing Plans
- Prioritize Areas of Interest
- Interviews and Focus Group Planning
- Identify Resources and Capacity: CLIMATE *RESOURCE LIBRARY*
- Review Peer Climate Plans

## IV. Prioritize and Develop Climate Resiliency Plan

- Develop Adaptation Goals and Actions: High and medium-priority hazard areas. Goals and actions
- Write Climate Actionable Resiliency Plan: Assessment outcomes, fold in Asset Pairs, into Climate Change Adaptation Strategies to solutions
- Leadership, Staff and Community Review: Share Vulnerability Assessment, initial ideas, brainstorm and gain feedback

## V. Implement Action

- Create Timelines for Actions: Review adaptation strategies and develop timeline(s) from inception to implementation
- Create Plan for Updates: Periodic update plan for adaptation to changes in challenges and capacity to prepare and respond.
- Community and Allies Strategic Action Planning Meeting
- Review actionable strategies, synergies and potential conflicts, shared actions
- Fund Implementation: Apply for funding for proposed actionable adaptation strategies early in advance of the implementation phase.

# CLIMATE RESOURCE LIBRARY

Over 200 sortable open-source resources to support climate researchers and planners to navigate and choose from climate resources, templates, modeling and mapping links.  Arranged so users can sort and use them by the tasks outlined in the Framework.   Updated regularly. Search engine updates pending.

# Community Based Participatory Research

Vulnerability Assessments and Climate Planning are best completed in community. To support Community Based Participatory Research the NCTCC created three surveys that target different audiences.

**Surveys:** Support community participatory research, gather community needs and concerns. Printed for events, focus-groups, online survey platforms and interviews

- COMMUNITY SURVEY
- STAFF AND COUNCIL SURVEY
- CLIMATE CHANGE RATED CONCERN SURVEY

**Survey Tools:**

- CLIMATE SURVEY TRACKER
- SURVEY DEFINITION SHEET
- VISUAL REFERENCE SPREADSHEET

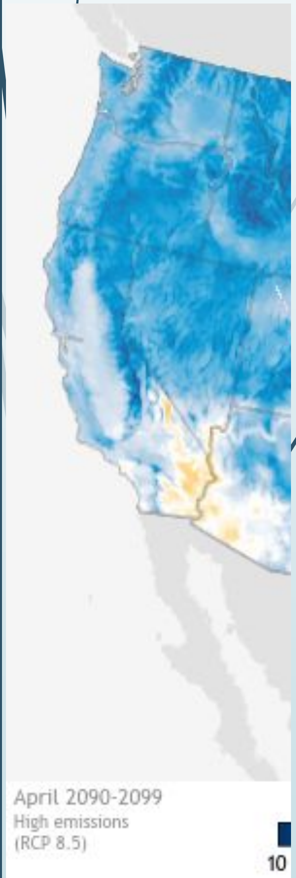
# Survey Tools and Support

Respondents share what they see in their territories with continuity, understanding that individuals use different words for similar responses.

- Discuss results of surveys with the community for refinement.
- Community planning discussions key to community participatory research, feedback loop, expand the resulting Climate Plan into a living and growing actionable plan.
- Ethnographic interviews folded into the community participatory research activities. Questions asked in interviews are part of the interview questions.
- Each of the NCTCC partners administered the survey differently using survey monkey, one-to-one interviews, or in focus groups.
- Staff of CIEA and NCTCC partners who piloted surveys available to other Tribes for support

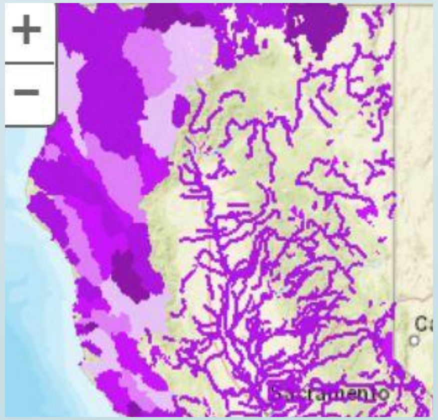
# ArcGIS Mapping Capacity

- NCTCC Mapping Workgroup was created in 2023
- Reviewed the mapping resources gathered, discussed which are most important to overlay, result is a comprehensive visual representation of data useful in climate planning. Entered into CLIMATE RESOURCE LIBRARY under maps.
- Hands on Beginner, Intermediate ArcGIS trainings: Seth LaRosa, UC Berkeley at Sonoma State University's Geology Department lab




# Tribal Planning/ Geospatial Planning & Analysis

- Mapping key to Vulnerability Assessments and Climate Resiliency Planning
- Share maps of traditional territories with overlays data
- Maps useful administering surveys for reference when surveying to provide locations of concerns



# NCTCC 2025 – 2027 Direction

**Species Resiliency**

Species resiliency discussions between tribal staff, including those with Tribal Knowledge, and with western species experts:

- Beaver & restoration of watershed resiliency in face of climate stressors
- Elk ranges, genetic diversity and transportation infrastructure barriers
- Ocean kelp and sun star distribution
- Mountain lion, key predator challenges

Align key species for different food webs with climate planning. Expand the original workplan Tribal partners are stewarding lands for all species including tracking species resiliency, and pathogens in populations.

**UN Convention on Climate Change**

2024 Summit update from Faith Gemmill, Indigenous Environmental Network including preliminary overview of the COPs treaty meetings and dangers of cap and trade policies on wider global loads.

# California North Coast Tribal Capacity and Climate Resilience Project SRF with CIEA support. NOAA Funded.

**Capacity Building:** Workshops to improve Tribal watershed restoration capacity administration, develop restoration and planning projects, create climate and watershed restoration work opportunities for tribal members and Tribes compensated for leadership and staff time in consultations.

- **Support:** Administering climate vulnerability assessments, developing Climate Resiliency Plans to develop coastal, watershed and cultural resource resilience goals, priorities, and processes for Tribes to make actionable progress.
- **Identify projects:** Ready to move to a planning grant phase.

**For more information contact:**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# *Thank you!*

Sherri Norris, CIEA Executive Director

**California Indian Environmental Alliance (CIEA)**

*NCRP Tribal Engagement Coordinator*

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# Reorienting to Recovery (*R2R*)

## Stretching into the Whole

Salmonid Restoration Federation Conference
May 1st, 2025

Dr. Natalie Stauffer-Olsen
Trout Unlimited

Photo Credit: California Department of Water Resources

# An acknowledgement

Many people are hurting right now

Laws that protect waterways, species, and the environment are being dismantled

Funding that makes our work possible is disappearing

Many colleagues are retiring and/or their positions are being eliminated

# Please take this moment…

Make yourself comfortable

Take some deep breaths

Learn about new ways we can move forward

This offers some good news and solutions!

# Presentation Overview

- Intro to R2R
  - The problem(s)/need
  - The opportunity
  - The project plan, approach, and phases
- Outcomes
- Accomplishments
- Stretching into the whole
  - Lessons learned
- Questions

Photo Credit: California Department of Water Resources

# Key themes

1. The structure of the process matters
2. Don’t reinvent the wheel
3. Create efficiencies across geographies
4. Funding must match the scope of the effort required

# The problem(s)

- **CV Salmon Populations in precipitous decline despite massive investments**
  - No single regulatory space positioned to recover Salmon on its own
  - Management actions for habitat, hydrology, harvest and hatcheries (4Hs) applied incoherently
  - If our efforts are not working now, problems will only intensify with climate change
- **A fractured society**
  - Culture of oppositional politics
  - Rampant distrust
  - Limited forums for dialogue across difference
  - Many conversations lacking key voices

# An opportunity

- **Convergent Evolution**
  - Collaborative Science and Adaptive Management Program (CSAMP) expands focus beyond BIOPs to Salmon Recovery
  - Uncommon Dialogues  Unlikely connections and new understanding
    - TU and SWCs
- **Diverse support** (SWCs, NOAA, BOR, DSP, DWR)
- **Precedent from the Columbia Basin** (Colombia Basin Collaborative)

# Vision: a collaborative approach

- **A new, non-regulatory, transparent, and inclusive** process to develop:
  - A broadly supported scientific definition of salmon recovery
    - Common objectives
  - A summary of the other key values (impacted (+ or -) by actions to recover salmon)
    - Common value set
  - A salmon recovery scenario (i.e. suite of actions) that:
    - Integrates actions across the 4Hs
    - Equitably distributes the pain and gain of achieving recovery across the range of values
- **A holistic, comprehensive vision for salmon restoration** with substantial *buy-in* and support

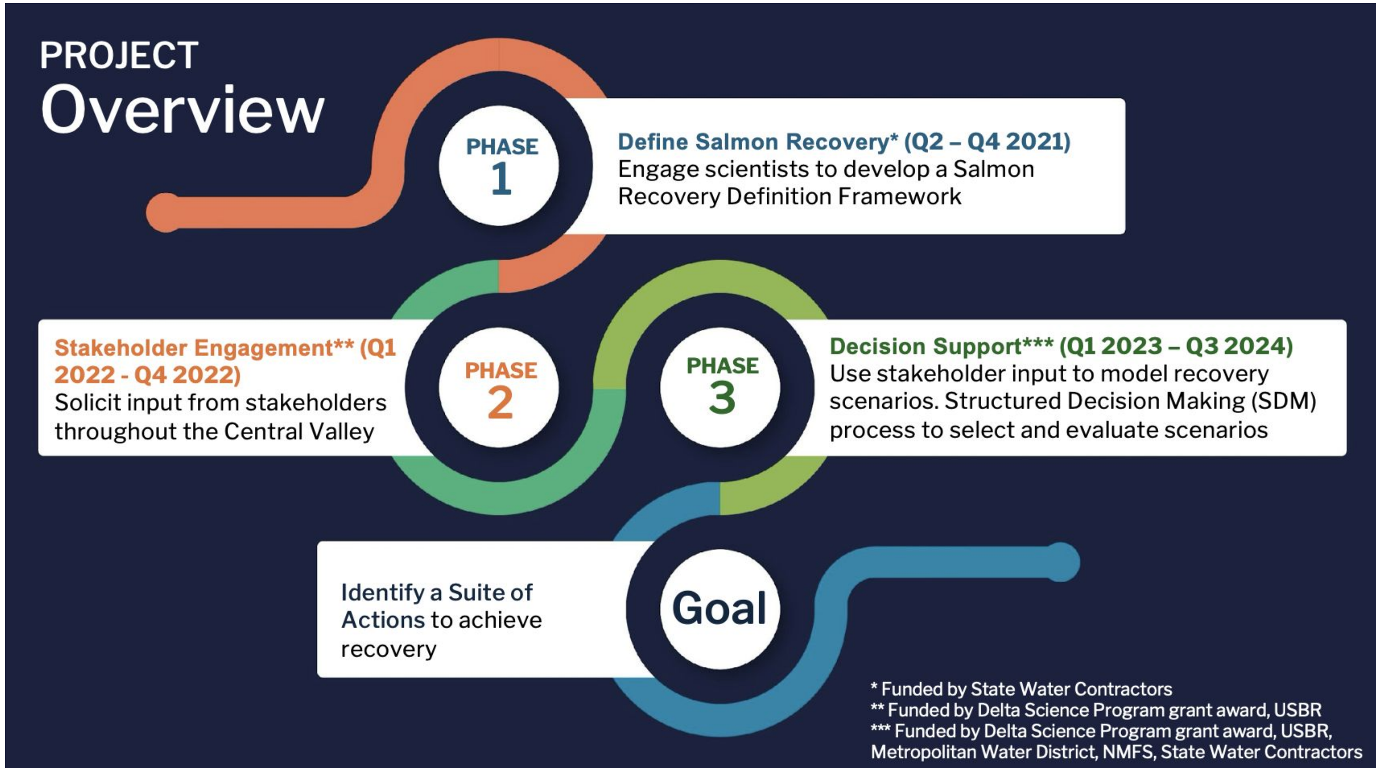
# Project Planning Team

| | |
|---|---|
| CA Indian Environmental Alliance | Michelle Rivera<br>Sherri Norris |
| Compass Resource Management | Brian Crawford<br>Michael Harstone |
| Essex Partnership | Bruce DiGennaro |
| FlowWest | Liz Stebbins<br>Erin Cain<br>Mark Tompkins |
| Kearns & West | Maryls Jeane<br>Rafael Silberblatt |
| Qeda Consulting | Noble Hendrix |
| Metropolitan Water District | Alison Collins |
| NMFS Southwest Fisheries Science Center | Ann-Marie Osterback |
| State Water Contractors | Darcy Austin |
| Trout Unlimited | Natalie Stauffer-Olsen<br>Rene Henery |
| The Bay Institute | Gary Bobker |
| Valley Water | Darcy Austin<br>Frances Brewster |

# A collaborative approach

- Design: three Phases over 3+ years: 1) Defined salmon recovery, 2) Collected and distilled values, 3) Developed recovery scenarios using structured decision making (SDM) and lifecycle models and consensed on one (platypus)

- Participation and Engagement
  - Inclusive groups
    - Phase 1: Science Advisory Team (SAT)
    - Phase 2: Forum
    - Phase 3: Forum, SAT, SDM Working Group
  - Diverse funding

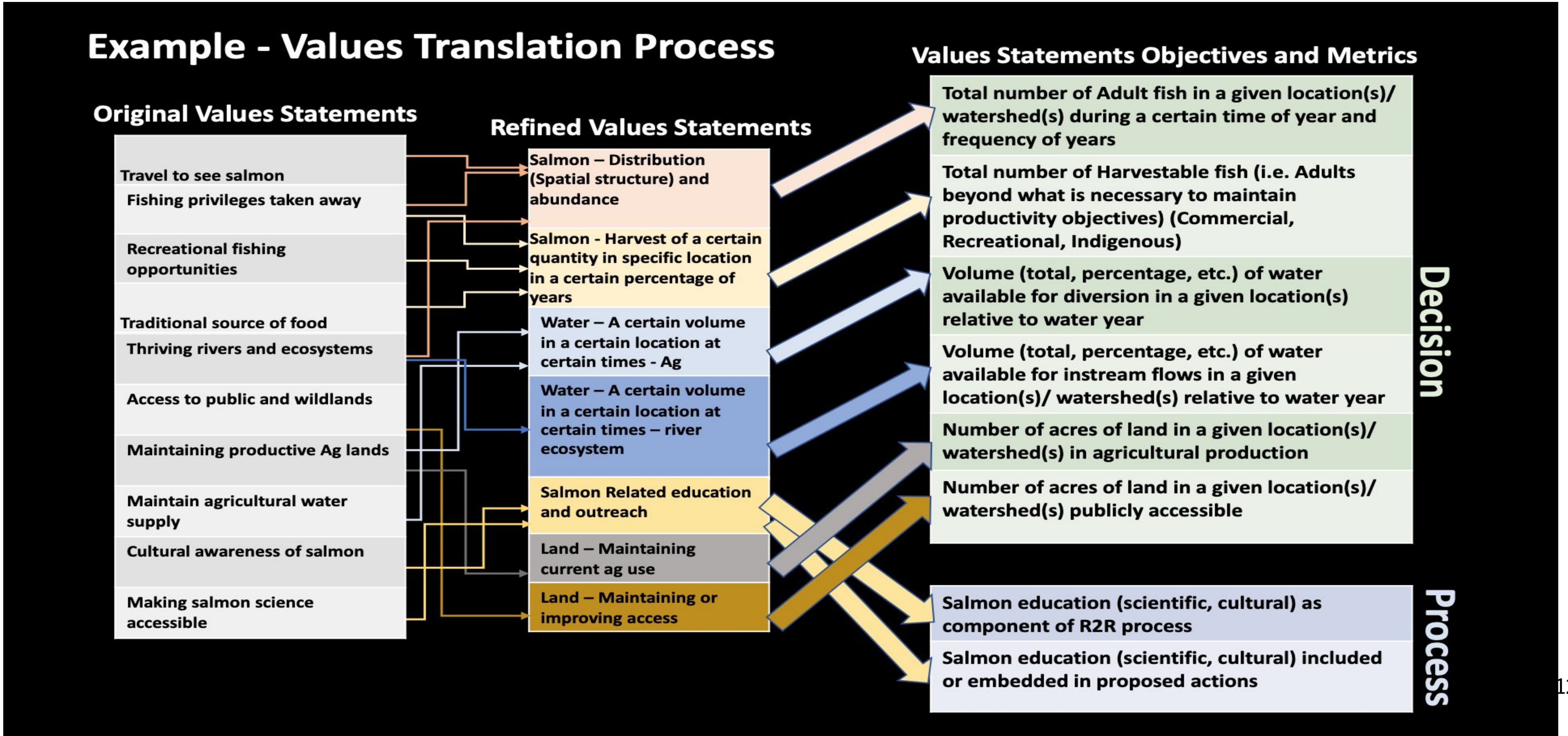


# Phase 1: Defining Recovery

**Establish a common objective: Define CV Salmon Recovery** (broad sense – beyond regulatory definition)

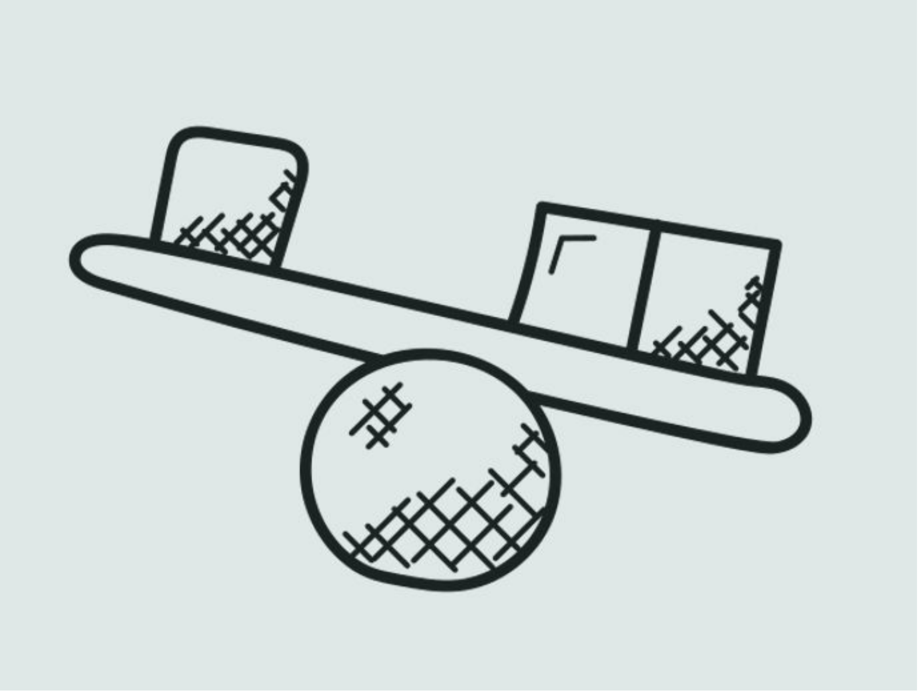
* Viable salmonid population parameters (VSP)
  * Diversity
  * Spatial Structure
  * Productivity
  * Abundance
* Objectives, metrics, targets

# Phase 2: Harvest Values



# Phase 3: Recovery Scenario Development Using SDM

- Identified **SDM working group** (Representative, Diverse)
- Built out **existing salmon lifecycle models to integrate all 4Hs**
- **Salmon recovery** and **balancing values-**primary and secondary objectives of **SDM process**
- **Developed and refined scenarios** (suites of actions) to balance pains and gains



# Outcomes

**Phase 1 outcomes:**

- Scientific non-regulatory recovery definition created/agreed upon
  - Viable salmon population (VSP) (Lindley et al. 2007) parameters met
  - Trust and coherence built, consensus approach

**Phase 2 outcomes:**

- 563 value statements collected
- Refined to 18 performance measures in a few objective categories
  - Water (various human uses), Land (production, access), Salmon (human use and nature), Ecosystem and other species, $$
- Process objectives as well (equity, education, etc.)
- Awareness of shared values, trust built, mutual understanding gained

# Outcomes

**Phase 3 outcomes:**

- Recovery Scenario (platypus) identified and consensed on for advancement and further refinement
  - Scenarios focused on a single factor (habitat, hydrology, harvest or hatcheries) do not achieve recovery - **need all-H integration**
  - **Recovery is possible** (*never-before modeled*) - multiple types of actions (4Hs) are needed
  - **Currently planned actions** are **important but insufficient** – need to be part of a broader package to avoid continued declines and stranded assets
  - Actions in **dry years are key to achieving recovery**

# Accomplishments

- **Modified and made available salmon lifecycle models for 4H integrated planning**
  - Stitched together existing efforts
  - Able to model the scale of different actions, understand potential efficiencies, and gaps
  - Set expectations for planned efforts
- **Cross pollination with other large efforts (CBC, Salmon Climate Initiative)**
- **First iteration of communication tools for a broader audience** (ShinyApps (QR code), StoryMaps)
  - Share the current impacts on salmon, how people connect to and care about them, what we can do to work towards recovery, and what we can expect soon if we don't shift our path forward

# Stretching into the whole…

- **Lessons learned that can support advancing a climate-resilient recovery approach for Pacific salmon**

  **1. The structure of the process matters**

  - Transparency around values-expands the opportunity horizon
    - Helps create a common picture of the world and common objectives
  - Inclusivity-funding, time, type of forum/engagement, flexibility, etc.
  - Structured decision making (SDM)
  - Facilitation and planning team
  - Together, allows people to stretch, and new possibilities to open

  **2. Don't reinvent the wheel**

  - Uplift, integrate, synthesize what is already happening (as opposed to replacing)
  - Keeps energy consistent and engaged

# Stretching into the whole…

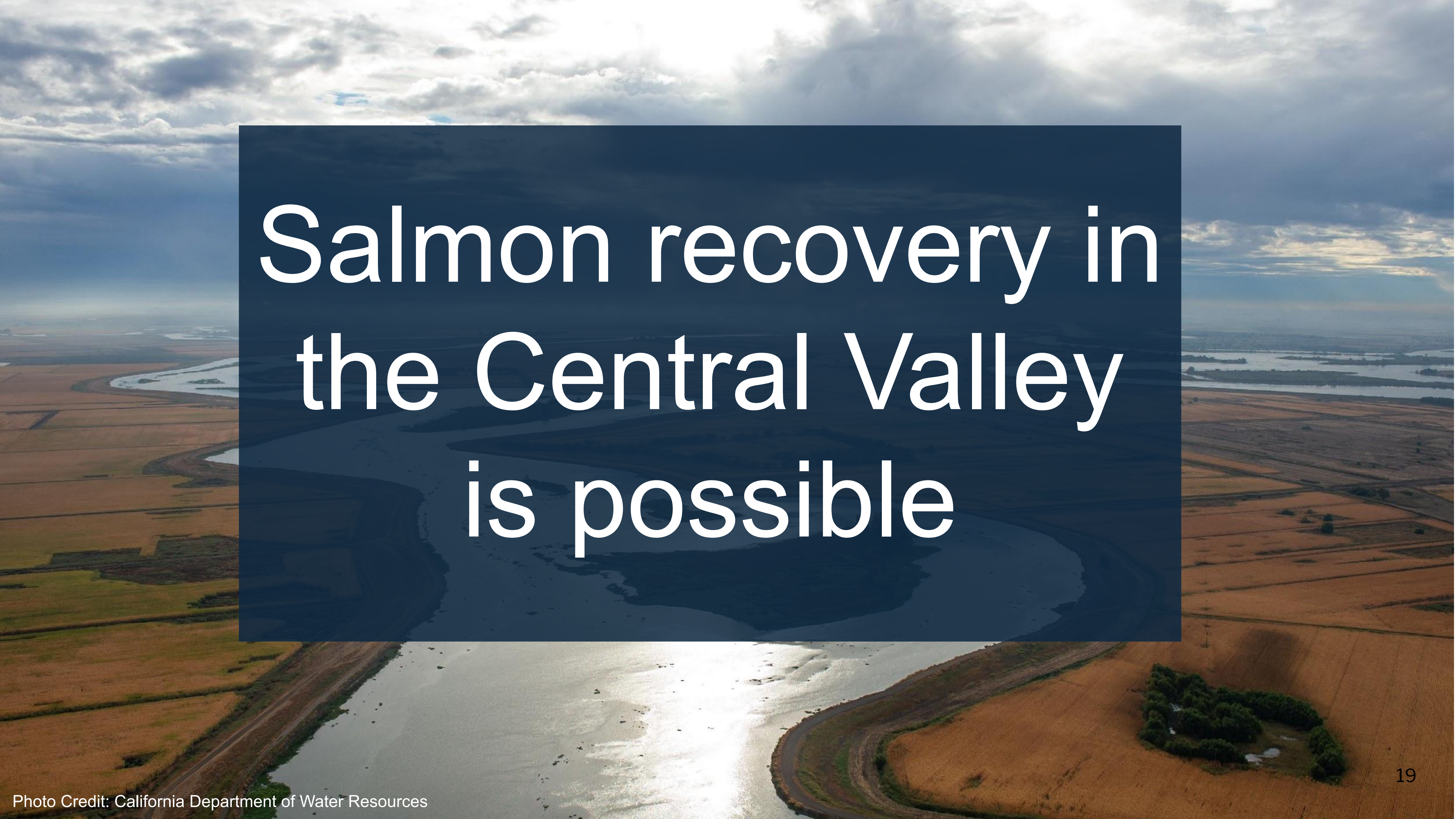
- **Lessons learned that can support advancing a climate-resilient recovery approach for Pacific salmon**

**3. Create efficiencies across geographies**

- Used lifecycle models
- Data/information comparable across regulatory, disciplinary and geographical differences
- Share information/communicate

**4. Funding**

- Bigger pots of money are necessary
- Long-term and stable
- Importance of neutral funding
- Sufficient to support inclusivity



# Salmon recovery in the Central Valley is possible

Photo Credit: California Department of Water Resources

# Thank you!

Nstauffer-Olsen@tu.org

Photo Credit: California Department of Water Resources

# History (cont.)

**A New Approach (cont.)**

- **Diverse Funding**
  - **SWCs - Initiate project and Phase 1 **
  - Delta Science Program and BOR - funding for Phases 1, 2 and 3
  - MET, NOAA, - supplemental funding for phase 3
  - The Water Foundation, SWCs – Tribal engagement

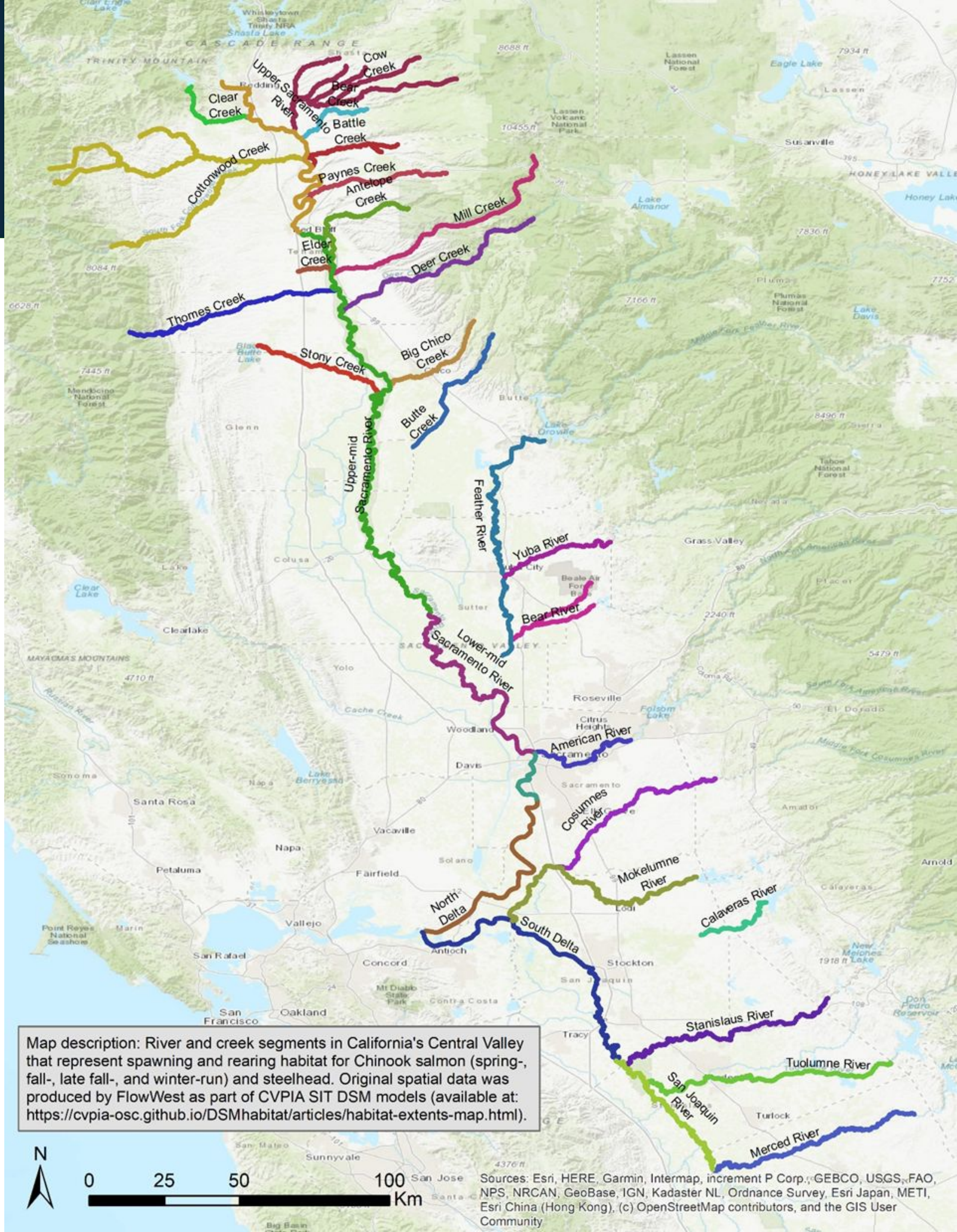
# History (cont.)

**A New Approach (cont.)**

- Design:
  - Three Phases over 3+ years: 1) Recovery Definition, 2) Values Identification, 3) Recovery Scenario Development

# R2R Location and Scope

- **Goal: to identify a preferred recovery scenario(s) that meets salmonid recovery targets, balances other interests, and achieves a critical mass of support**
- Considering all runs of CA CV salmon, beginning with fall-run
- Spatial: 31 reaches in the Sacramento & San Joaquin River systems, & ocean
- Temporal: 20-year time horizon



# Next Steps

## Phase 4 - From Collective Vision to Collective Implementation

*(*if/when funding is secured*)*

- **Map actions to real world efforts and identify and fill gaps** (Integration with Floodplains Forward, HRL, Recovery Plans, Stock Assessment, etc.)
- **Continue refining recovery scenarios** (specificity for actions, timing, location)
- **Model flow component** (Develop CALSIM run with COEQWAL)
- **Develop an implementation framework** (Feasibility & barriers, uncertainty, monitoring, funding strategies)
- **Broader outreach & engagement** (Regulators, existing collaboratives, regional Interests, other geographies)

# Next Steps (cont.)

Phase 4 - From Collective Vision to Collective Implementation

Success will hinge on continued funding, engagement, and leadership from our core partners

- SWCs, DWR, NOAA, BOR

# Phase 1: Recovery Definition

**Goal:** *Collaboratively Develop a scientific definition of CV Salmon Recovery structured in terms of measurable objectives and associated quantitative metrics and targets*

# Phase 1: Recovery Definition

**Phase 1 - Recovery Definition Overview**

- **Productivity**
  - Sufficient to support viability, refers to population growth rate and related parameters over the entire life cycle
- **Spatial Structure**
  - Recover and preserve spatially explicit populations that are sufficient to support redundancy and representation
- **Diversity**
  - Recover and preserve genetic/life-history diversity of natural populations
- **Abundance****
  - An expression of all other biological recovery thresholds being met + values

PHASE 1

# Recovery Definition

Thank you to the following scientists (and organizations) for helping to develop the recovery definition framework over the course of twelve workshops (and subsequent working groups) in 2021

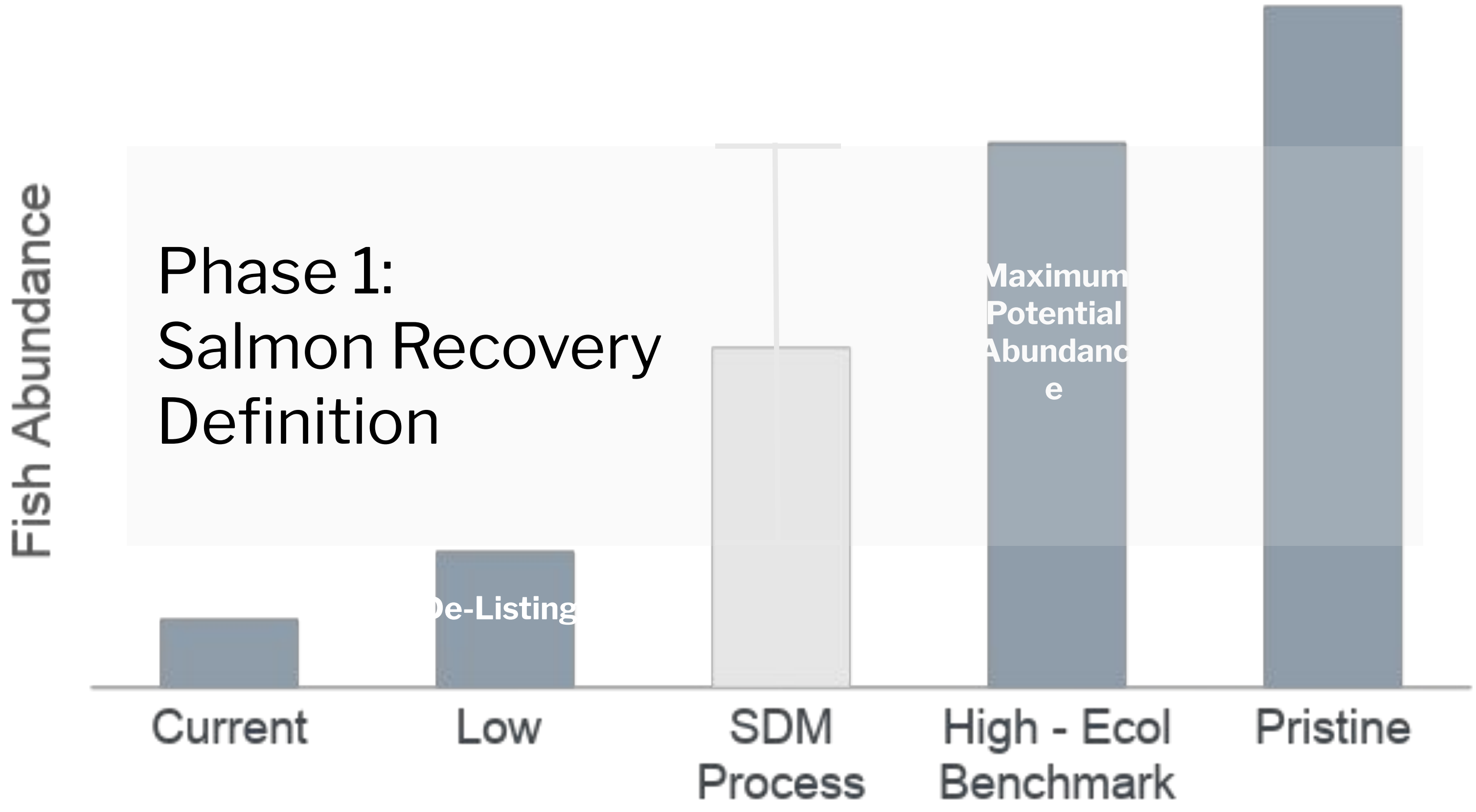
| | |
|---|---|
| Anchor QEA | John Ferguson |
| Cramer | Brad Cavallo |
| CDFW | Brycen Swart |
| CDFW | Carl Wilcox |
| DSC | Pascale Goertler |
| DWR | Brett Harvey |
| Metropolitan | Alison Collins |
| NGO | Bruce Herbold |
| NOAA | Ann Marie Osterback |
| NOAA | Brian Ellrott |
| NOAA | Cathy Marcinkevage |
| NOAA | Kate Spear |

| | |
|---|---|
| NOAA | Rachel Johnson |
| NOAA | Steve Lindley |
| PWA | Chuck Hanson |
| QEDA | Noble Hendrix |
| SWRCB | Erin Foresman |
| TNC | Julie Zimmerman |
| TU | Natalie Stauffer-Olsen |
| TU | Rene Henery |
| USBR | Josh Israel |
| USBR | Mike Beakes |
| USFWS | Matt Dekar |
| USFWS | Megan Cook |

# Abundance

TARGETS BASED ON CARRYING CAPACITY

Setting the abundance target will requires a values-driven conversation as part of the SDM process in Phase 3



# Phase 2: Engagement and Values

- Held workshops to share salmon stories and gather values
- Participants Reflected back values to each other (intentional way of interacting aimed to build relationships and mutual understanding)
- Assembled list of 563 value statements through surveys and small group activities
- Refined the values list
    - Removed redundancy
    - Sorted between decision & process
    - Proposed quantitative metrics
- Held workshops to translate values to metrics that can be related to decision support models in Structured Decision Making process

# Illustrative Consequence Table - SDM through the Phases

## Phase 1

**Defined scientific parameters for salmon recovery**

## Phase 2

**Define values when thinking about salmon recovery**

**Catalog actions to recover salmon**

| Area | Endpoint (Fund. Objectives) | Metrics (Performance Measures) | Unit | Scenarios (Near Term) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| Environment | Salmonids<br>• CHK WR<br>• CHK LF<br>• .... | Abundance PM 1<br>... | TBD | | | | | |
| | | Productivity PM 1<br>... | TBD | | | | | |
| | | Biological Diversity PM 1<br>... | TBD | | | | | |
| | | Spatial Structure PM 1<br>... | TBD | | | | | |
| | | Other PMs (ecosystem, etc.)<br>... | TBD | | | | | |
| | Ecosystem (Other Species) | PMs<br>... | | | | | | |
| Socio-Econ | Harvest * | Commercial PM 1<br>... | | | | | | |
| | | Tribal PM 1<br>... | | | | | | |
| | Financial | Habitat Restoration PM 1<br>... | | | | | | |
| | | Operations PM 1<br>.... | | | | | | |
| | | Other $ PMs<br>... | | | | | | |
| | Cultural | Cultural PM 1<br>... | | | | | | |
| | Recreation | Fishing Opportunity PM 1<br>... | | | | | | |
| Other | TBD | ... | | | | | | |

## Phase 3

**Decision Support**
(Options Assessment)

- Collaboratively develop a suite of recommended actions that maximizes progresses toward salmonid recovery while balancing the diverse range of values, perspectives and priorities.

# Phase 3: Recovery Scenario Development Using SDM

- Positioned 1) Salmon Recovery and 2) Balancing participant values and primary and secondary objectives of SDM process
- Identified SDM working group (Representative, Diverse)
- Built out existing CVPIA Salmon decision support lifecycle model to integrate all 4Hs
- Developed and refined scenarios (suites of actions) through iteration with life cycle model and SDM working group deliberation
  - Modeled Bookend, Blended, and Balanced Scenarios
  - Considered the scale and opportunity for integration of HRL
-

# SDM Trajectory

Values → Performance metrics → Bookend scenarios → Blended scenarios → Balanced scenarios

## Potential actions to model were collected via Forums and SDM workshops:

**Bookend Scenarios** included the following actions

- Run of River flows
- Max habitat
- No harvest
- 2x hatchery output

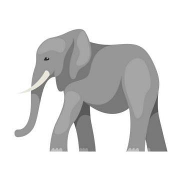
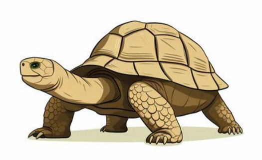
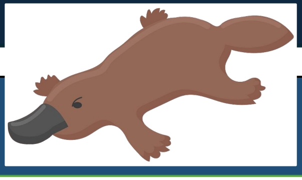
**Blended Scenarios** included the following actions:

- Ecological functional flows
- Rice field habitat
- Harvest of hatchery fish only
- Terminal hatcheries

**Balanced Scenarios** include the following actions:

- Habitat actions for San Joaquin
- Functional flows for San Joaquin
- HRL actions
- Phased hatchery practices
- Tribal harvest prioritized

# Phase 3: Balanced Scenarios

| **Action category** | **Baseline** | **Elephant**  | **Tortoise**  | **Platypus**  |
|---|---|---|---|---|
| **Habitat** | Current habitat and planned habitat projects | 1) Current and planned + near-future habitat***<br>2) Floodplains (Sac)<br>3) Food subsidies (all yrs, Jan-Mar)***<br>4) Predation reduction (small-scale, all yrs) | 1) Current and planned<br>2) Floodplains/rice fields (Sac/SJ)<br>3) Food subsidies (dry yrs)<br>4) Predation reduction (large-scale, dry yrs) | 1) Current + Max habitat<br>2) Food subsidies (all yrs)<br>3) Predation reduction (large-scale, all yrs) |
| **Hydrology** | Current flow operations | Planned flow operations*** | Functional Flows (FF) (Sac/SJ, dry yrs) | FF (Sac/SJ, all yrs) |
| **Harvest** | Current ocean and river harvest rates | 1) Intelligent habitat harvest** (ocean, in-river, all yrs)<br>2) Tribal harvest prioritized | 1) No harvest of dry year cohorts (ocean, in-river)<br>2) Harvest only hatchery fish (ocean, in-river, all yrs)<br>3) Tribal harvest prioritized | 1) No harvest of dry year cohorts (ocean, in-river)<br>2) Intelligent habitat harvest** (ocean, in-river, all yrs)<br>3) Tribal harvest prioritized |
| **Hatcheries** | Current hatcheries operations | Phased hatchery and weirs | Phased hatchery and weirs | Terminal hatchery/ocean outplanting (all yrs) |

* Harvest only fish additional to what is required to meet CRR>1. Harvest numbers would vary by year.

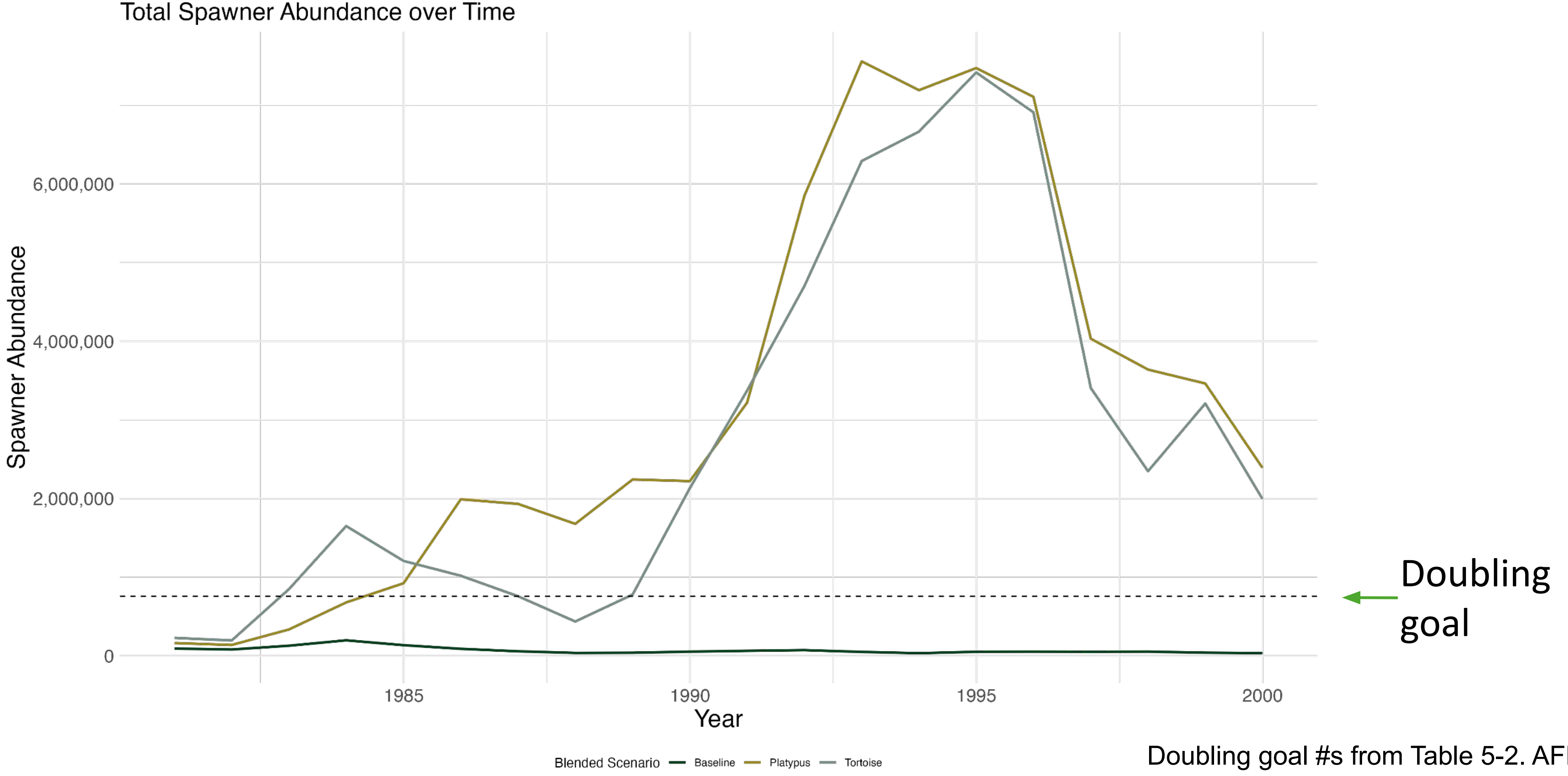
** Harvest only fish additional to what is required to meet habitat capacity. Harvest numbers would vary by year.

*** This scenario includes planned Habitat + Spring flow actions, which are expected in the near future, and proposed as part of the Healthy Rivers and Landscapes Program.

# Phase 3: Balanced Scenarios

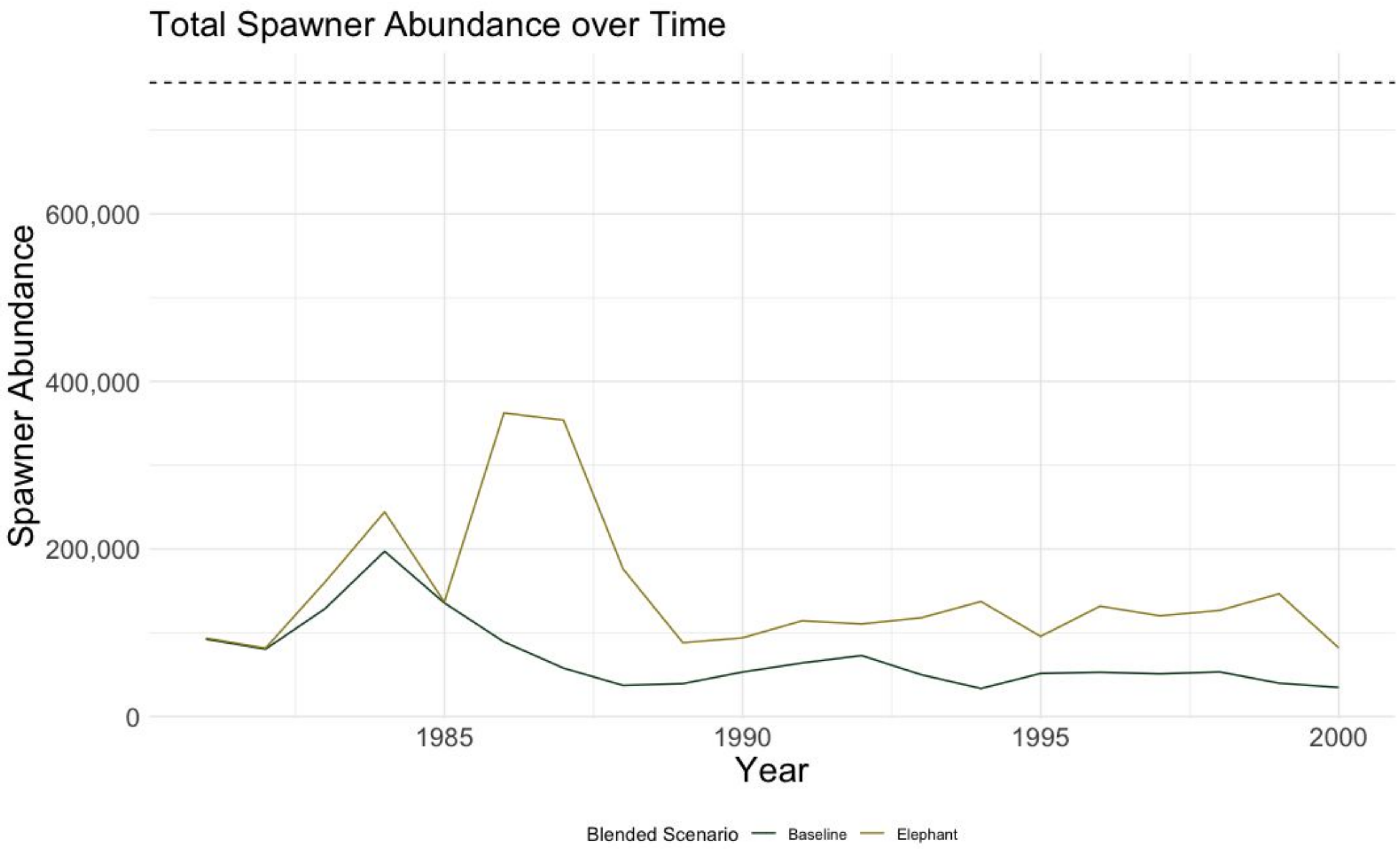
| Objective | Less Preferred / More Preferred | Performance Measure | Unit | Preferred Direction | Baseline | Elephant | Tortoise | Platypus |
|---|---|---|---|---|---|---|---|---|
| **Salmonid biological recovery** | | | | | | | | |
| 1: Adult abundance | Avg | Adult abundance (at spawning) | # fish | Higher | 79,510 | 148,696 | 2,825,781 | 3,232,640 |
| 2.1: Cohort Replacement Rate (CRR) | Avg | CRR (natural spawners) | CRR | Higher | 0.48 | 1.39 | 2.24 | 3.54 |
| 3.2: % of independent viable populations | | Total # of independent viable pops / potential independent pops | % | Higher | 0 | 0 | 16 | 31 |
| 4: pHOS | Avg | pHOS (weighted by trib) | pHOS | Lower | 0.67 | 0.37 | 0.09 | 0.16 |
| **Habitat & ecological processes** | | | | | | | | |
| 7.2: Habitat diversity | Avg | Floodplain / In-channel habitat | Ratio | Higher | 3 | 6 | 10 | 15 |
| 9.2: Functional flow metric | | Constructed scale | 1 to 3 | Higher | 1 - No | 1 - No | 2 - Some | 3 - Yes |
| **Harvest** | | | | | | | | |
| 12.1: In river harvest | | Harvestable adults | # fish | Higher | 21,584 | 20,056 | 20,003 | 188,977 |
| 12.2: Ocean harvest | | Harvestable adults | # fish | Higher | 206,325 | 331,717 | 350,472 | 2,086,399 |
| **Water & agriculture** | | | | | | | | |
| 13.2: Water supply: Divertible water for municipalities | | SWP & CVP municipal exports | MAF | Higher | 2.0 | 1.8 | 1.6 | 1.4 |
| 14: Agriculture: Land in ag production | | Constructed scale | 1 to 4 | Higher | 3 - High | 2 - Med | 3 - High | 1 - Low |

# Abundance Plot




Doubling goal #s from Table 5-2. AFRP

# Abundance Plot - Elephant



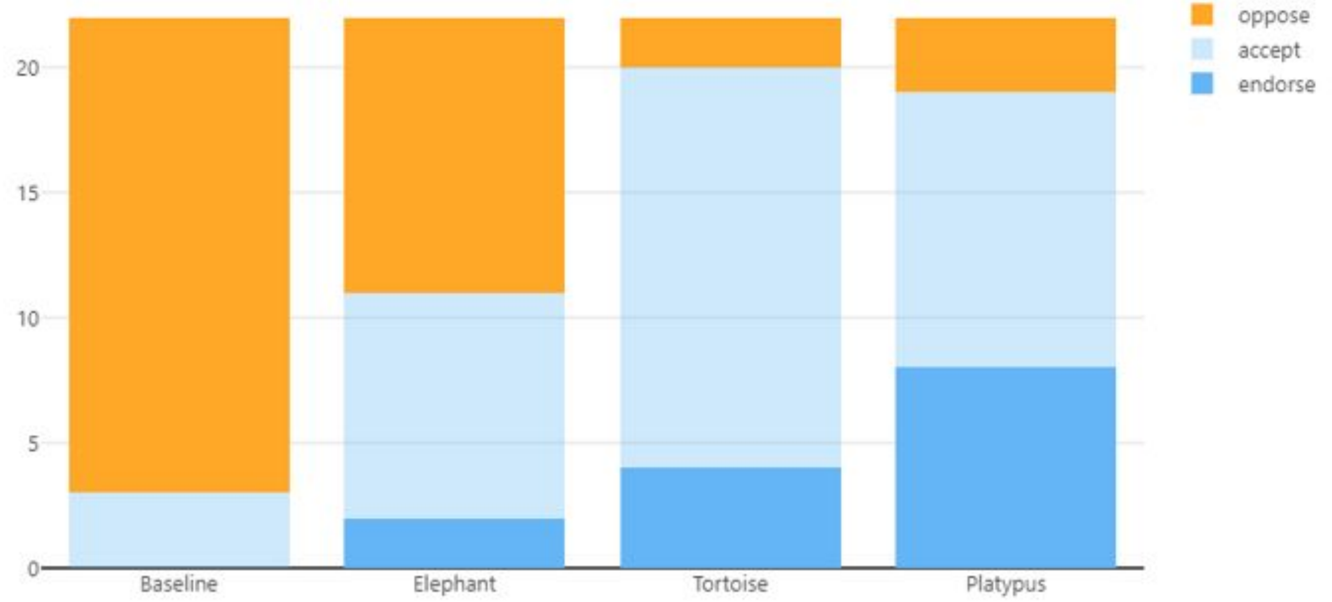

Doubling goal

- Only scenario that uses CalSim3 (different operations assumptions and spatial coverage, including higher resolution on some HRL Program tributaries) and therefore cannot yet be appropriately compared with the other R2R scenarios.
- The R2R baseline scenario currently contains a roughly 60% overlap in habitat projects that are proposed as part of the HRL Program.
- The HRL Program targets achievement of one quarter of the full doubling goal over an 8 year period.
- Incorporating HRL Program flow and habitat actions into models took longer than expected; additional actions needed to meet recovery, can be done in future.

# SDM Working Group Initial Responses

Scenario to Advance = Modified Tortoise

- More actions in wet years
- More nuanced dry year flow considerations
- Including Elephant actions




| Alternative | Endorse | Accept | Oppose |
|---|---|---|---|
| Baseline | 0 | 3 | 19 |
| Elephant | 2 | 9 | 11 |
| Tortoise | 4 | 16 | 2 |
| Platypus | 8 | 11 | 3 |

# Spring-/winter-run, and steelhead actions

- What else could we do to benefit other salmonids in the CV?

| | Spring-run | Winter-run | Steelhead |
|---|---|---|---|
| Habitat | • **Reintroduction above dams**<br>• **Weirs to prevent redd superimposition from Fall run**<br>• **Food subsidies during rearing periods** | • **Reintroduction above dams**<br>• **Juvenile rearing habitat restoration, if focused only in the Sacramento River, has potential to have a negative impact on WR.**<br>• **Food subsidies during rearing periods** | • **Reintroduction above dams** |
| Hydrology | • **Shape Functional Flows for dry years to target out migration period**<br>• **Spring survival pulse flows** | • **Shape Functional Flows for dry years to target out migration period**<br>• **EFF Flows to support FR spawning habitat (Oct - Dec) may support WR fry rearing habitat**<br>• **EFF Flows to support FR floodplain habitat (Jan - April) may support WR smolt outmigration survival (also Jan - April)**<br>• **FR outmigration survival EFF pulse flows (May - July) may provide cooler temperatures to promote earlier WR spawn timing**<br>• **Dry season baseflow to support WR egg to fry survival**<br>• **Management of reservoir releases to provide downstream food subsidy** | • **Altered flow dynamics to stimulate anadromy**<br>• **Augmented flows to expand delta rearing habitat**<br>• **Augmented flows to improve through delta survival**<br>• **Management of reservoir releases to provide downstream food subsidy** |
| Harvest | | | |
| Hatcheries | • **Phased conservation hatcheries** | • **Phased conservation hatcheries** | • **Phase out of existing hatchery practices** |

# Accomplishments (cont.)

**Website**

**Key Reports**

- Phase 1
- Project Summary/ Phase 3

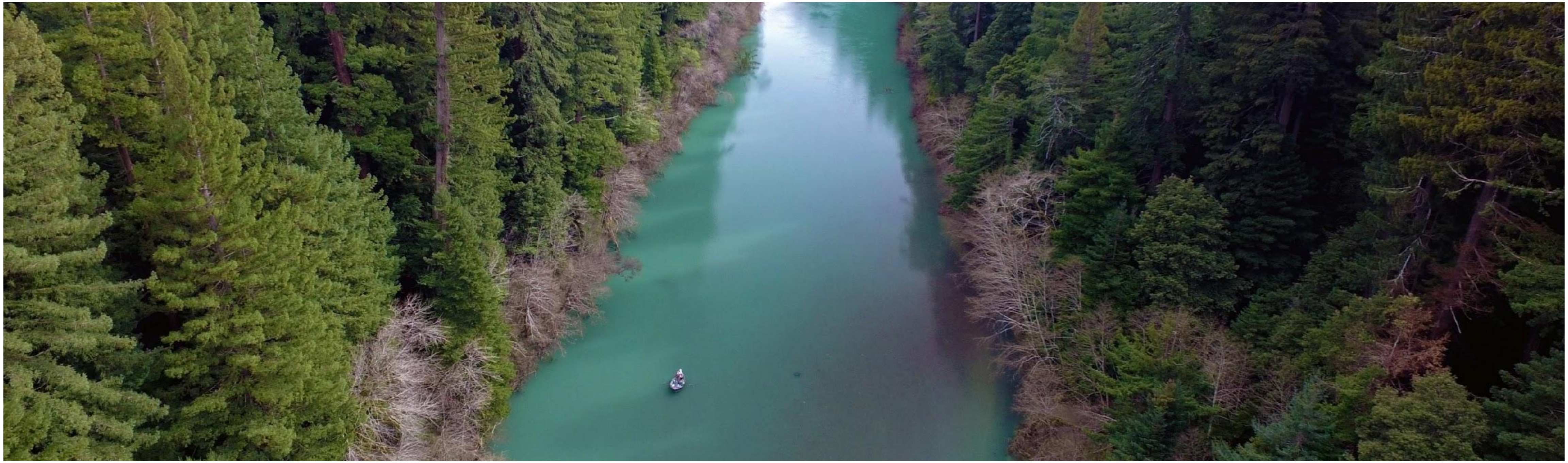
**First iteration of Communication tools for a broader audience**

- ShinyApps
- StoryMap

**Media**

- Estuary News

# Cool Corridors: How identifying and indexing riparian climate refugia contributes to the future protection and restoration of anadromous fish habitat in Northern California.



CALIFORNIA TROUT

FISH · WATER · PEOPLE

Christine Davis M.S., California Trout,

Farrah Tyler B.S., CalPoly Humboldt, and James Graham Ph.D., CalPoly Humboldt

H.


# The Eel River Watershed

## RESTORATION AND CONSERVATION PROGRAM

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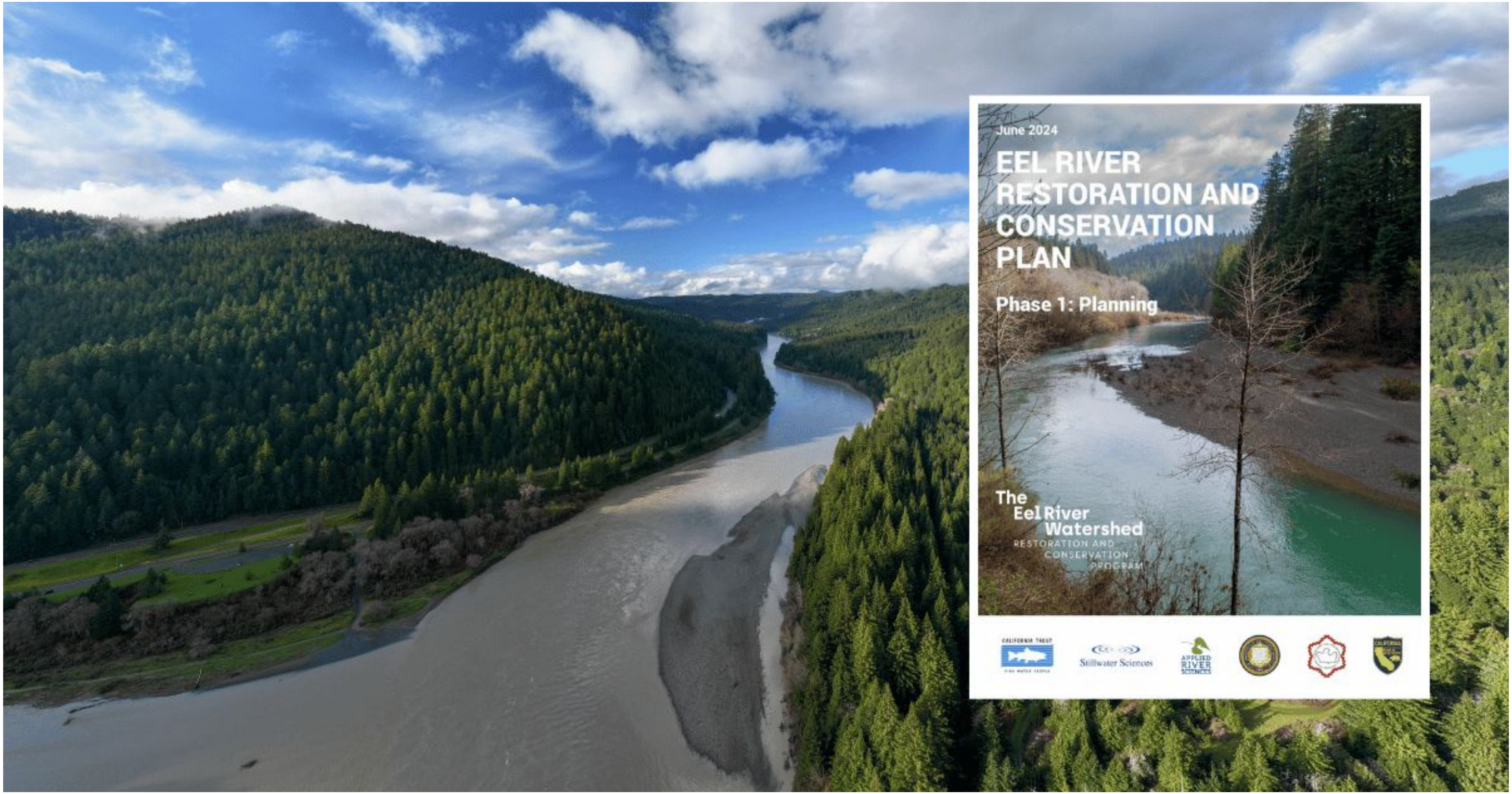
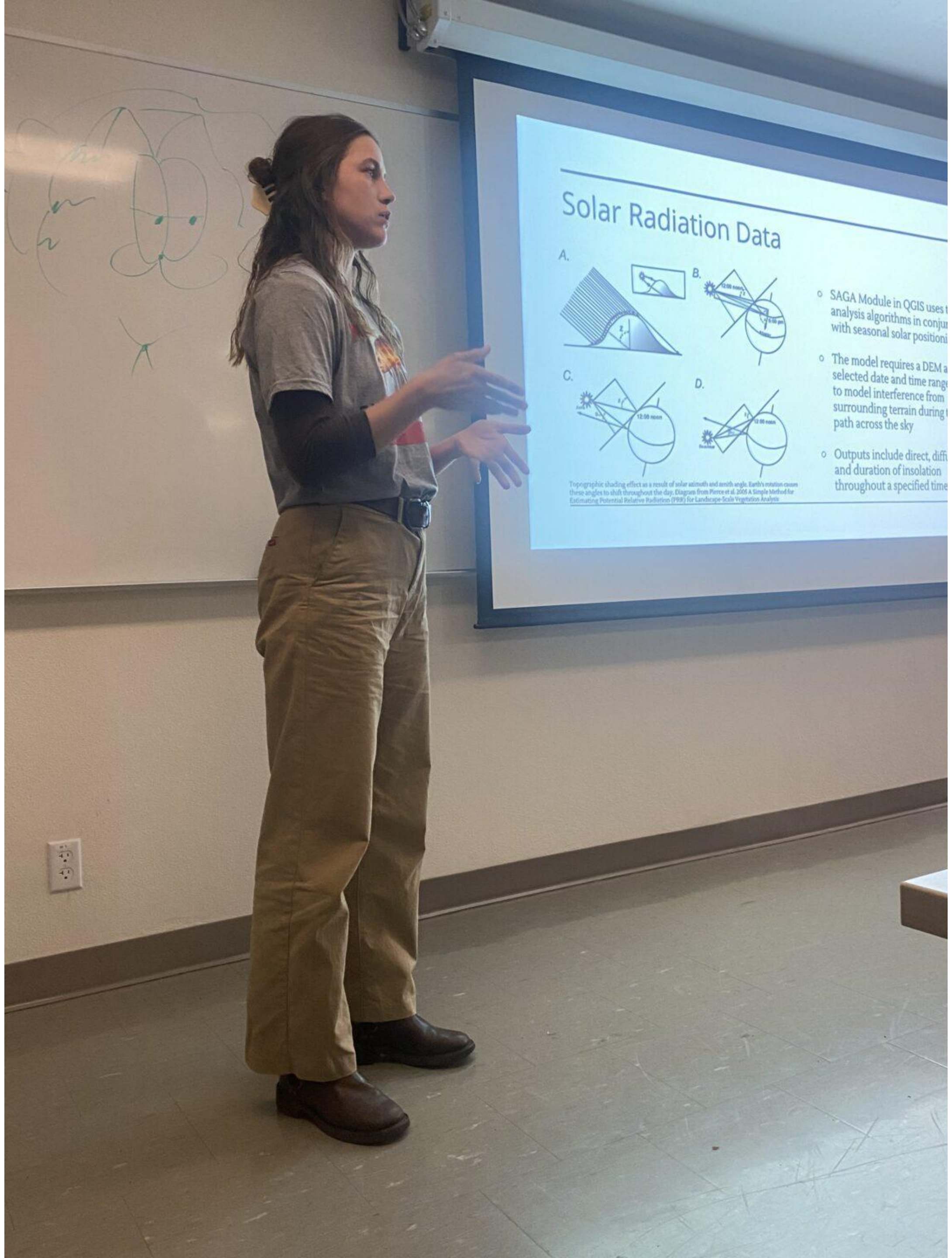
APPLIED RIVER SCIENCES

Stillwater Sciences


June 2024
EEL RIVER RESTORATION AND CONSERVATION PLAN
Phase 1: Planning
The Eel River Watershed
RESTORATION AND CONSERVATION PROGRAM
Stillwater Sciences
APPLIED RIVER SCIENCES




CALIFORNIA TROUT

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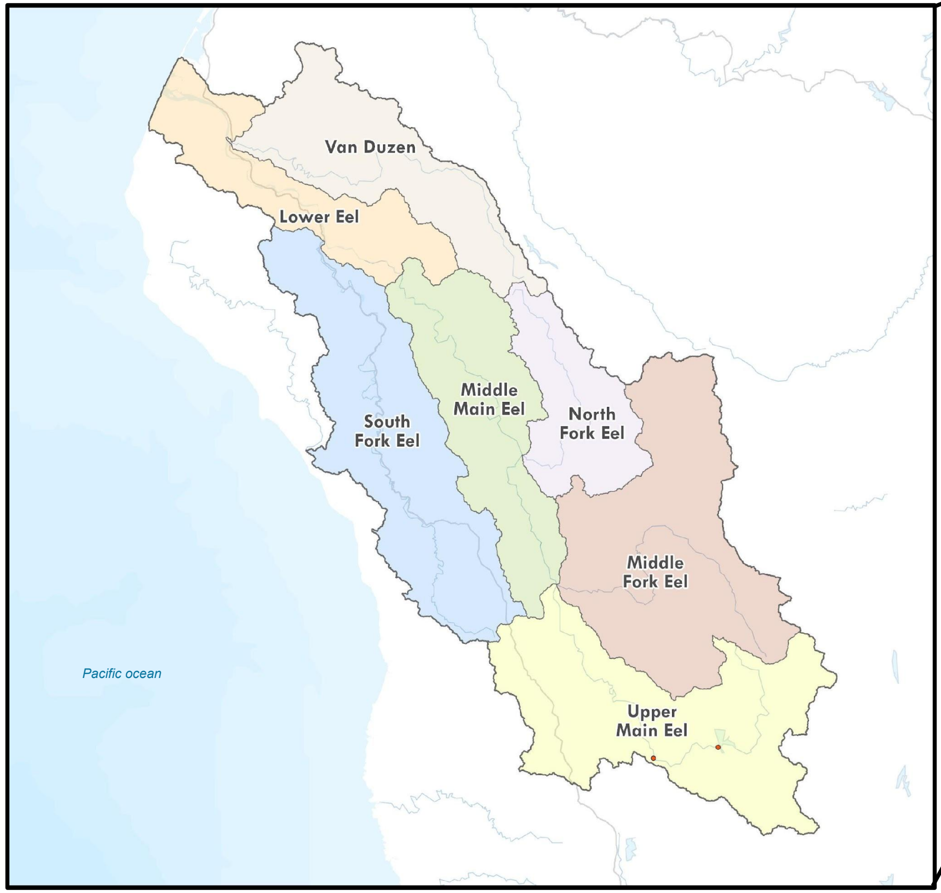
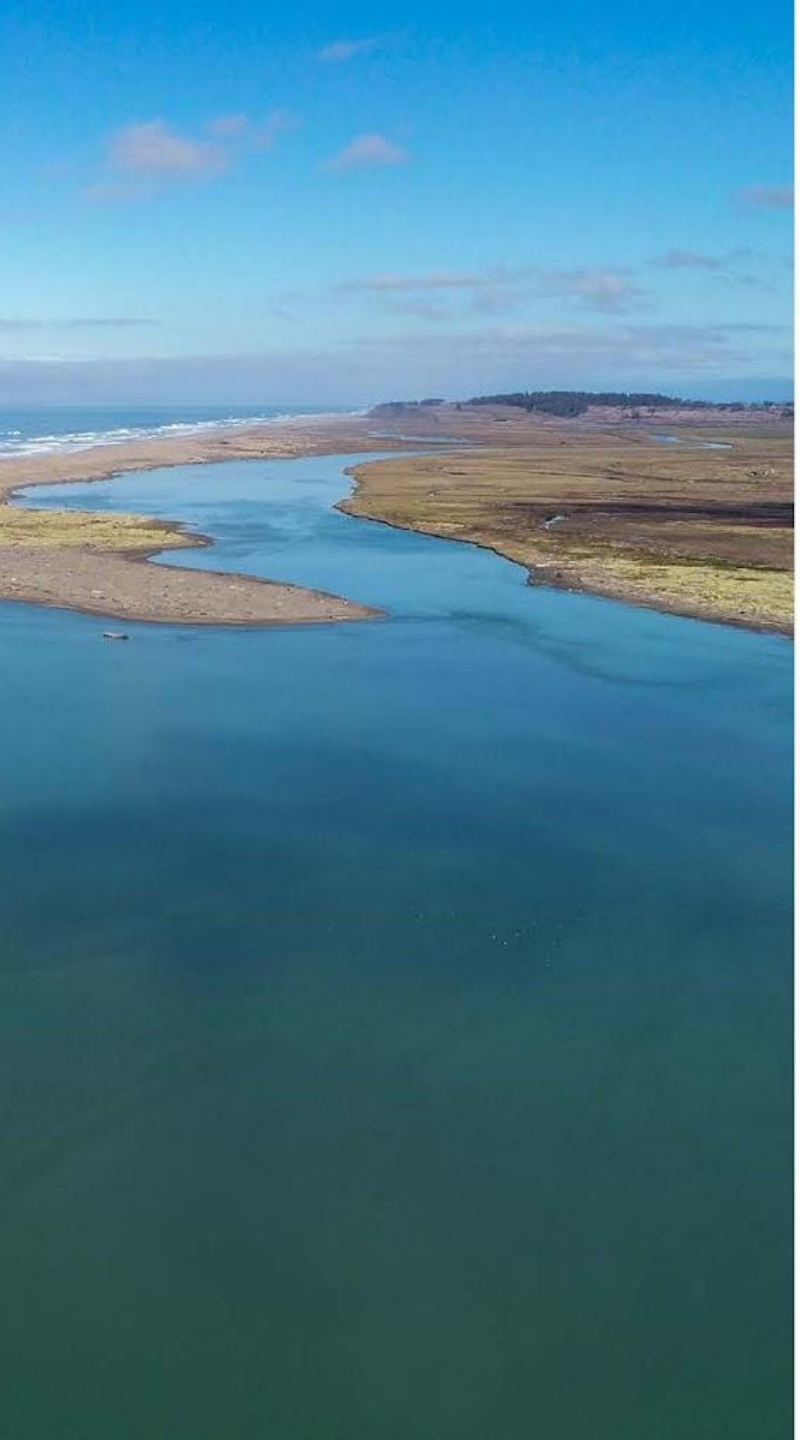
H.

# THE EEL RIVER WATERSHED

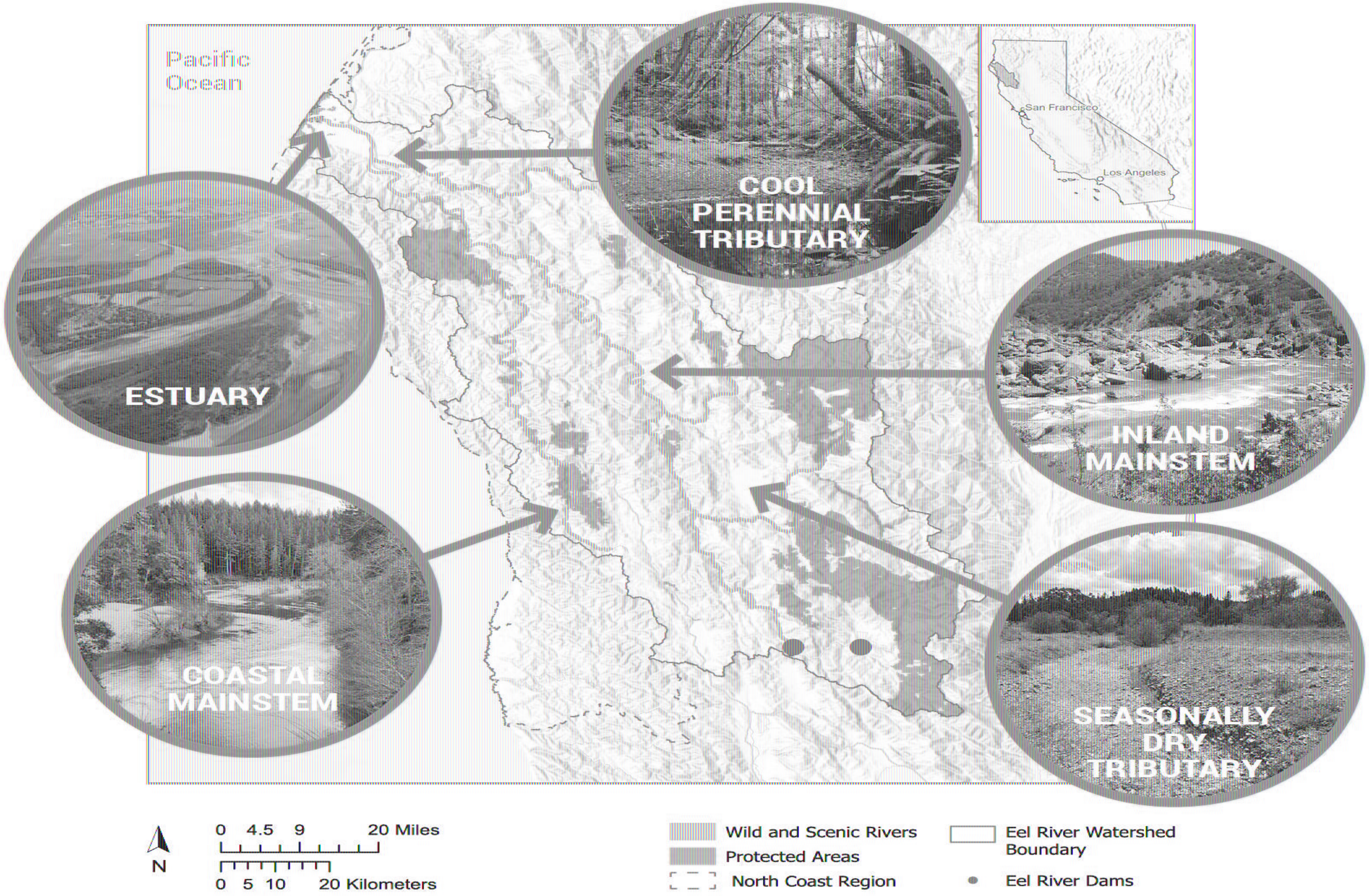


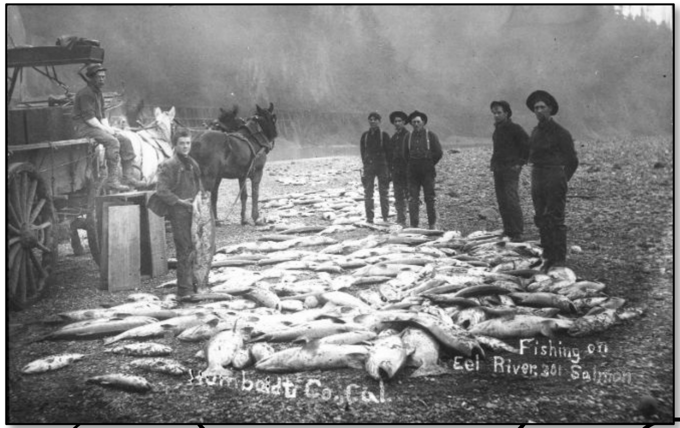



Photos: Michael Carl, Mike Weir

# Abundant Habitats

# The whole watershed is important







The Eel River Watershed

RESTORATION AND CONSERVATION PROGRAM

# What is riparian climate refugia?


Scott McBain


Darren Mierau


Riparian climate refugia characteristics (Krosby et al. 2018):

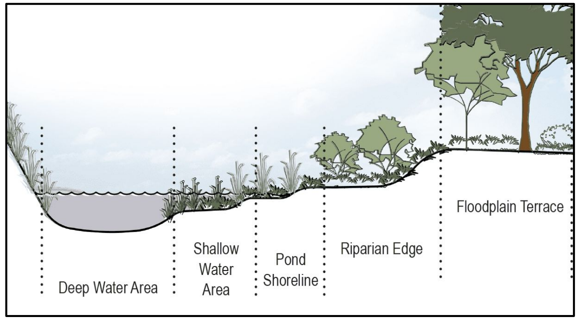
- mean annual temperature,
- canopy cover,
- riparian area width,
- potential relative solar radiation
- landscape condition

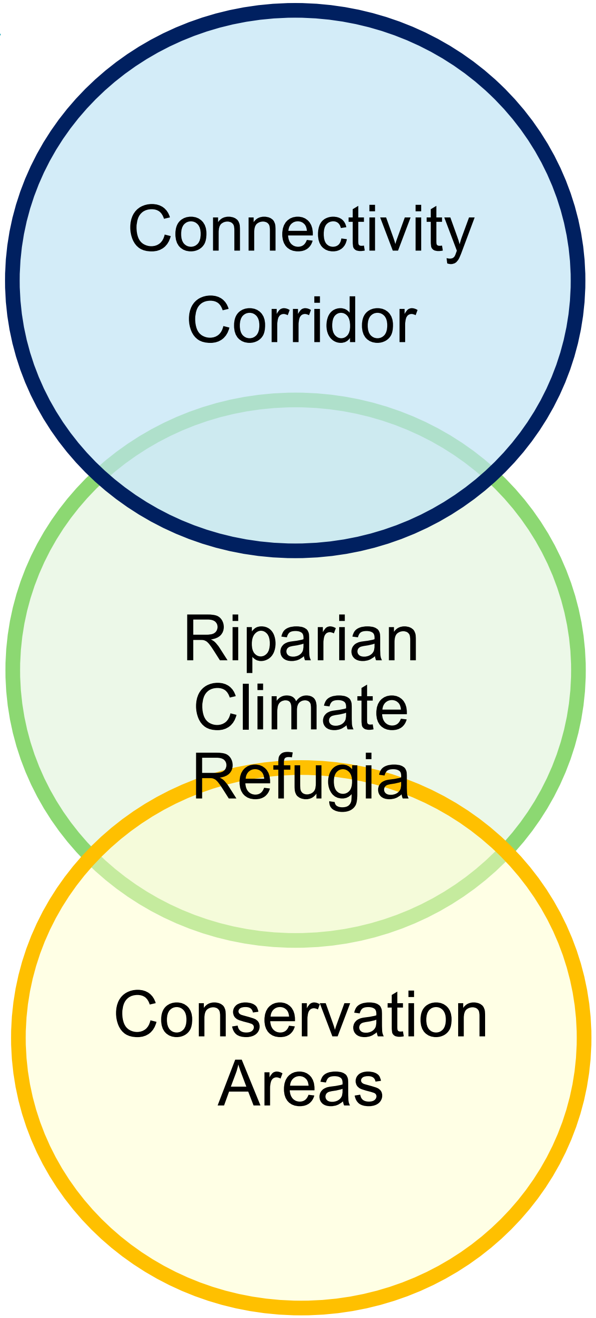

Photo: Clear Creek Credit: Derek Rupert

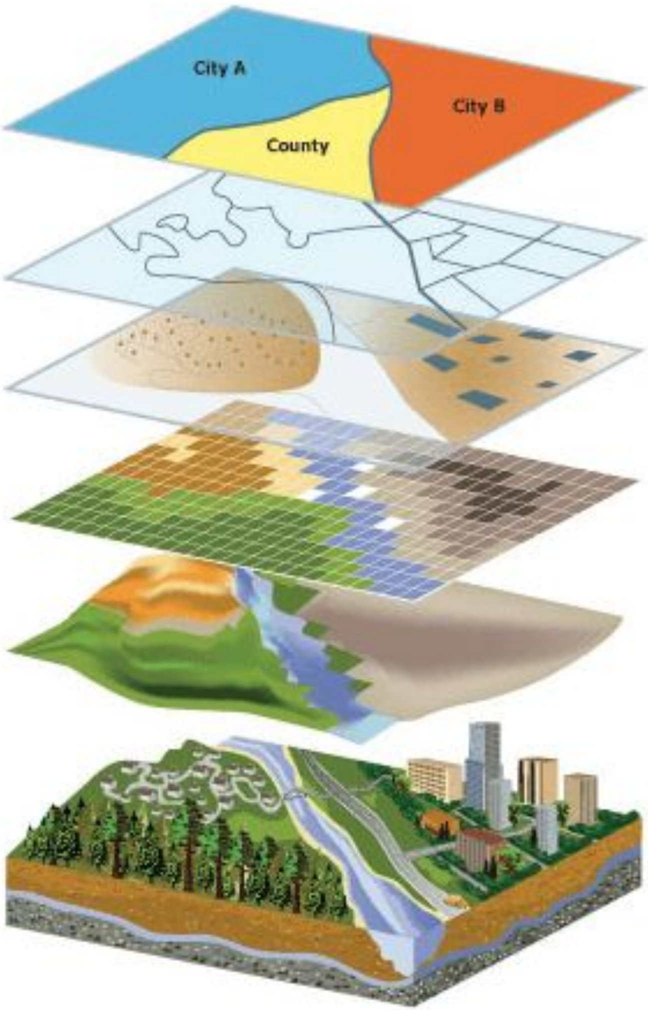
**Strategic** inclusion of climate refugia into conservation and restoration planning can contribute to **landscape level resilience** to climate change and land use change impacts (Keppel et al., 2012; Krosby et al., 2015).

To protect **remaining climate resilient areas** in the watersheds of California’s North Coast, strategic landscape level planning is needed to identify and include connected climate refugia networks in future protected area and restoration planning.

# Resilience strategy



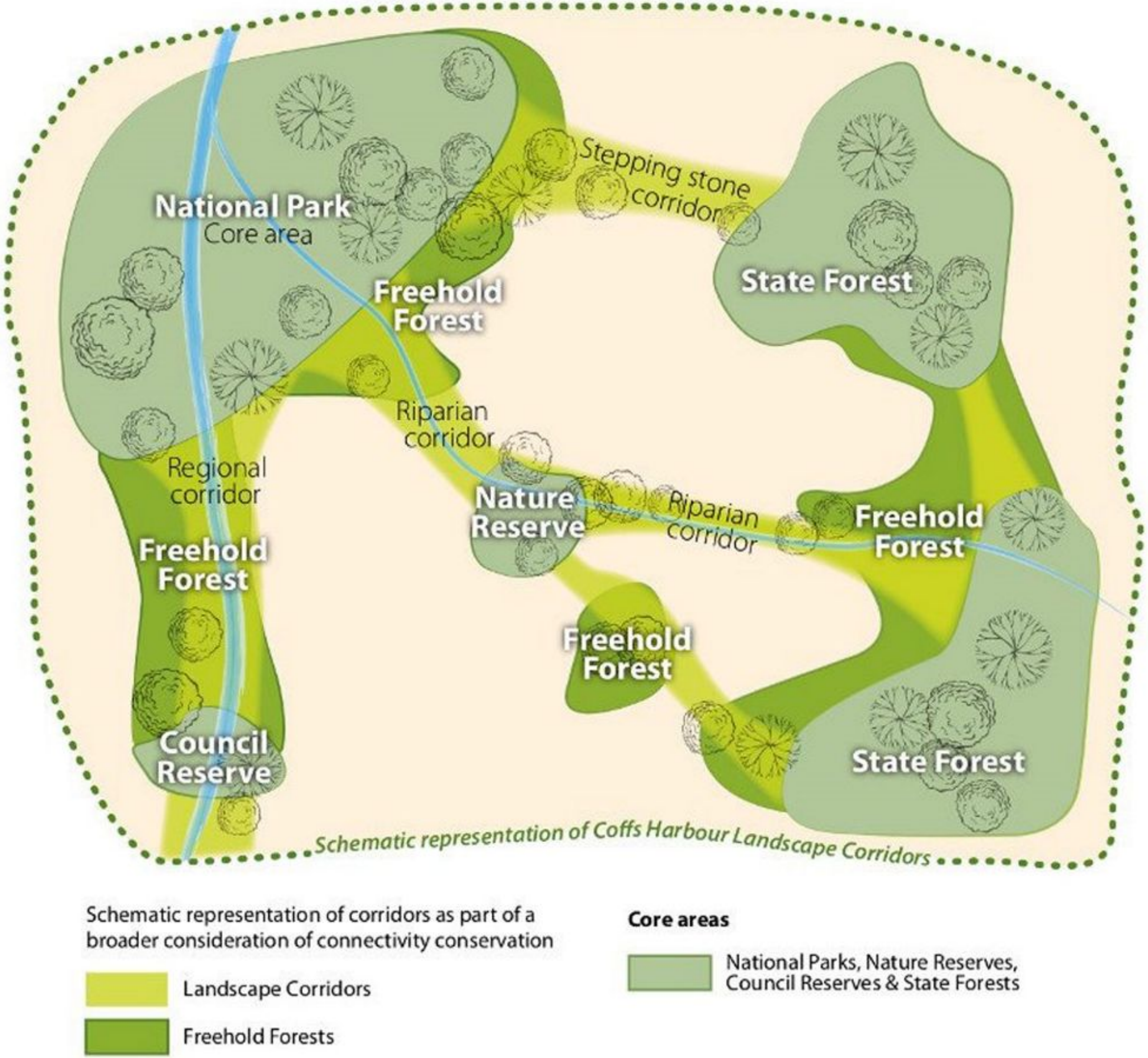



# Corridors

**Connectivity** is the most important aspect of conservation planning for biodiversity.
(Heller & Zavaleta, 2009)

# Riparian corridors

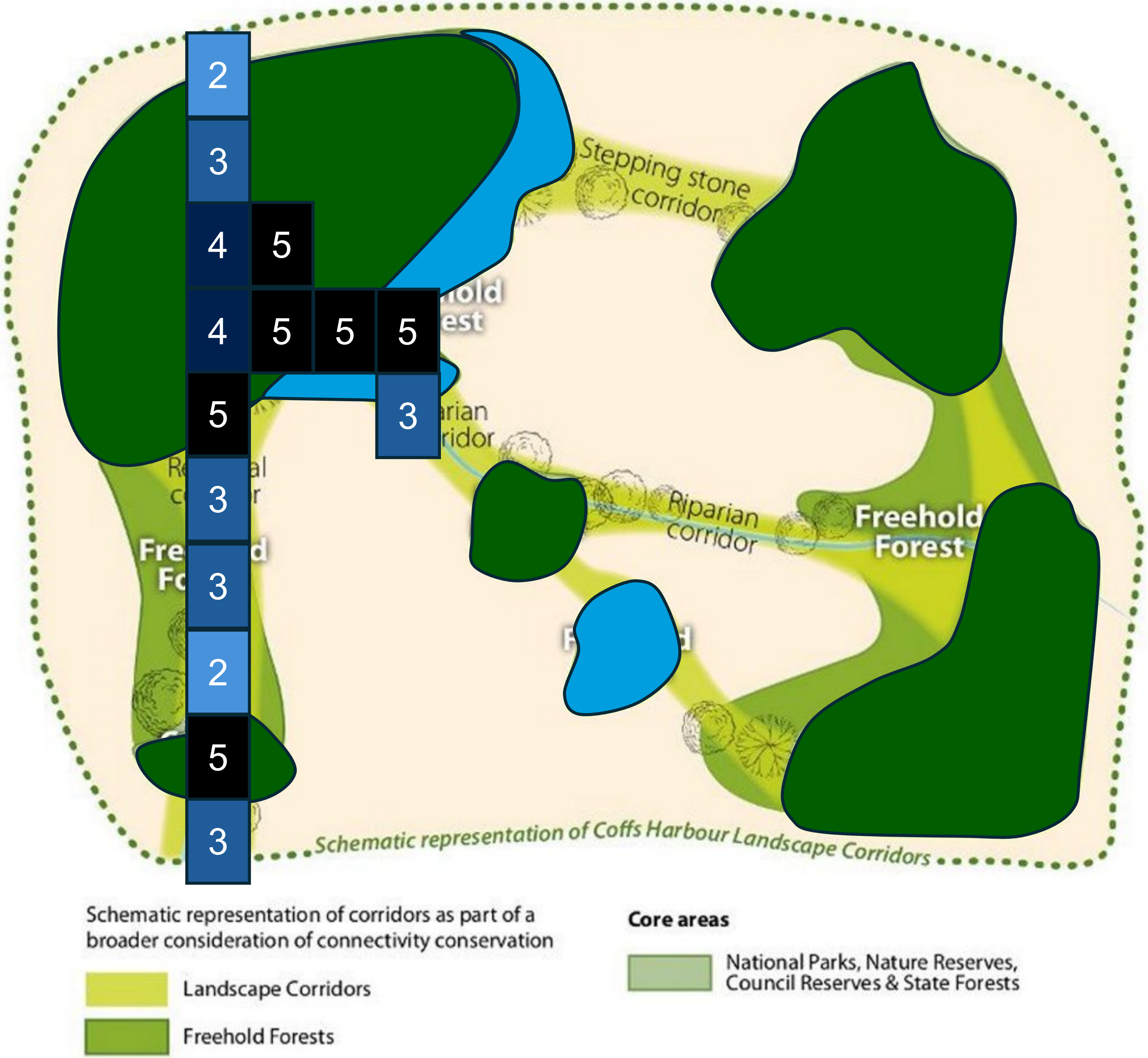
**Riparian corridors** complement existing protected areas creating linkages which support species movement.



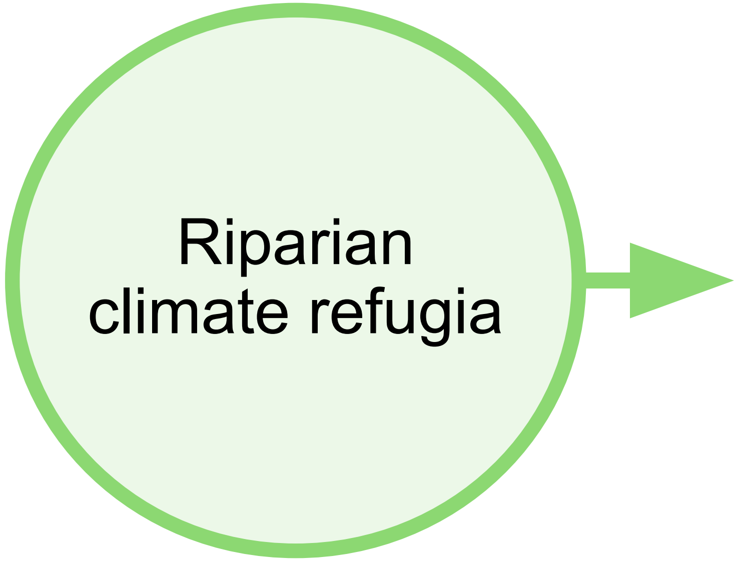
# Resilience strategy for conservation

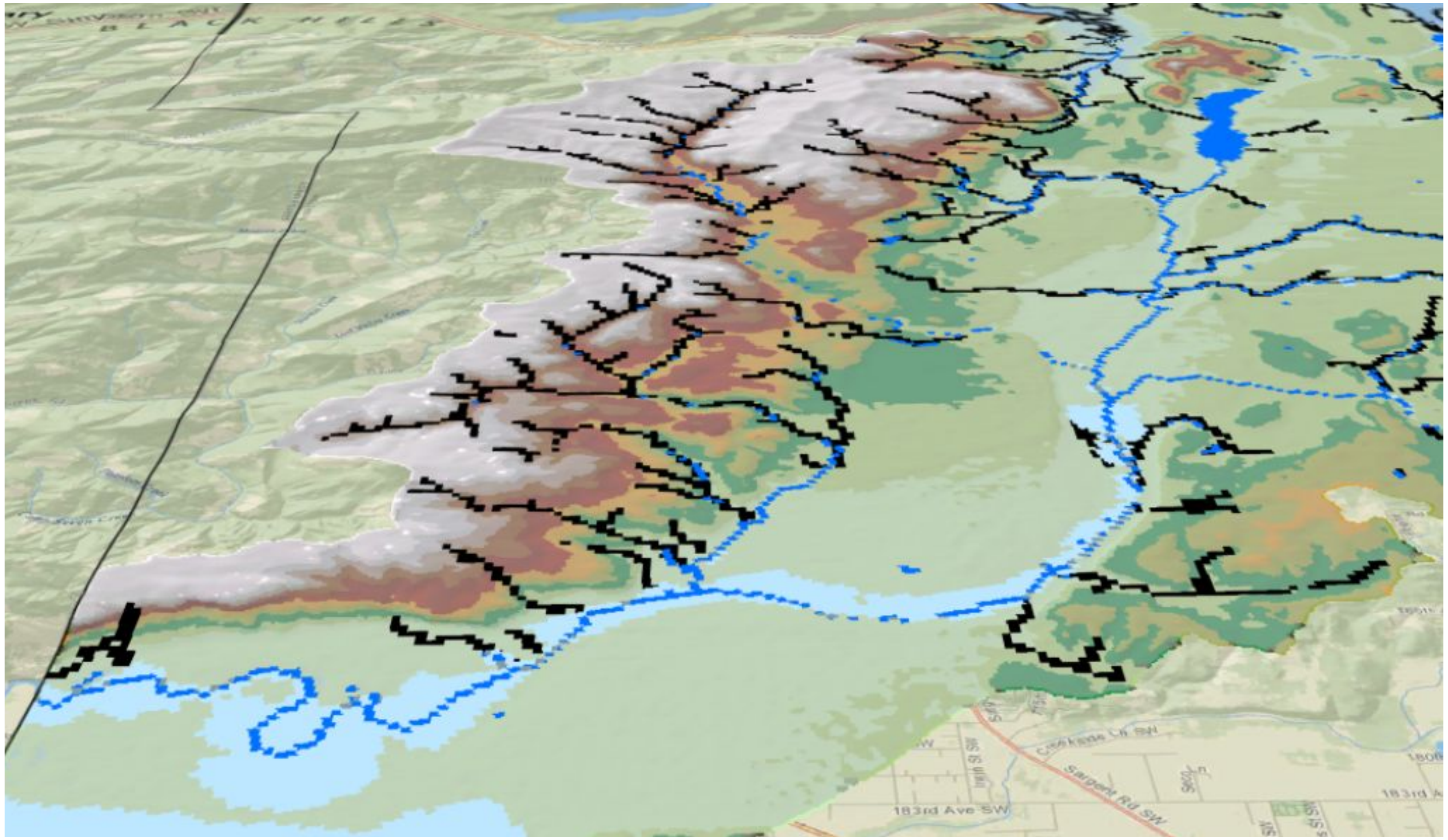
Riparian
Climate
Refugia

+ *Nexus to in-stream habitat data*

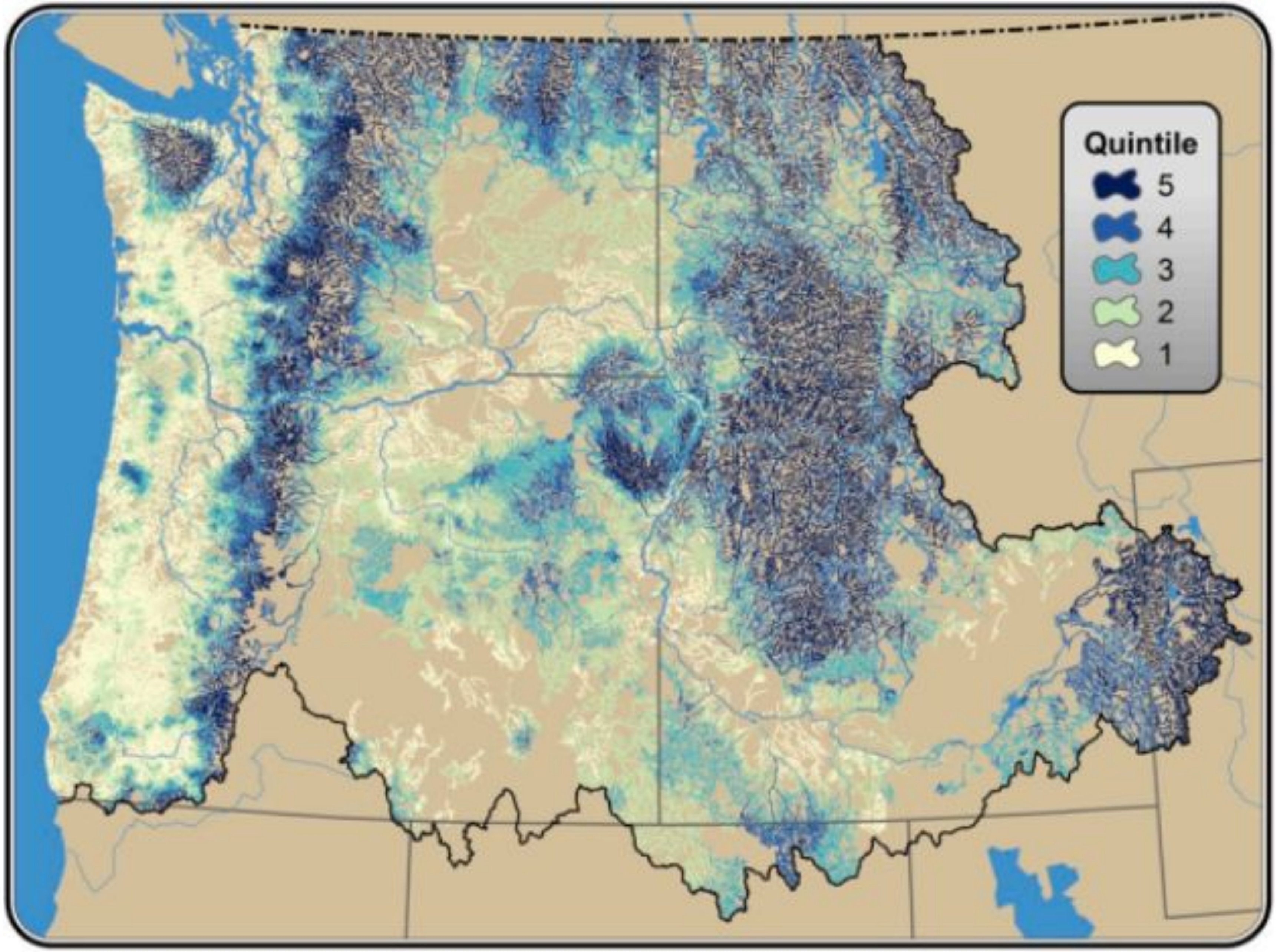


# Riparian climate refugia index



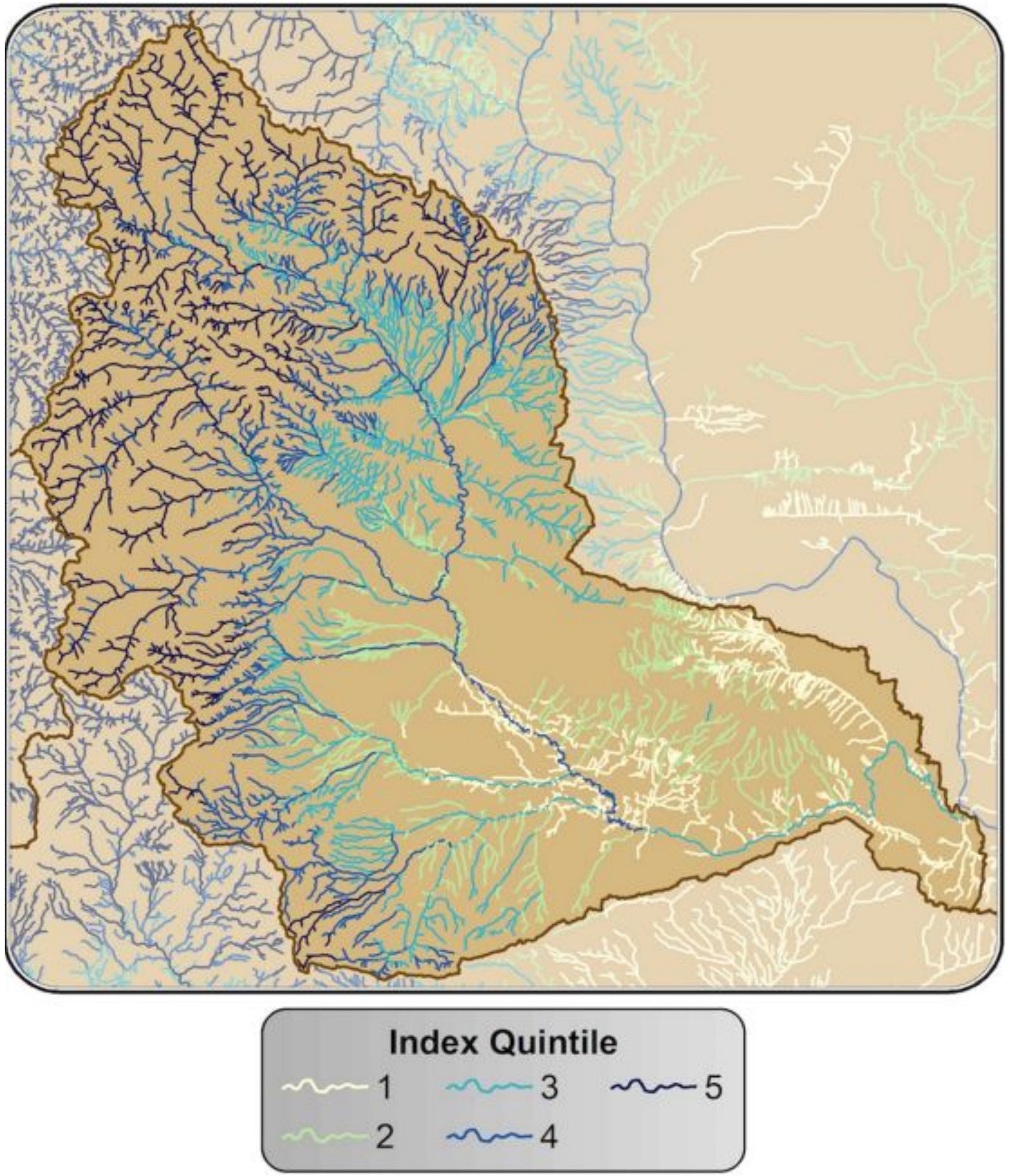
Data: ESRI, Riparian Climate Refugia Index data  (Krosby et al. 2018)


Quintile
5
4
3
2
1

# Research Objectives

1. Identify the environmental characteristics of climate-resilient riparian areas
2. Model riparian climate refugia (RCR) in the Eel River watershed at 30 m resolution
3. Assess the distribution of potential RCR across the watershed for connectivity planning and habitat quality assessments

# Identifying Riparian Climate Corridors to Inform Climate Adaptation Planning (Krosby et al. 2018)

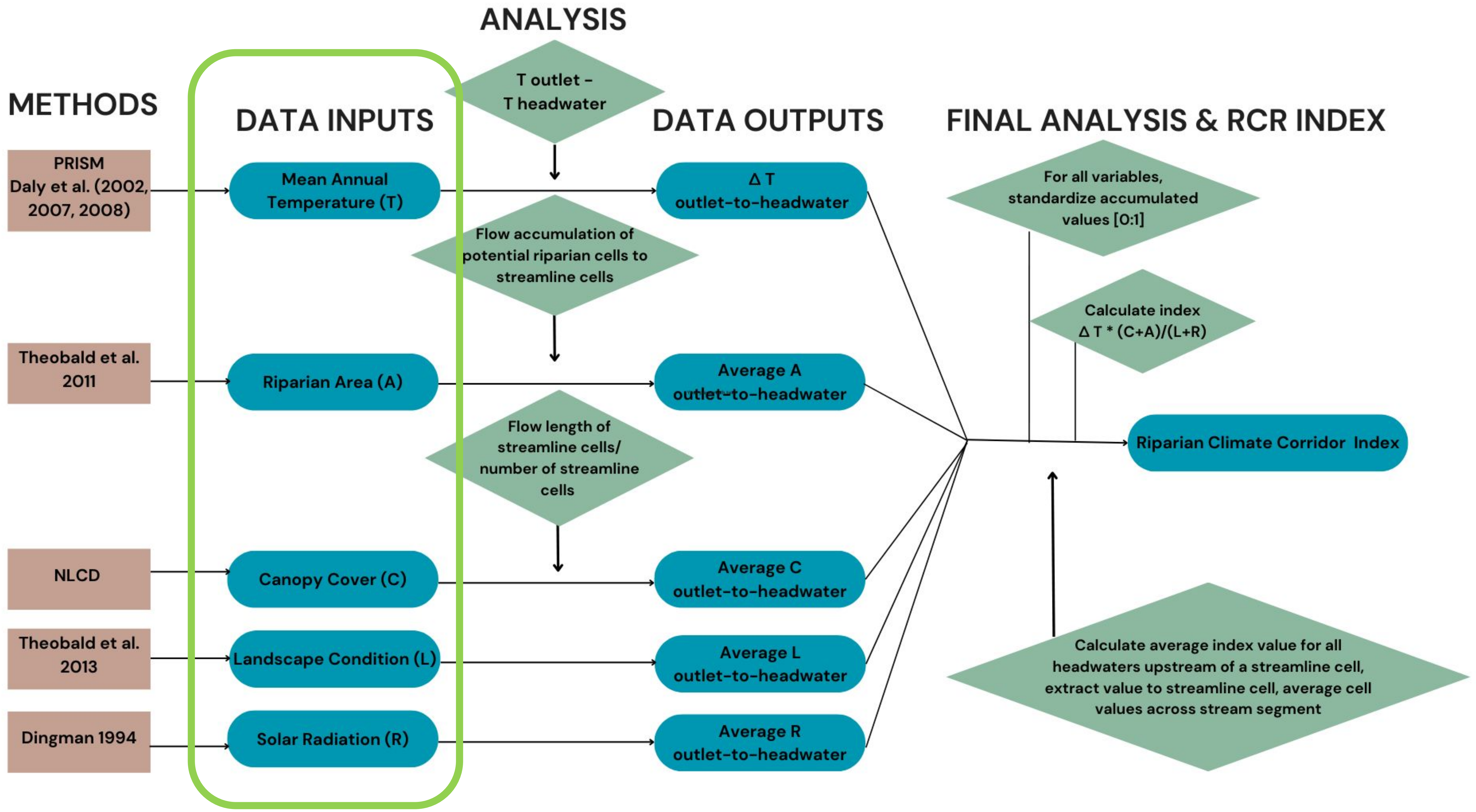



- Modeled riparian climate corridors in the Pacific Northwest at 270 m resolution
- Scaled index [0:1] of **potential refugia quality** in the riparian corridor
- Accumulated parameter values for stream reaches

Riparian climate-corridor index values for individual watershed in Krosby et al. 2018 analysis

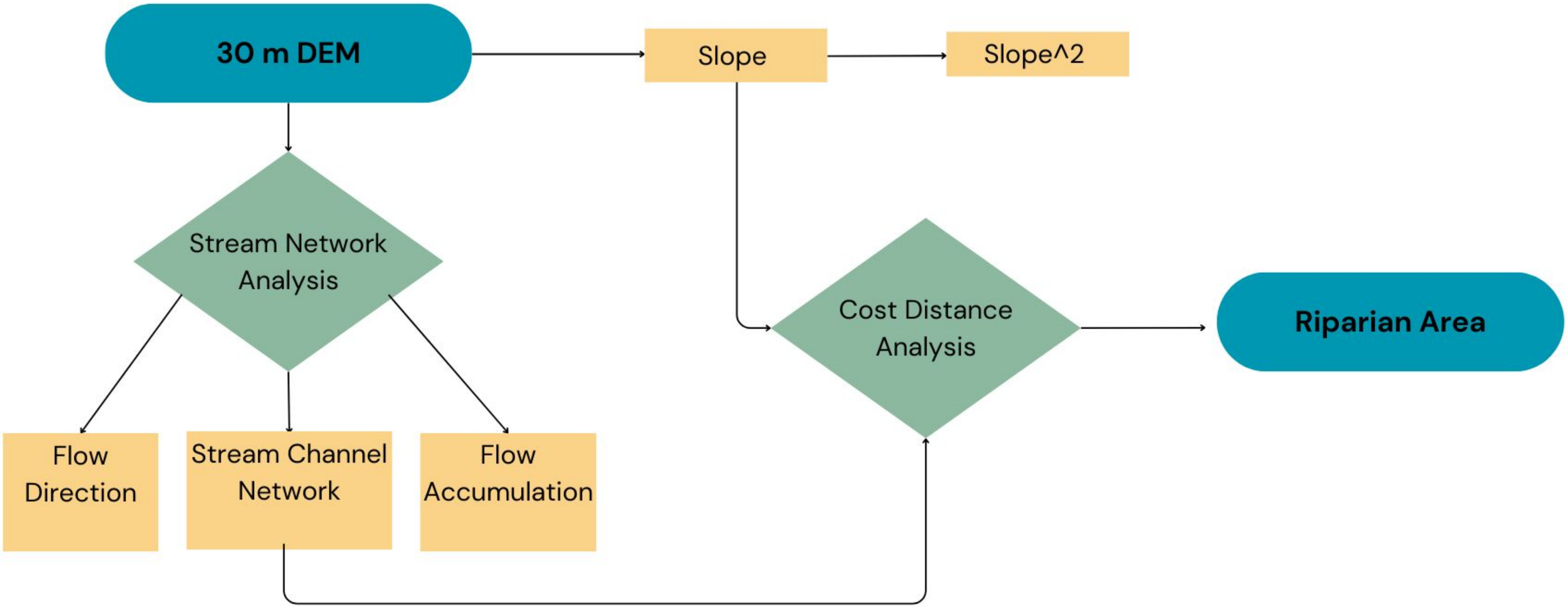
# Variables

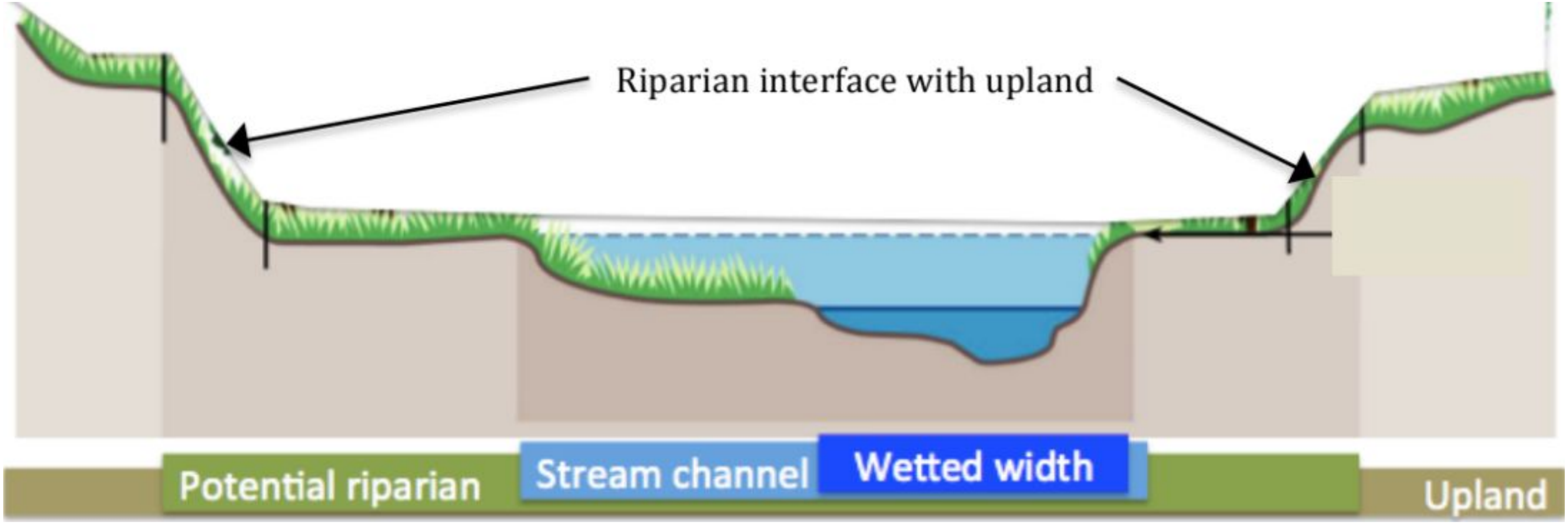
| Analysis Variable | Base Layer Resolution | Year Represented by Base Layer | Base Layer Sources |
|---|---|---|---|
| Riparian Area (A) | 30 m | 2010 (DEM) | This study, following the methods in Theobald et al. 2013 and using a DEM from CalTrout |
| Canopy Cover (C) | 30 m | 2022-2023 (Satellite data) | National Land Cover Dataset (NLCD) |
| Mean Annual Temperature (T) | 30 m | 2000-2022 (Remote Automatic Weather Stations); 2010 (DEM) | This study, following methods of Daly et al. 2002, 2007, 2008 and using a DEM from CalTrout |
| Mean Solar Radiation (R) | 30 m | 2022 (monthly mean radiation); 2010 (DEM) | This study, following the methods in Physical Hydrology, 3rd Edition, by Dingman, and using a DEM from CalTrout |
| Landscape Condition (L) | 30 m | 2023 (NLCD); 2023 (TIGER roads); historical resource extraction | This study, following the methods in Theobald et al. 2011 and using a DEM from CalTrout |



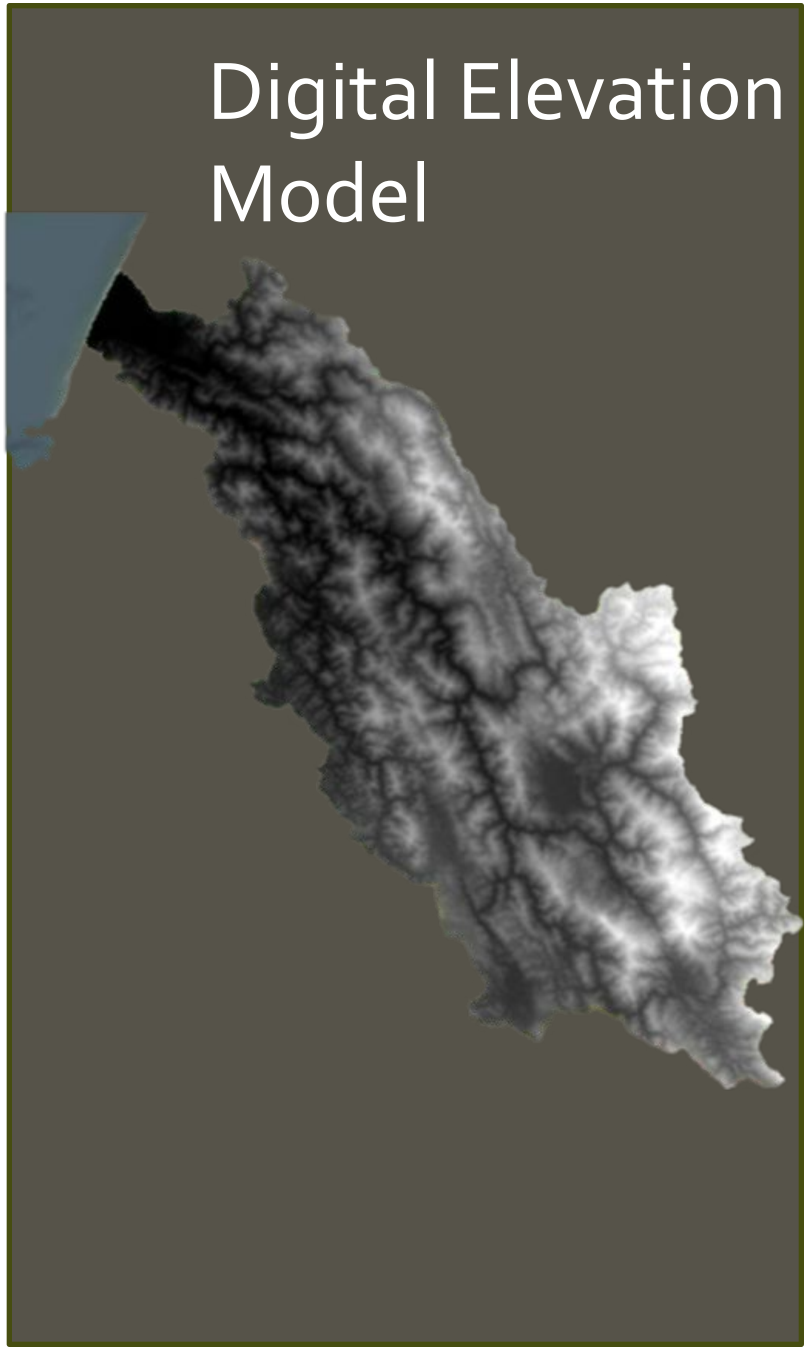
ANALYSIS
METHODS
DATA INPUTS
T outlet -
T headwater
DATA OUTPUTS
FINAL ANALYSIS & RCR INDEX
PRISM
Daly et al. (2002, 2007, 2008)
Mean Annual Temperature (T)
Δ T
outlet-to-headwater
For all variables, standardize accumulated values [0:1]
Flow accumulation of potential riparian cells to streamline cells
Calculate index
Δ T * (C+A)/(L+R)
Theobald et al. 2011
Riparian Area (A)
Average A
outlet-to-headwater
Flow length of streamline cells/ number of streamline cells
Riparian Climate Corridor Index
NLCD
Canopy Cover (C)
Average C
outlet-to-headwater
Theobald et al. 2013
Landscape Condition (L)
Average L
outlet-to-headwater
Calculate average index value for all headwaters upstream of a streamline cell, extract value to streamline cell, average cell values across stream segment
Dingman 1994
Solar Radiation (R)
Average R
outlet-to-headwater

# Riparian Area Workflow



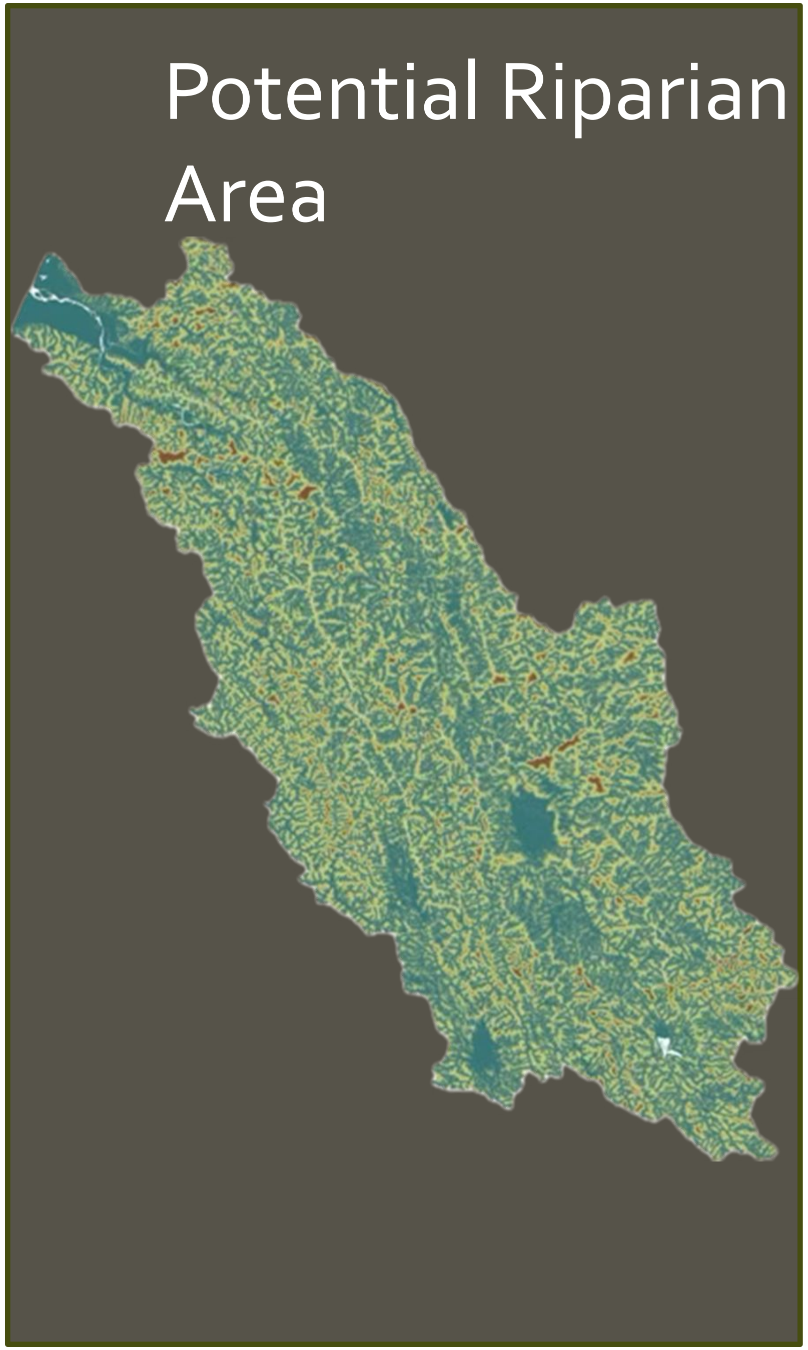



Conceptual representation of the valley bottom and riparian area (Theobald et al. 2013)


Digital Elevation
Model


Slope


Stream
Network


Potential Riparian
Area

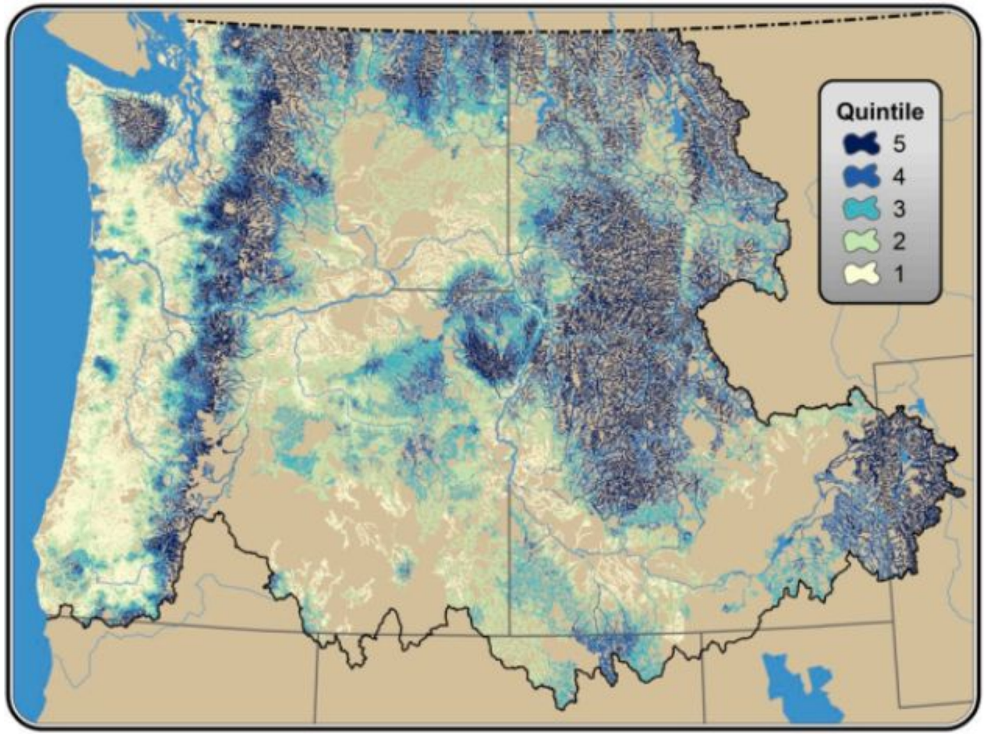
# Analysis & Validation

- Validate model results based on a combination of remotely sensed data and field data.
  - Determine riparian and non riparian areas
- Combination of high resolution RGB (1 m NAIP) and LiDAR to determine land cover types


**Angelo Coast Range Reserve. 2004 LiDAR.**
**Left processed into Bare-earth DEM. Right processed into Canopy elevation and Tree height.**

# Expected Results

- Differing values for mountainous regions near headwaters vs. lowlands
- Correlation with high value corridors and existing protected areas
- Sensitivity analysis and uncertainty analysis
- Effect of local but severe movement barriers




(Krosby et al. 2018) Riparian climate-corridor index values for the Pacific Northwest. Values are averaged across nested watershed scales (6th to 1st field HUCs), attributed to streamlines associated with potential riparian corridors.


Quintile
5
4
3
2
1

# In Summary, Conservation Approach

- Identify riparian corridors and potential protected area linkages.
- Model ecological and habitat values.
- Identify climate resilient riparian habitat (indexed 1-5).
- Facilitate the protection of key areas.
- Add information to potential restoration actions

# Overlay analyses, Eel R & C Program Phase II

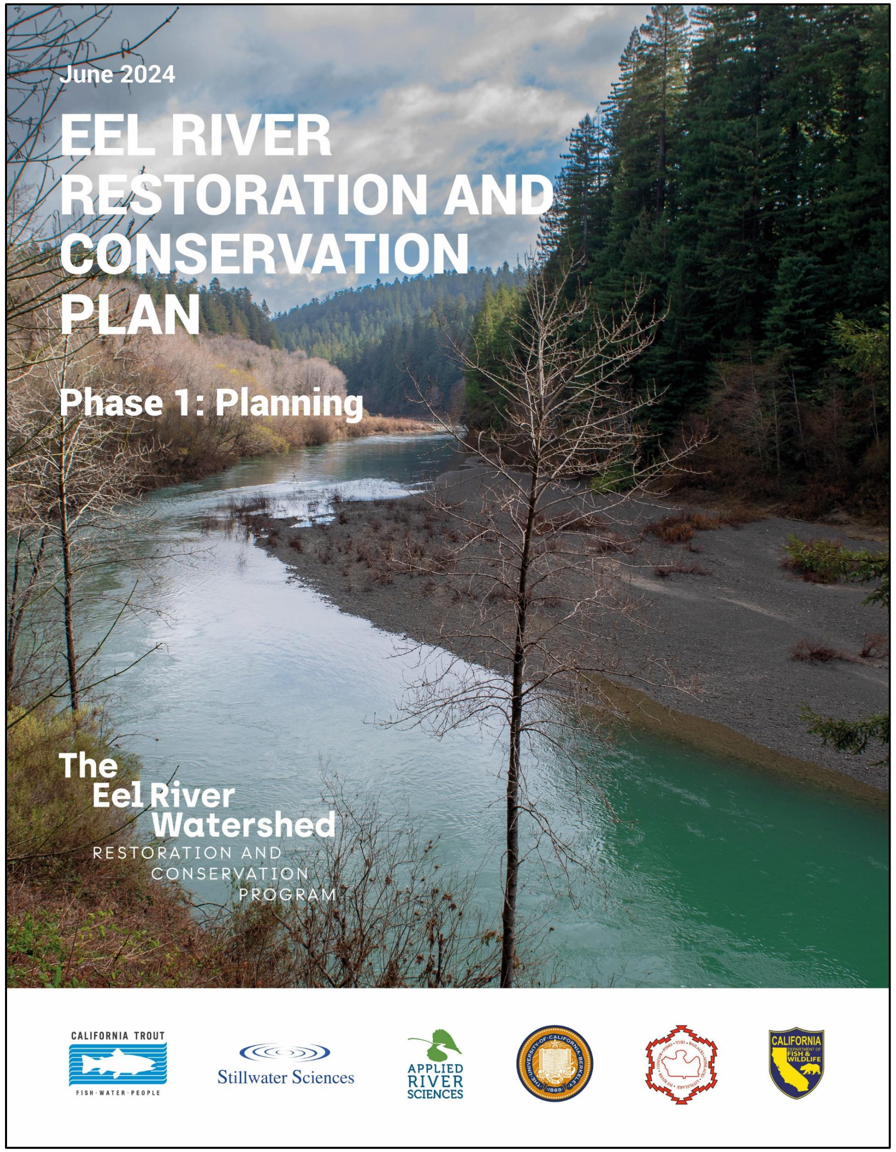
**Restoration prioritization:** Channel archetypes - in stream habitat, what fish need and where. HUC 12, suite of actions.

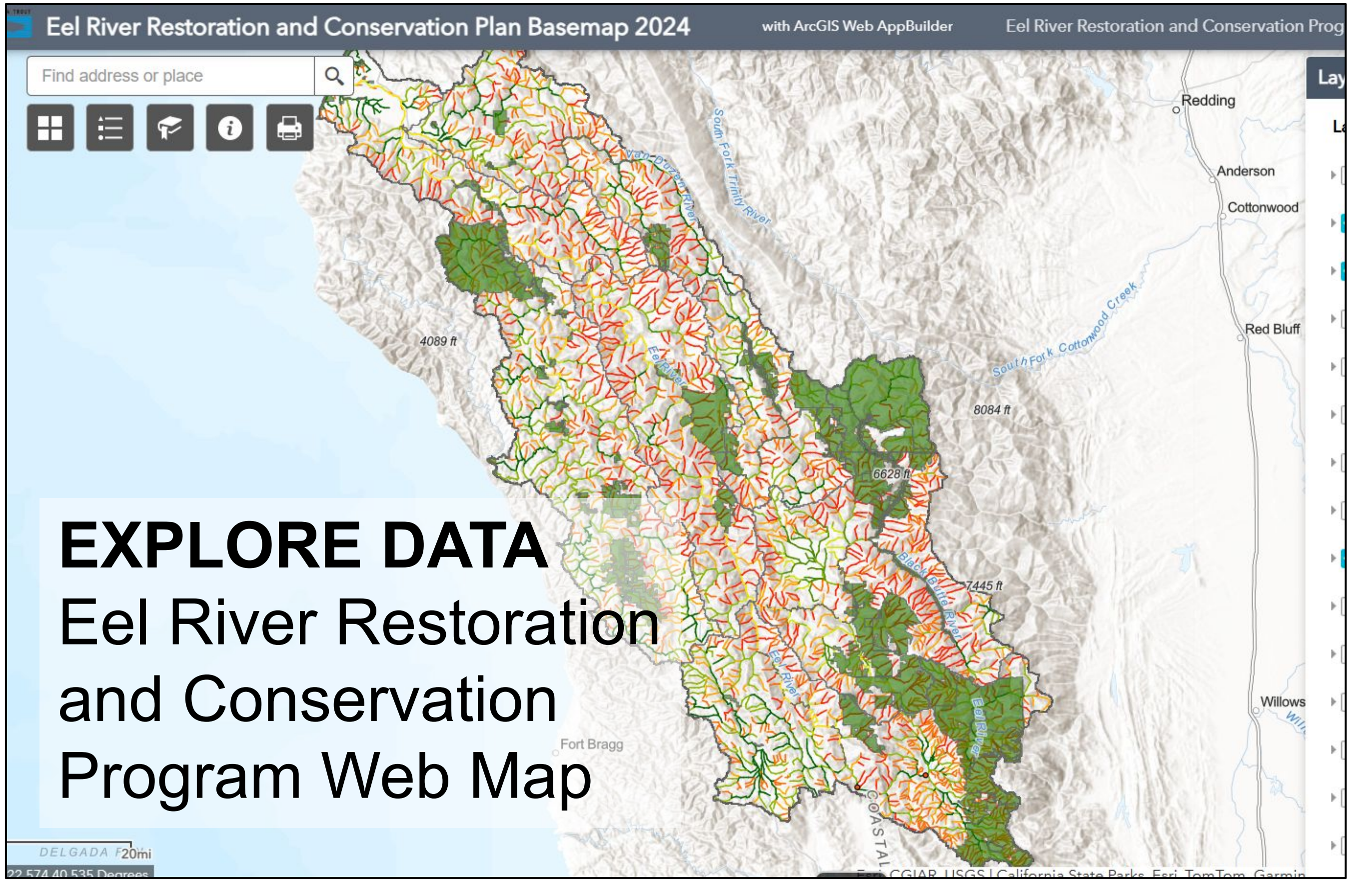
**Conservation prioritization:** Conservation areas, rerun in 2025, parcel data.

- Vegetation health index
- Biodiversity
- Aquatic and terrestrial species richness

**Riparian climate refugia index**

- Potential riparian area
- Solar radiation
- NDVI/Canopy cover
- Landscape impact index
- Temperature - mean of monthly




[Eel River Watershed Program | California Trout (caltrout.org)]

Anderson, M.G., *et al*. A resilient and connected network of sites to sustain biodiversity under a changing climate, *Proc. Natl. Acad. Sci. U.S.A.* 120 (7) (2023).

Groves, C.R., Game, E.T., Anderson, M.G. *et al.* Incorporating climate change into systematic conservation planning. *Biodivers Conserv* 21, 1651–1671 (2012).

Heller, N.E., Zavaleta, E.S. Biodiversity management in the face of climate change: A review of 22 years of recommendations, Biological Conservation, Volume 142, Issue 1,14-32 (2009).

Krosby, M., Theobald, D.M., Norheim, R., McRae, B.H. Identifying riparian climate corridors to inform climate adaptation planning. PLoS ONE 13(11), (2018).

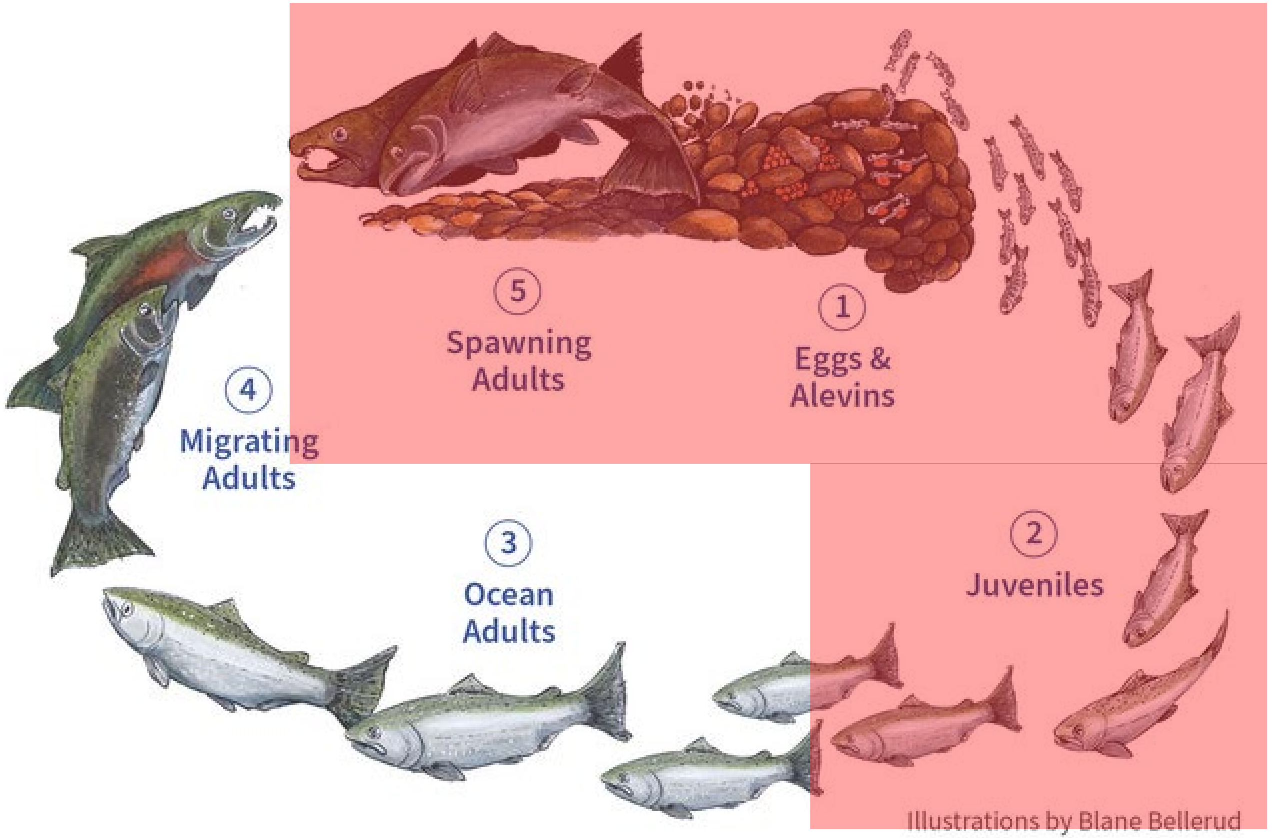
cdavis@caltrout.org

Eel River Watershed Program | California Trout (caltrout.org)

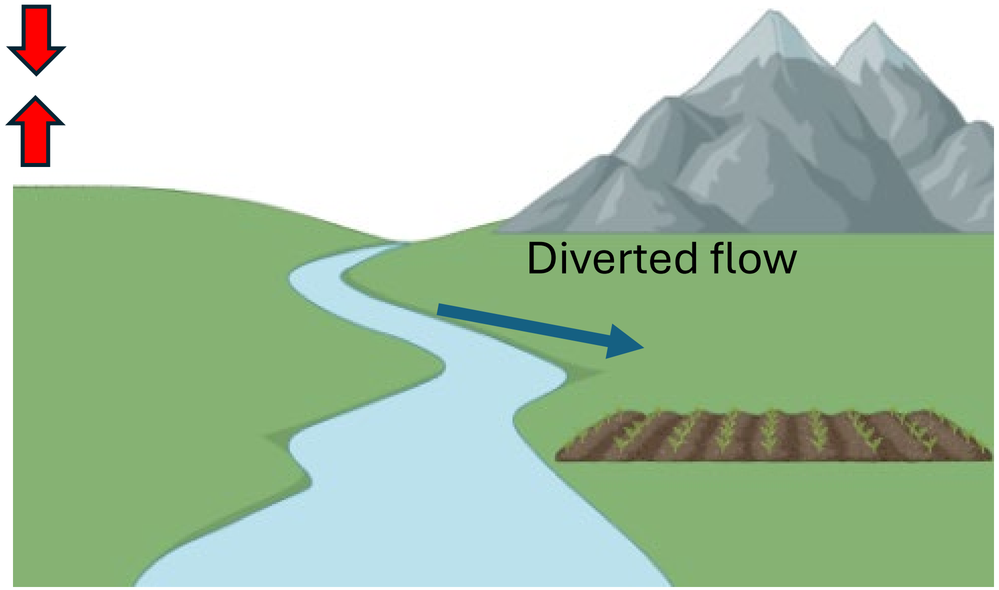
# Rapid Evolution and Persistence of Steelhead in a Warming World

Paige Gardner

# Salmon are Thermally Vulnerable



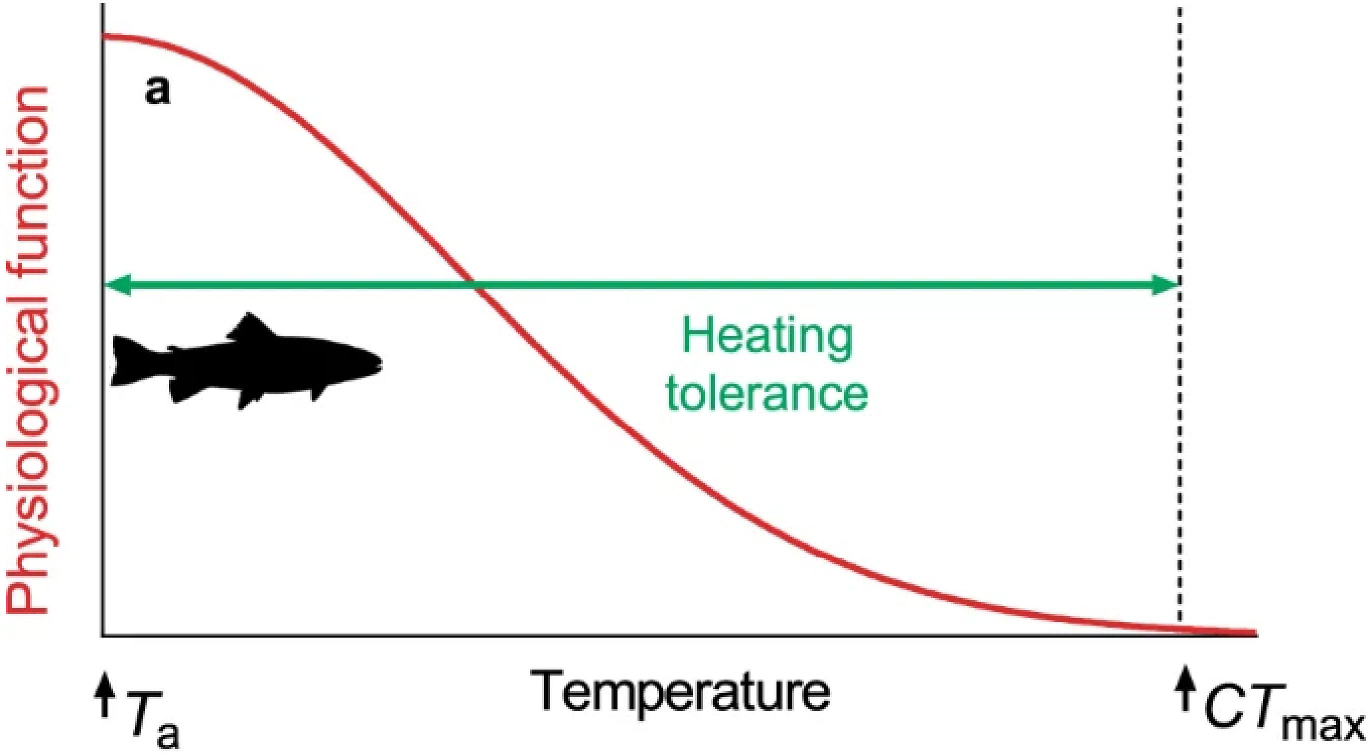

- Shifts in climate are decreasing access to cool, consistent water for freshwater life stages.



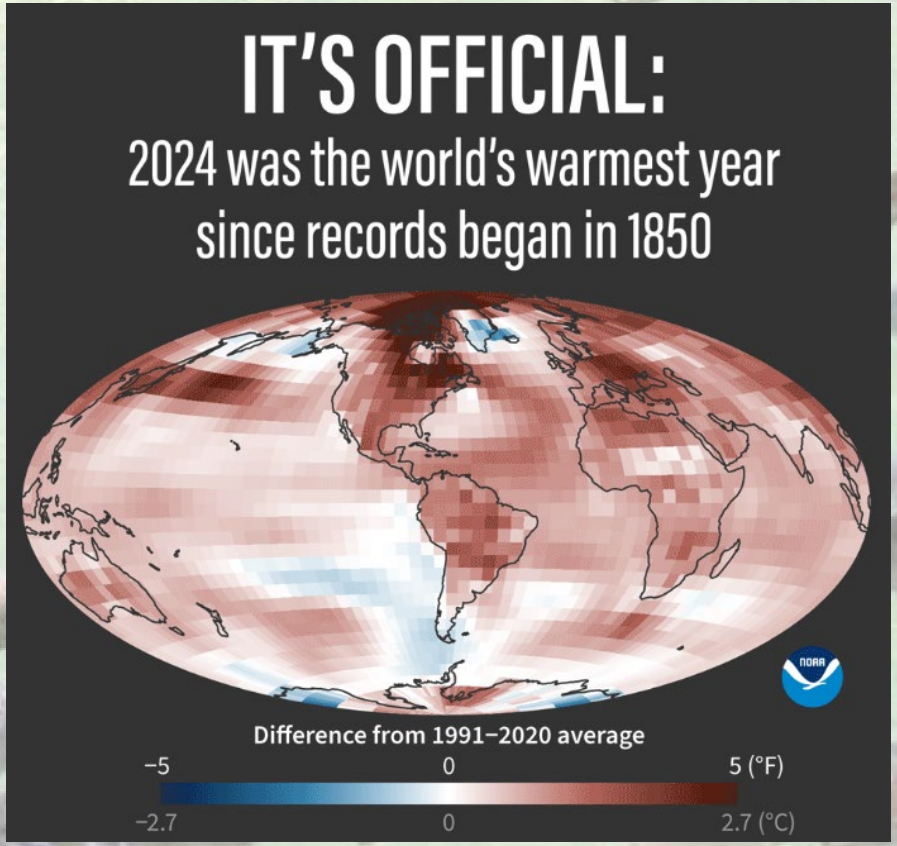
# Ectothermy and Environmental Challenges

Rising temperature can cause:

- Increased metabolism and metabolic demand
- Impaired growth and development
- Increased disease risk



# Can salmonids keep up with the rate of climate change?




CALTROUT NEWS

< Back to All News

Southern Steelhead Listed as Endangered under California's Endangered Species Act

April 23, 2024

Tags ▾ Categories ▾

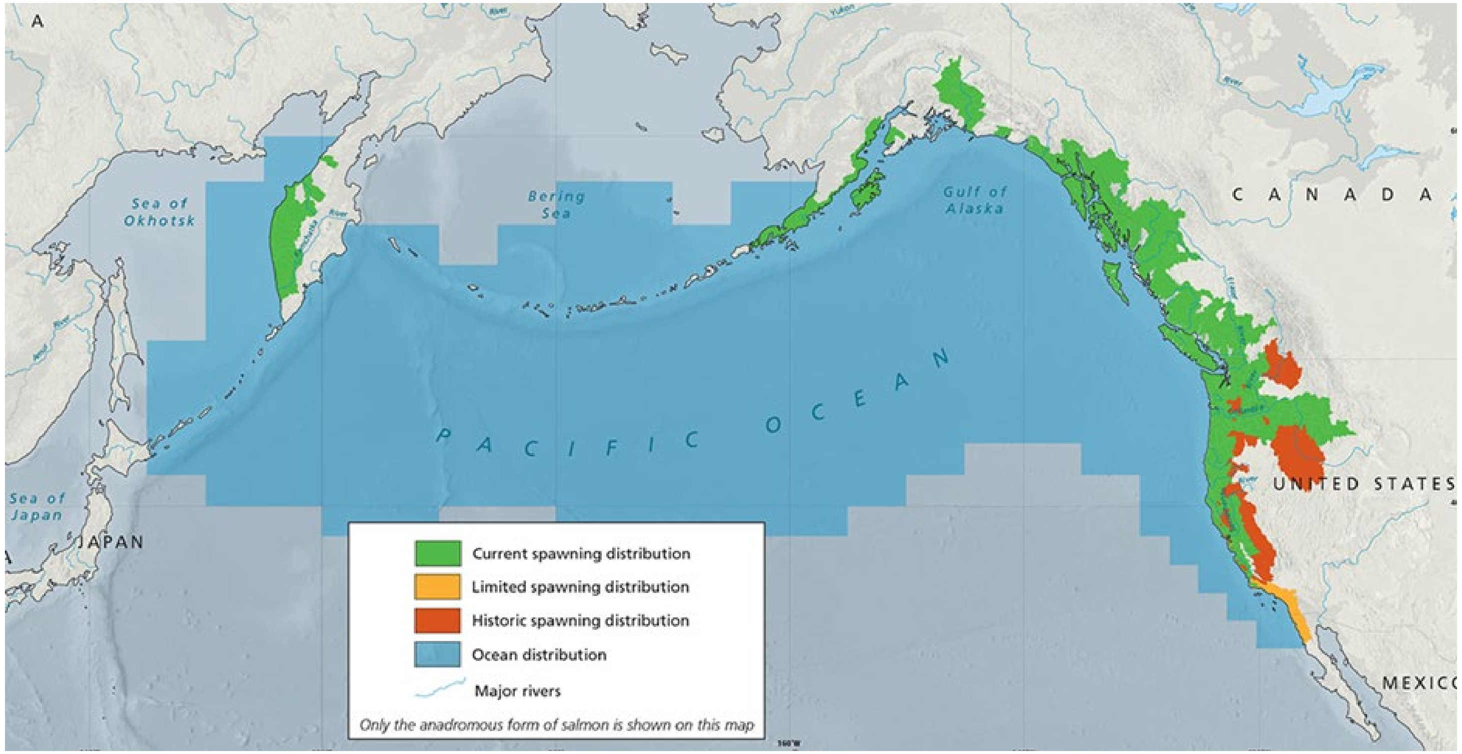
**Title: Over 90% of western United States coho salmon and steelhead trout subpopulations predicted to become thermally stressed with climate change**

Running title: Thermal stress of coho and steelhead

List of Authors: Alyssa M. FitzGerald[1,2]

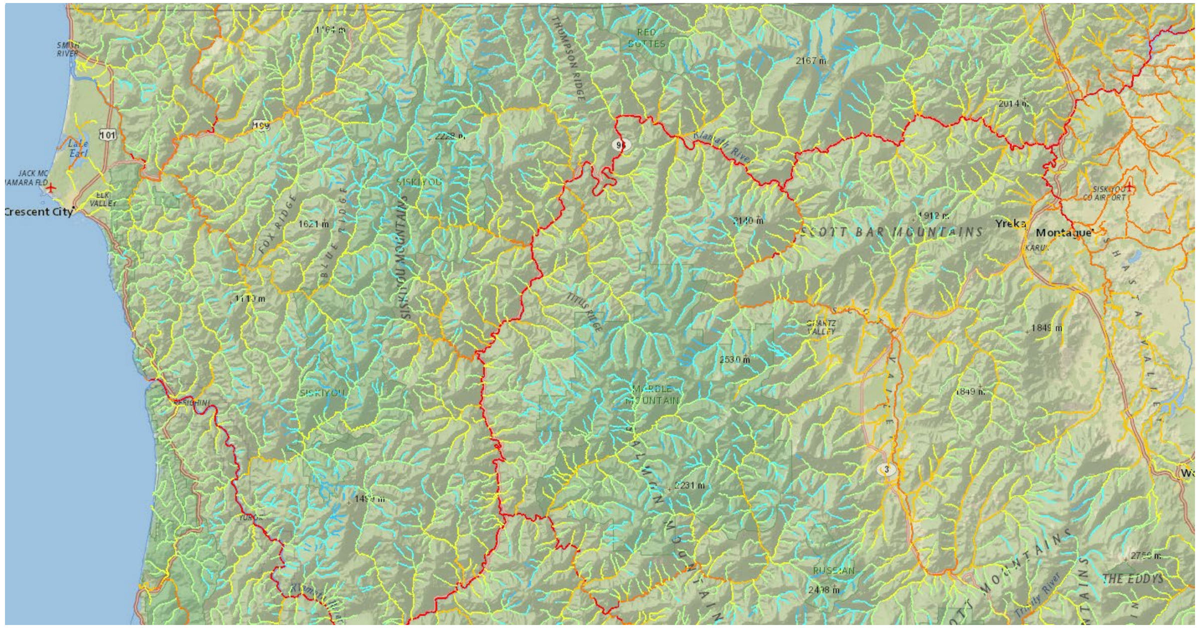
# Steelhead as a case study in thermal tolerance

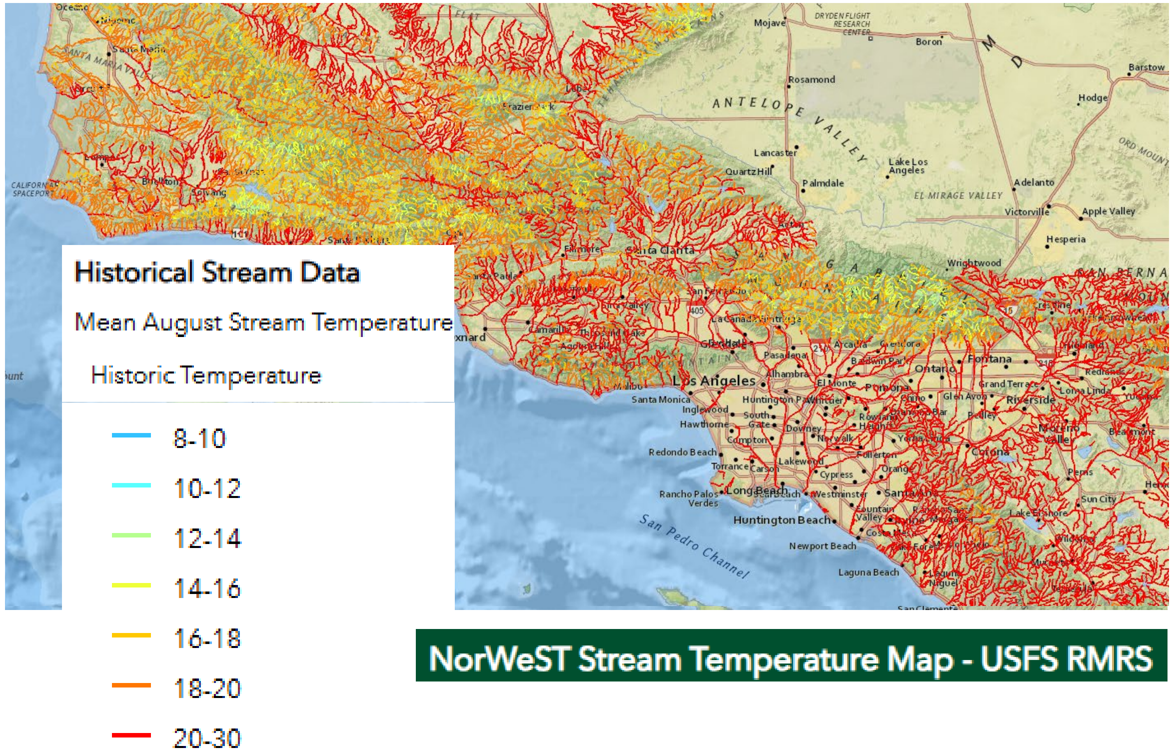
The most southernly distributed salmonid, steelhead historically persist in a large range of thermal regimes.




Map: Wild Salmon Center

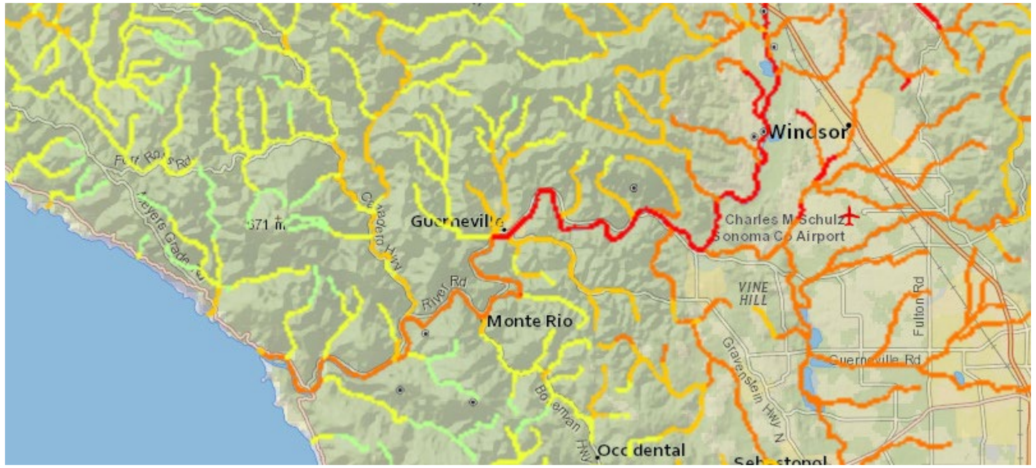
Photo courtesy of flyfisherman.com



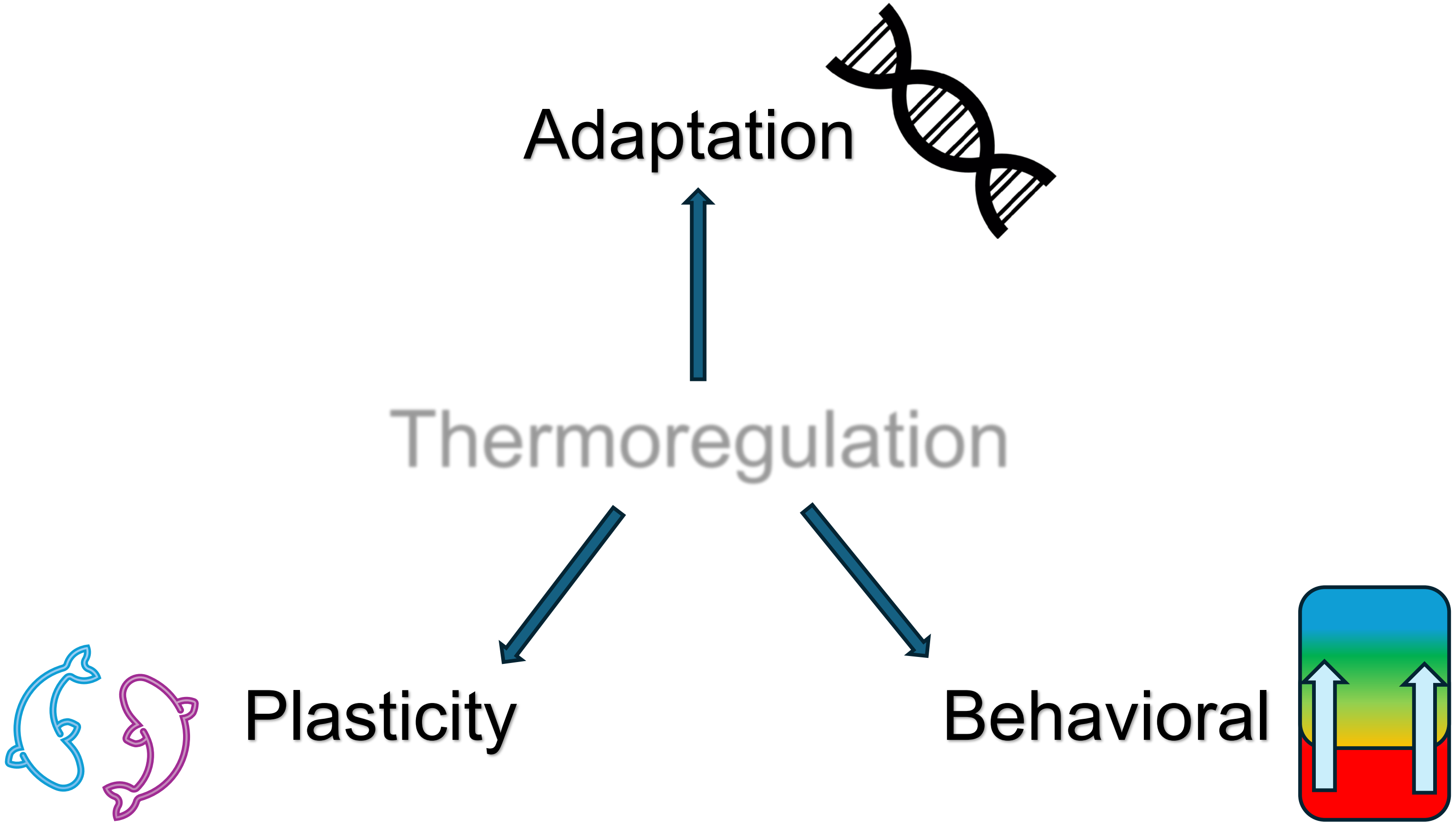




# A Natural Experiment

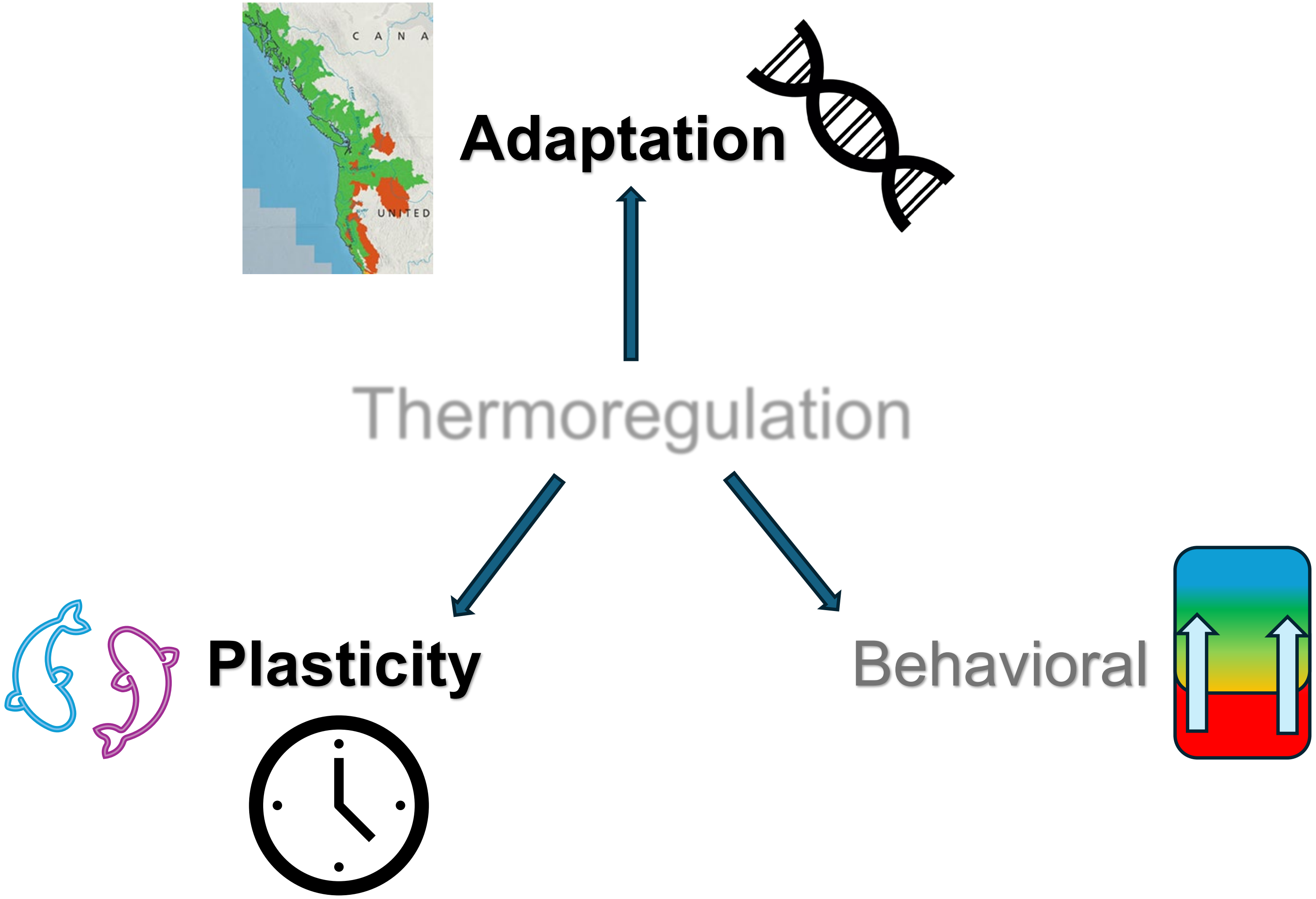
- Across latitude
- Within watersheds (e.g. Russian River)



# Pathways of Thermal Tolerance



# Pathways of Thermal Tolerance



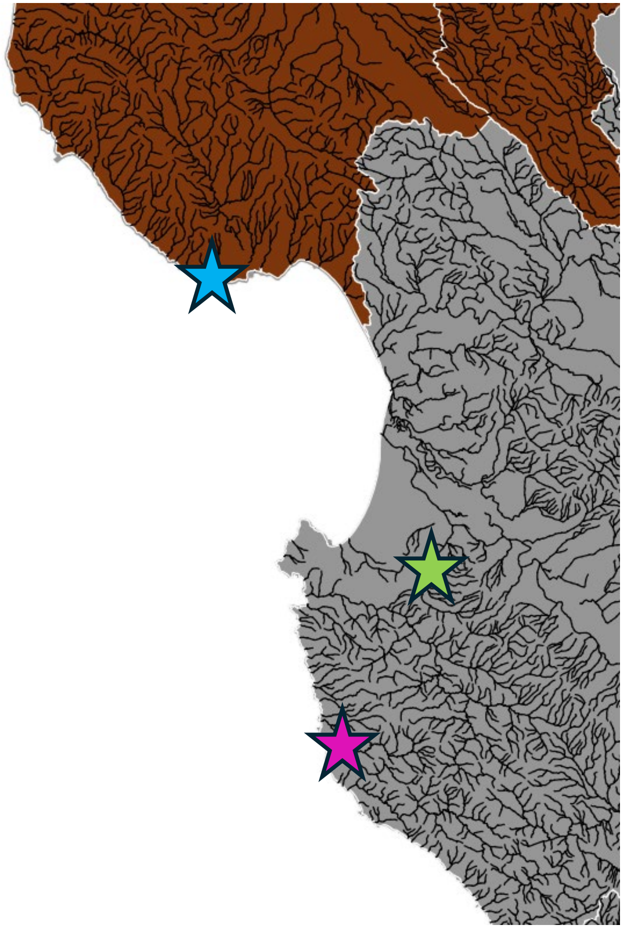
# Can Steelhead keep up with the rate of climate change?

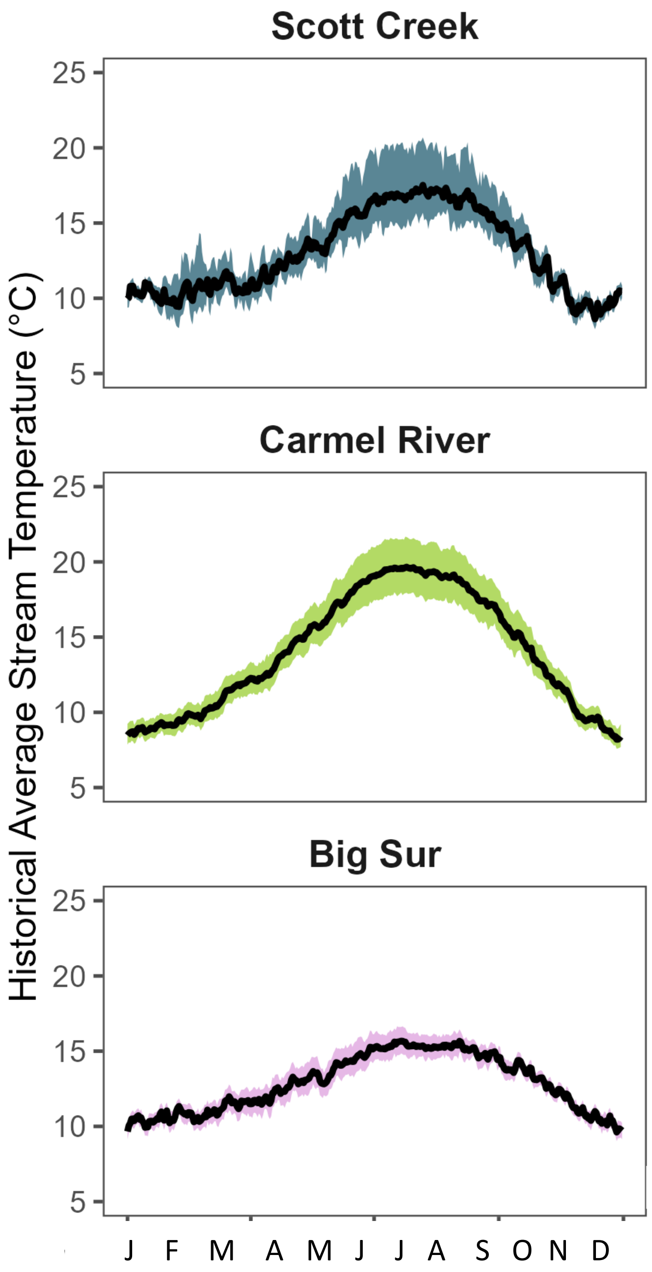
1) **Plasticity:** How does a heating event impact the thermal tolerance of individuals within a population?

2) **Adaptation:** Are populations from warmer streams better able to tolerate heat than those from cooler streams? Are there specific genomic regions associated with thermal tolerance?

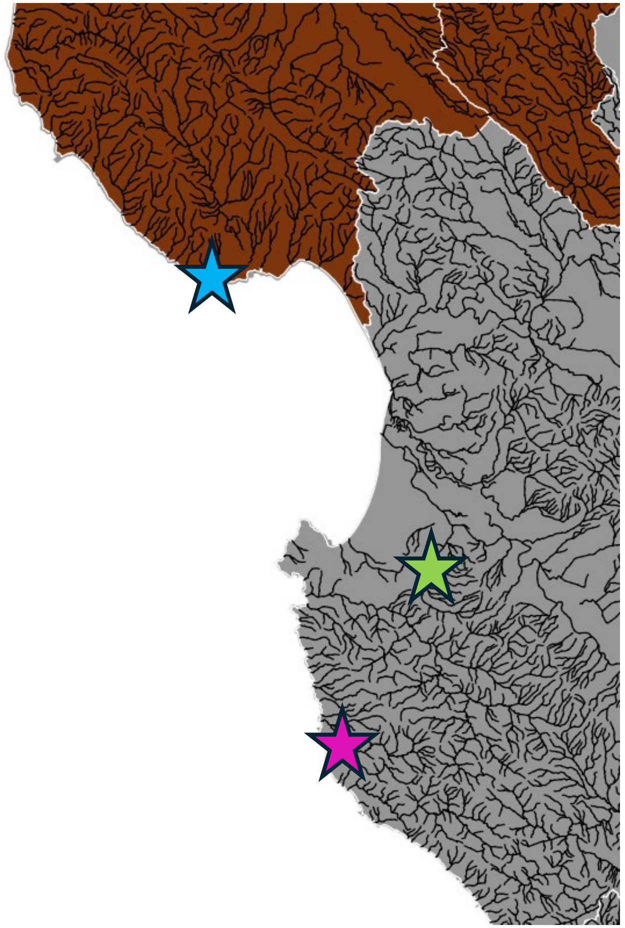
3) **Application:** How can we use both physiological and genetic information to inform conservation decisions?

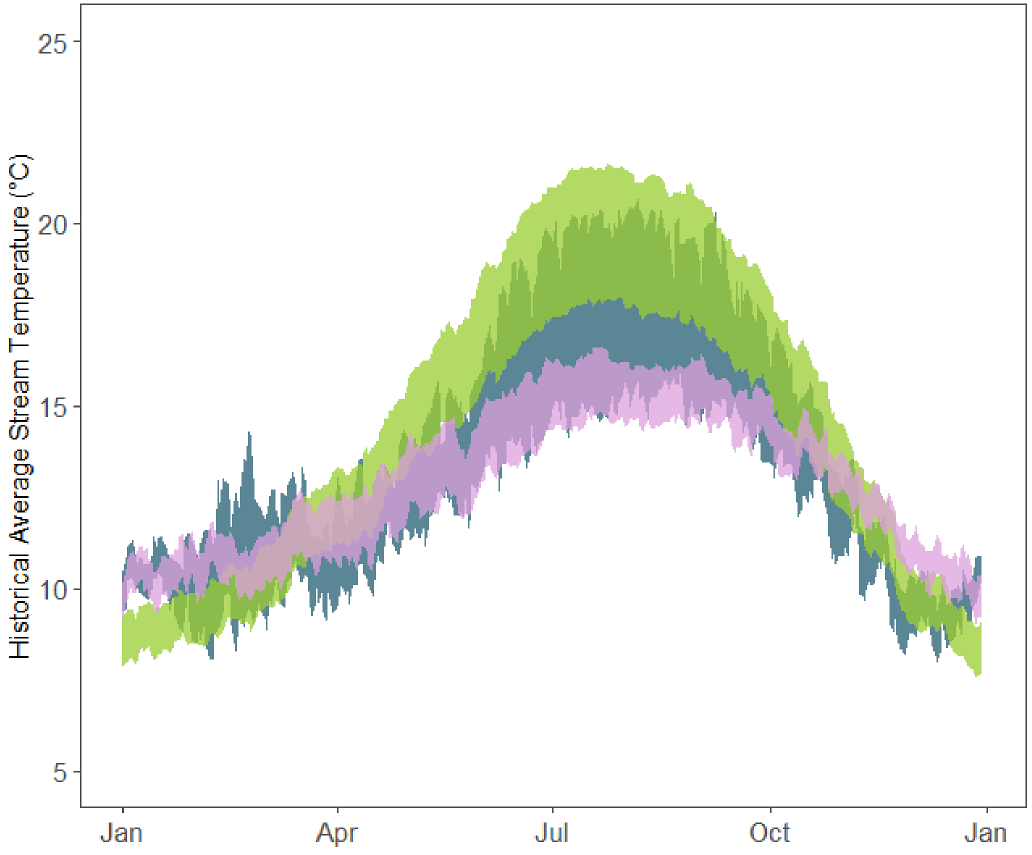
# Study Design

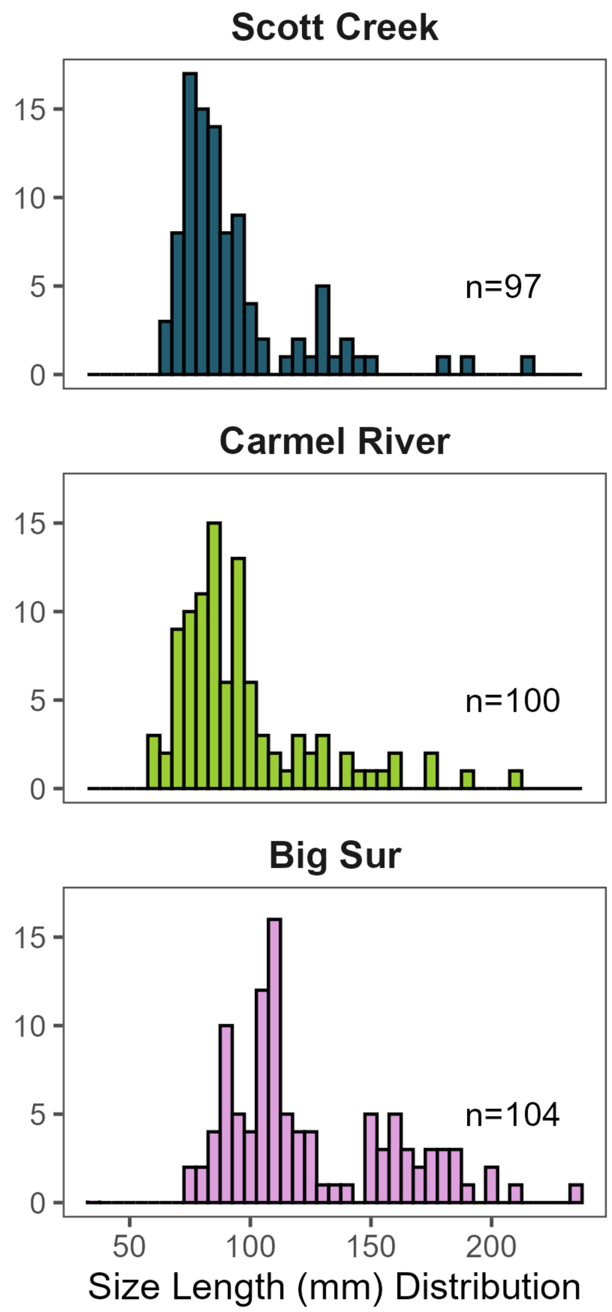




# Study Design



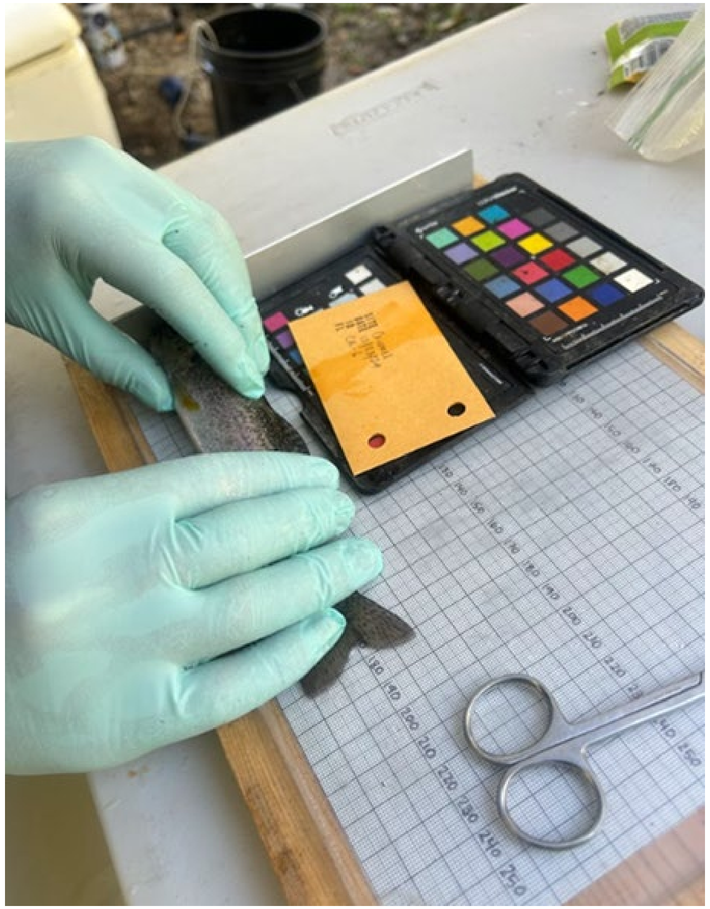


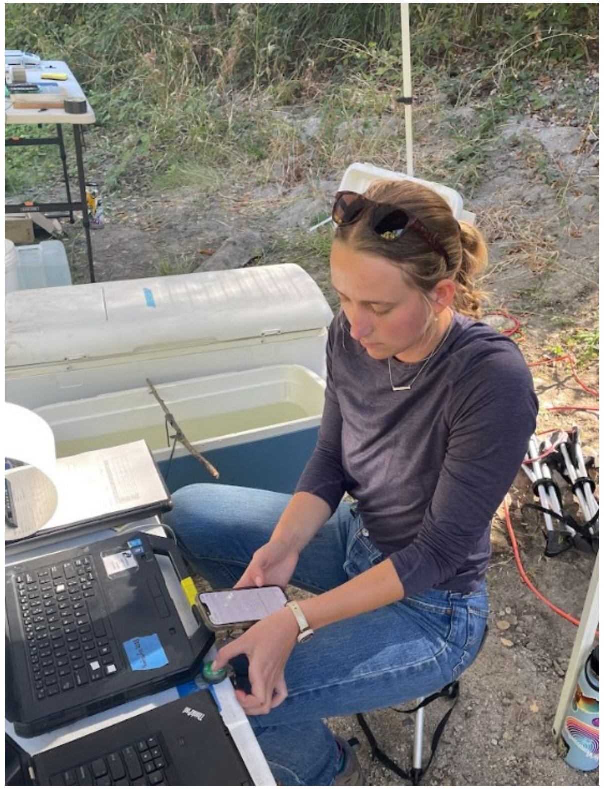
**Short-term Acclimation**

**CTmax**

**Genetics and Morphometrics**



# A Snapshot of the Field Work



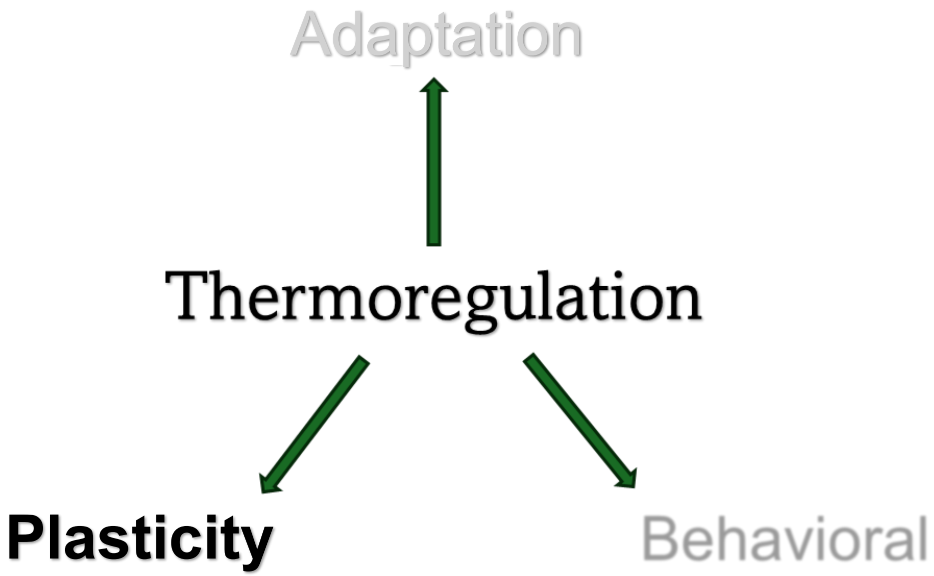
# Key Questions

1) **Plasticity:** How does a heating event impact the thermal tolerance of individuals within a population?

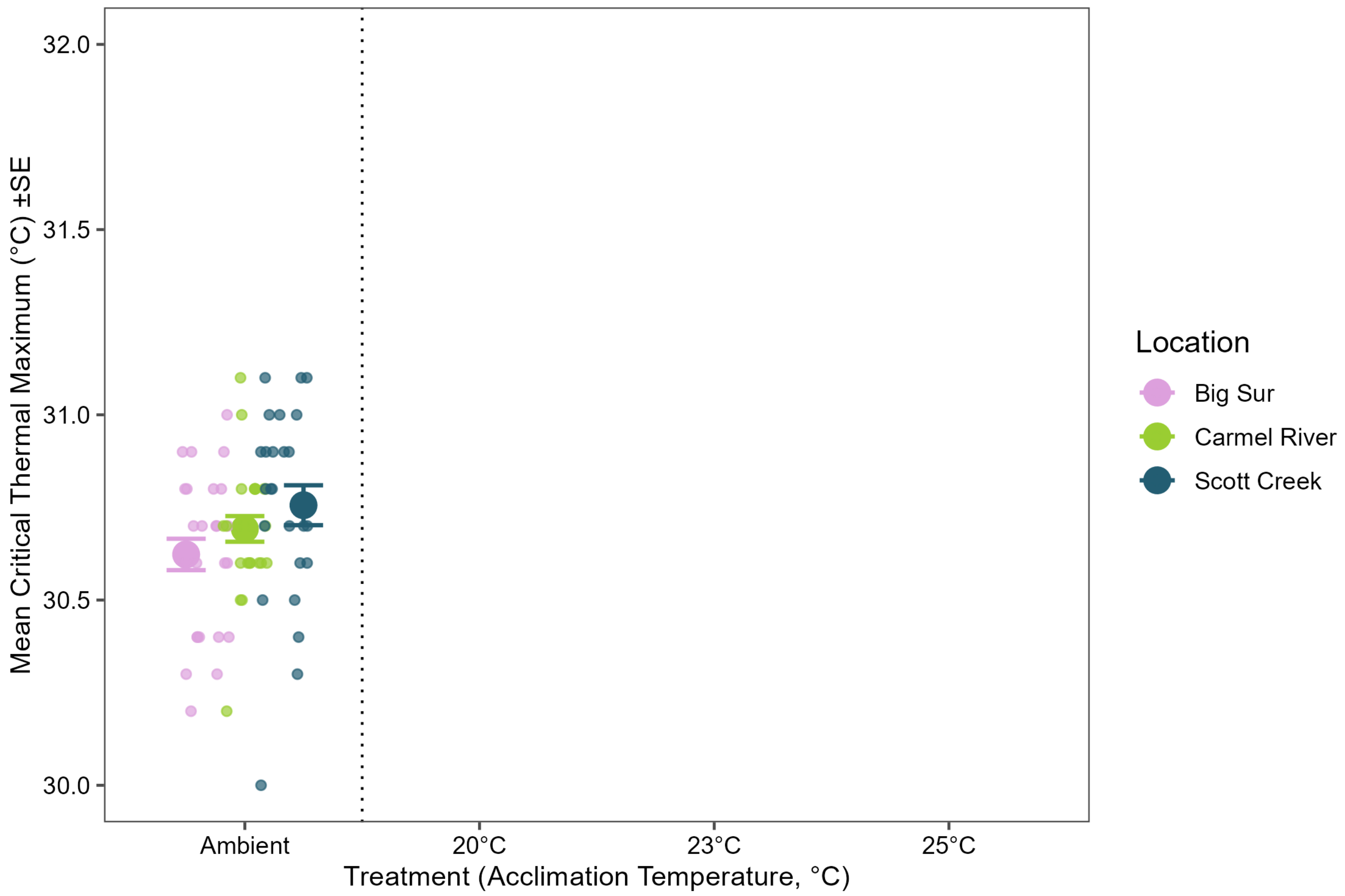
2) **Adaptation:** Are populations from warmer streams better able to tolerate heat than those from cooler streams? Are there specific genomic regions associated with thermal tolerance?

3) **Application:** How can we use both physiological and genetic information to inform conservation decisions?

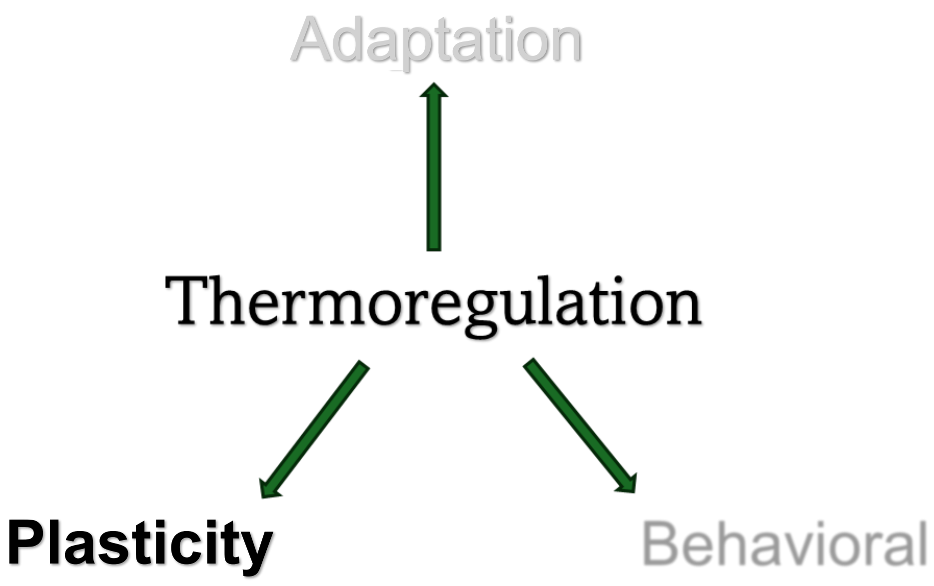
# Plasticity of Thermal Tolerance

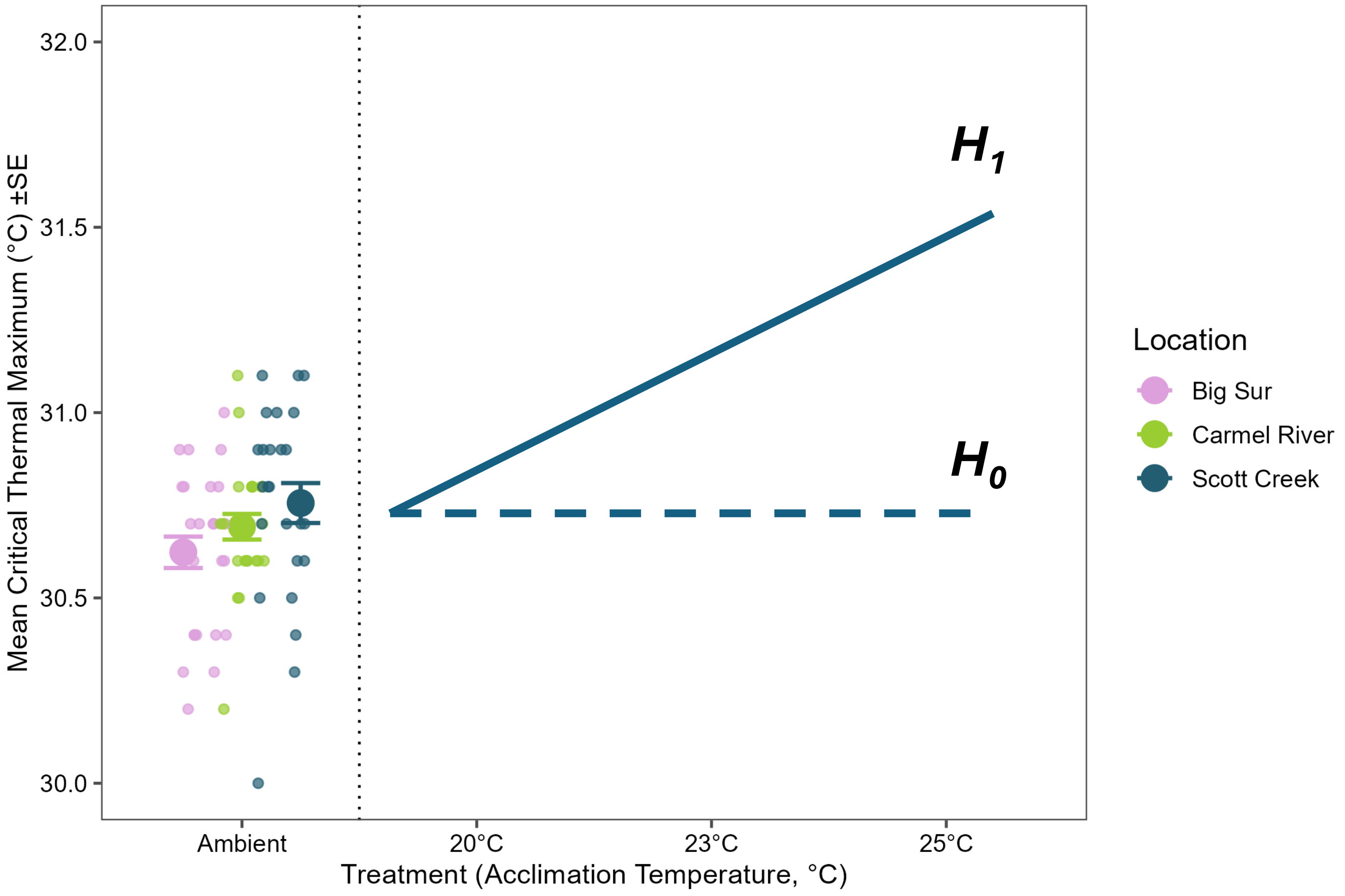



**Hypothesis:** Increasing acclimation temperatures will induce higher thermal tolerance, causing higher CTmax values.



# Plasticity of Thermal Tolerance

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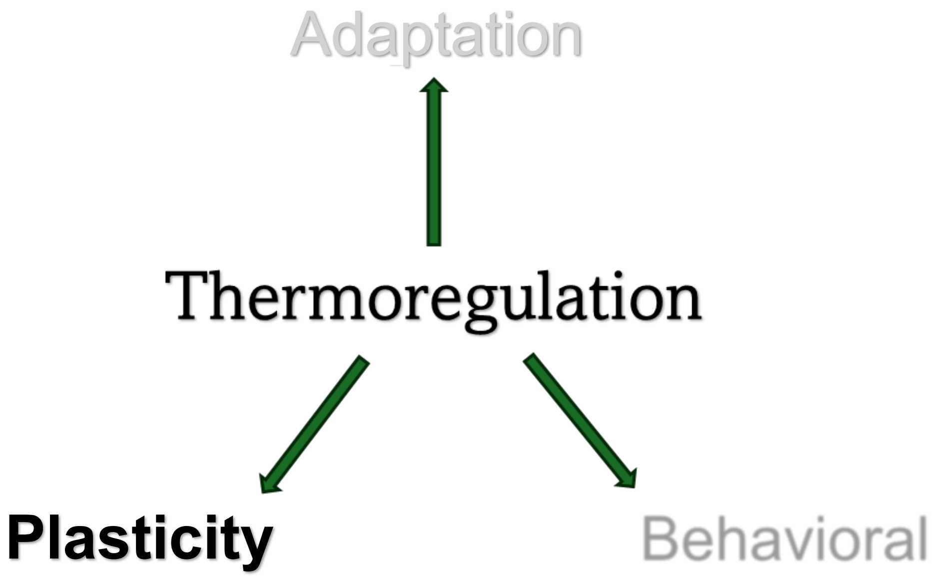
# Plasticity of Thermal Tolerance

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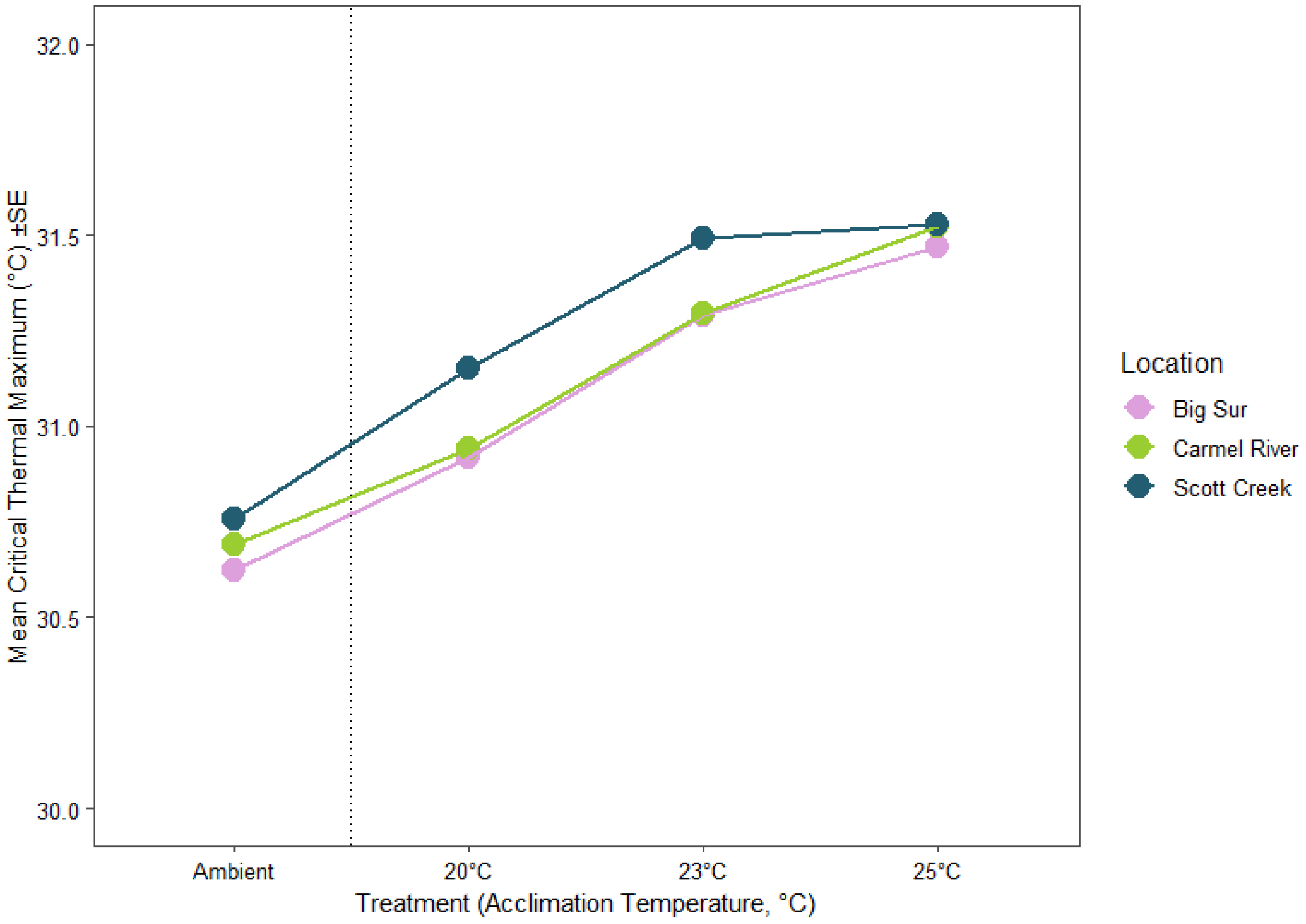
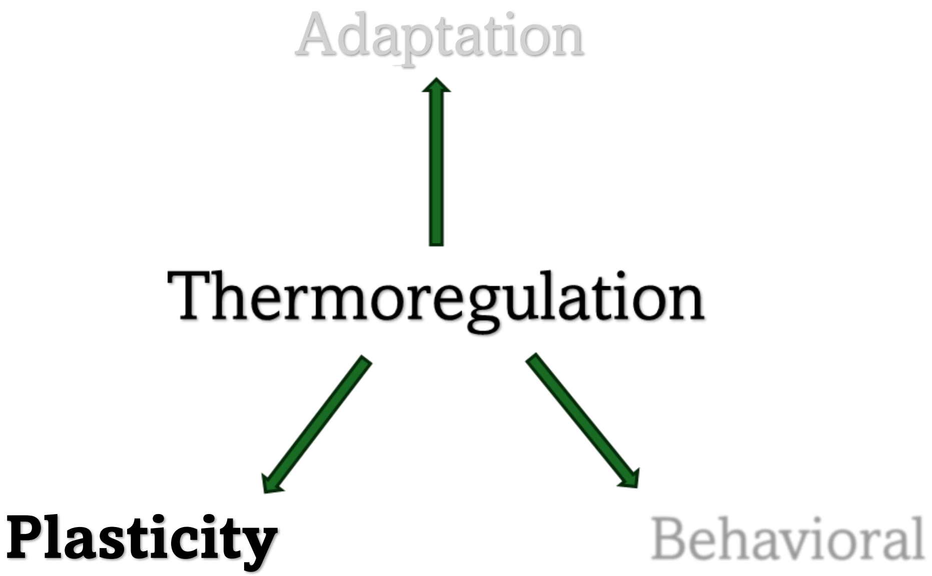


# Plasticity of Thermal Tolerance




**Conclusion:**
Thermal tolerance is impacted by environmental temperatures and has some amount of plasticity. However, *there is still an upper limit*.

**Hypothesis:** Increasing acclimation temperatures will induce higher thermal tolerance, causing higher CTmax values.

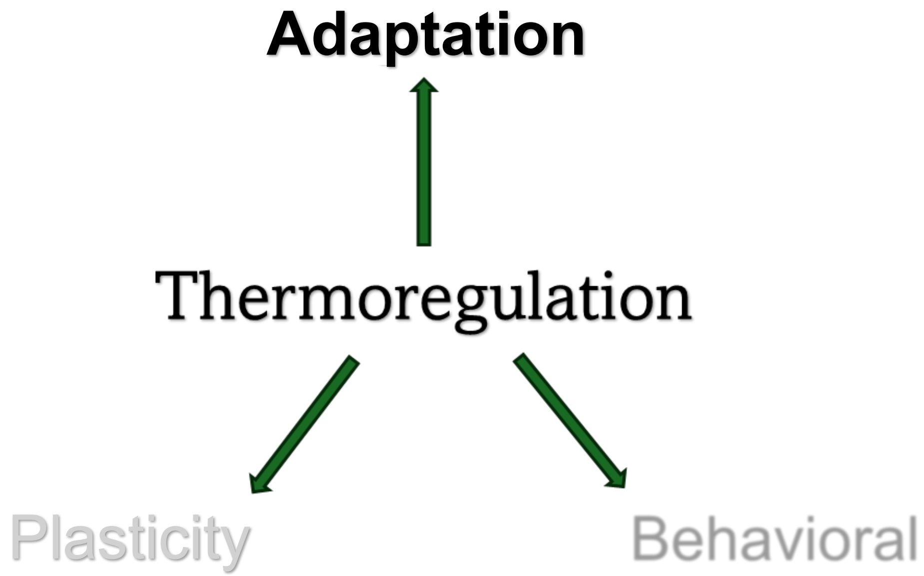
# Key Questions

1) **Plasticity:** How does a heating event impact the thermal tolerance of individuals within a population?

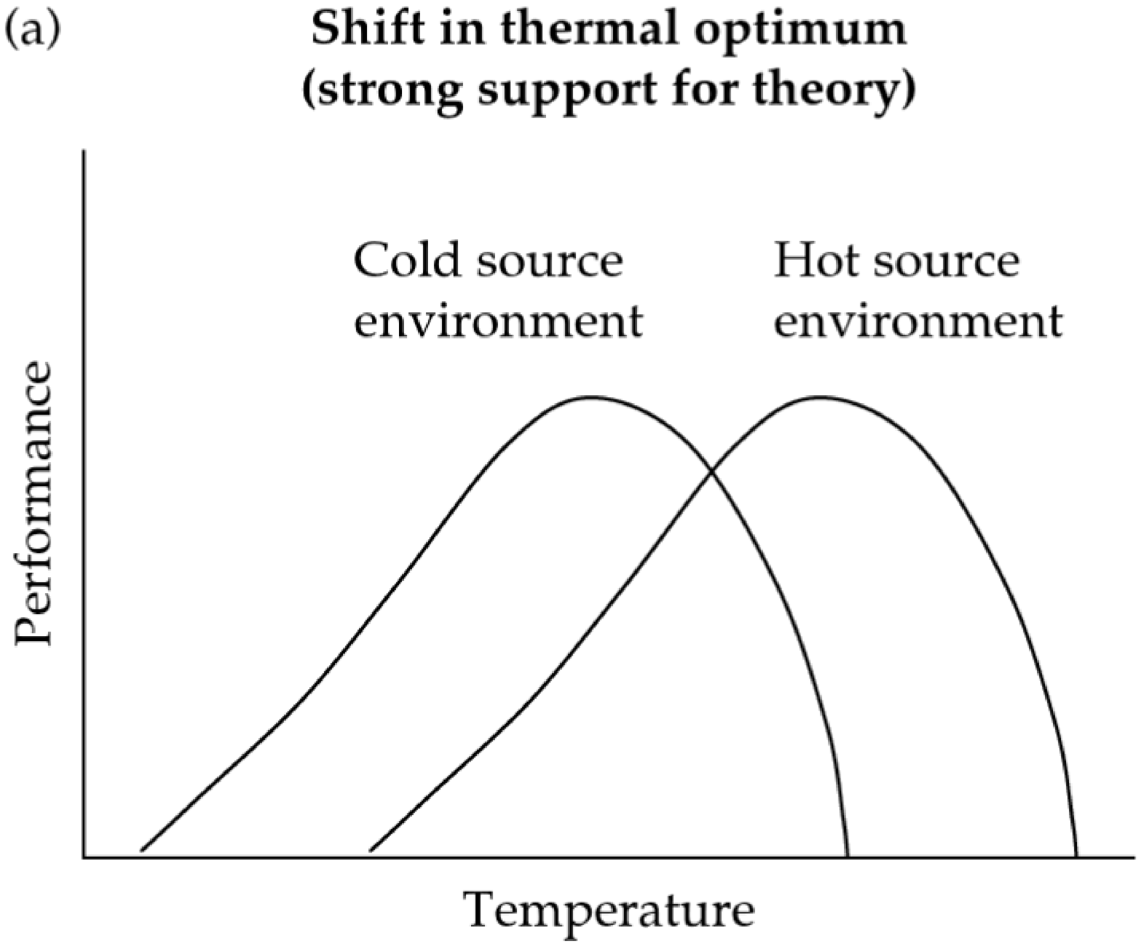
2) **Adaptation:** Are populations from warmer streams better able to tolerate heat than those from cooler streams? Are there specific genomic regions associated with thermal tolerance?

3) **Application:** How can we use both physiological and genetic information to inform conservation decisions?

# Local Adaptation

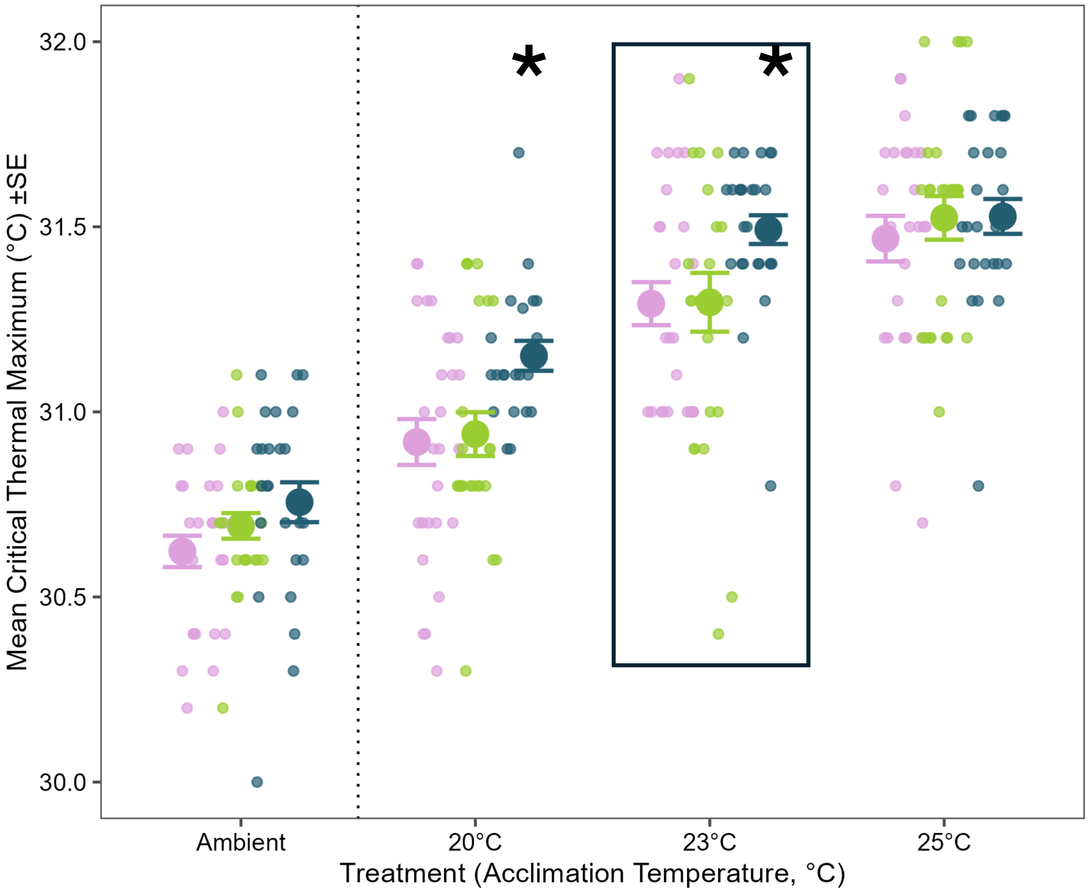


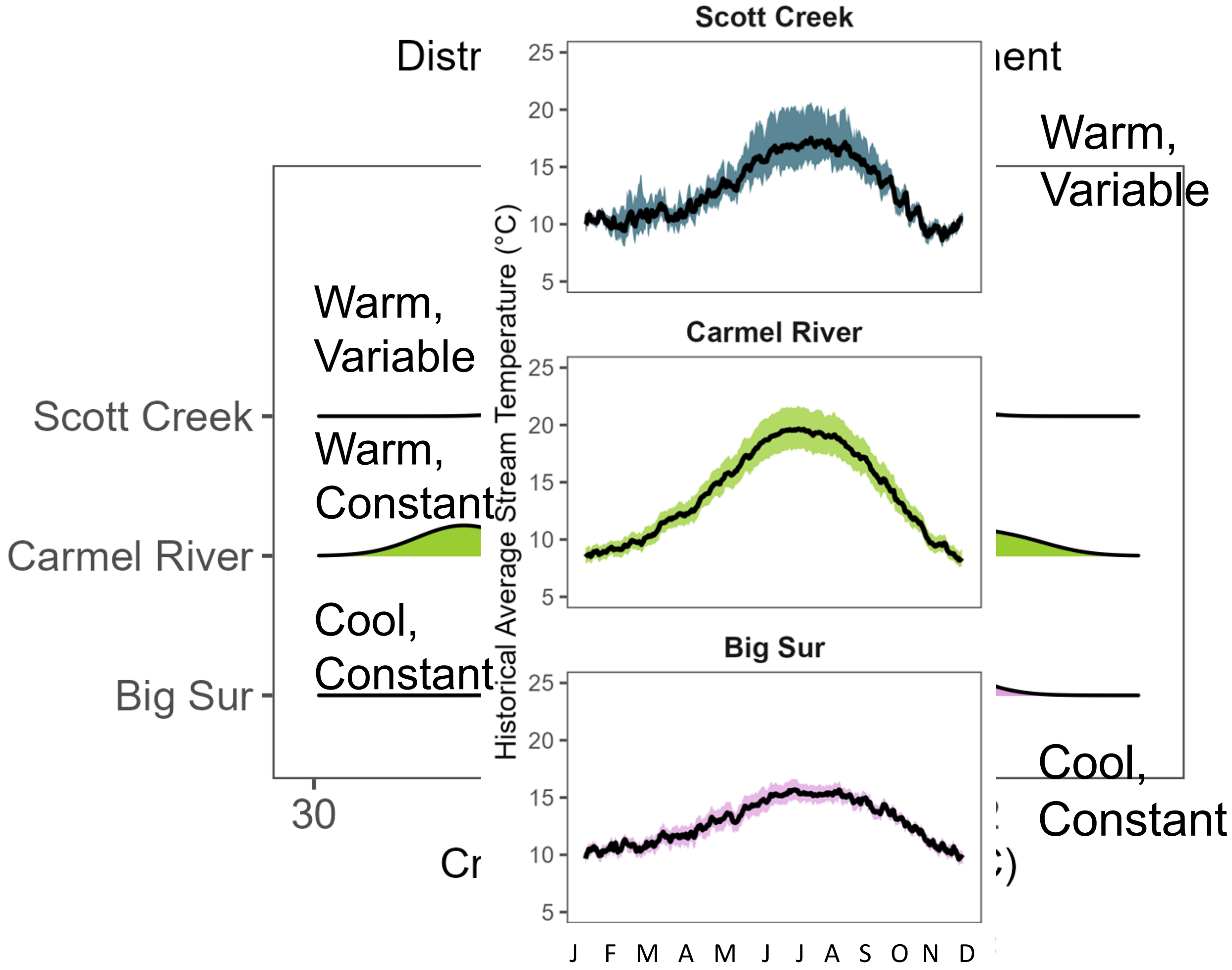

**Hypothesis:** Steelhead populations from warm streams can tolerate higher temperatures than those from cooler streams.



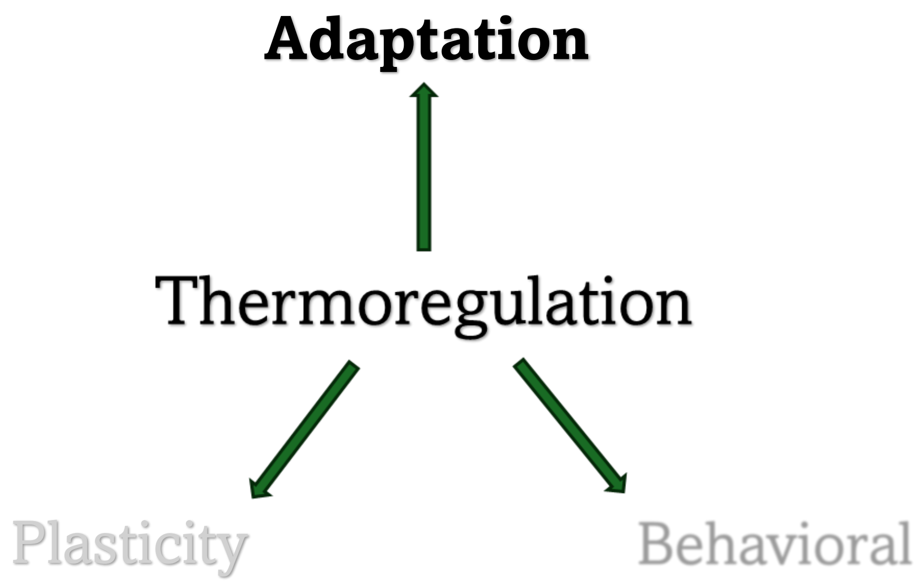

Angilletta, 2009

# Evidence for Inter- and Intrapopulation Variation



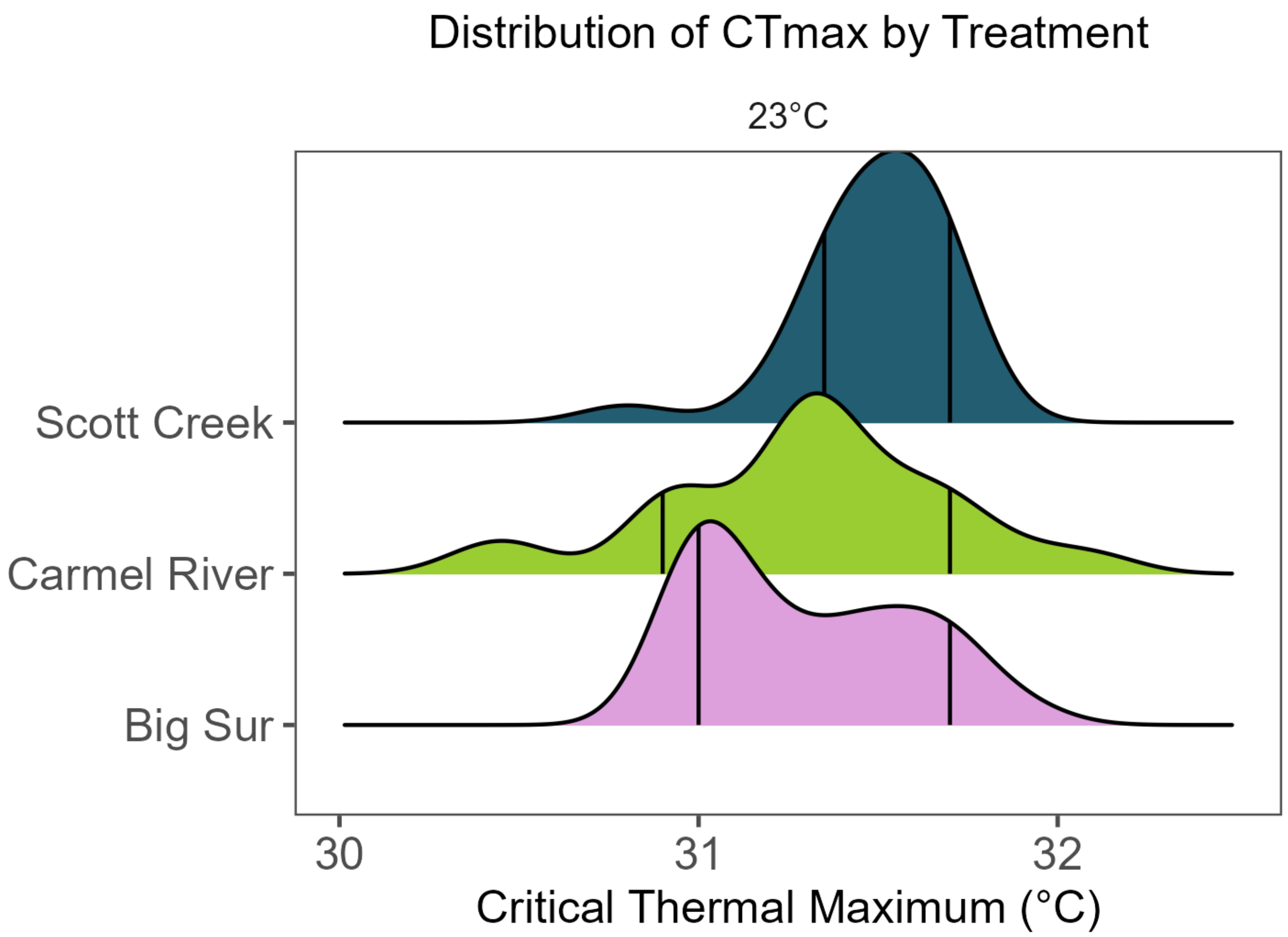
# Preliminary Results: Local Adaptation



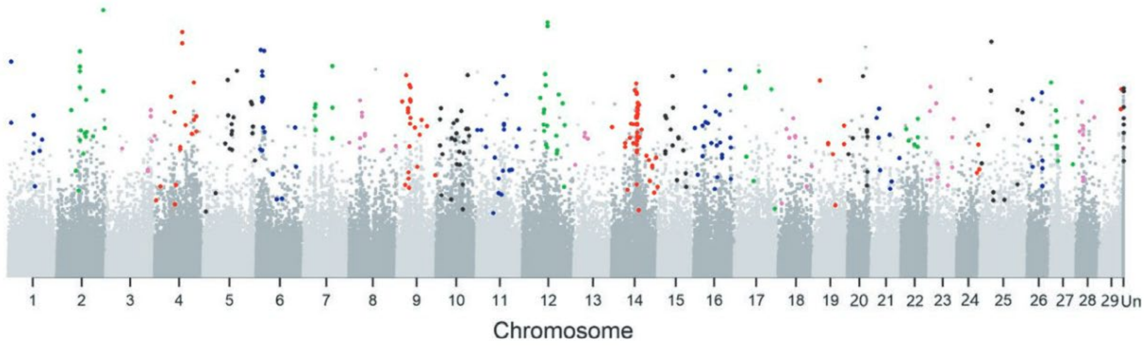

**Conclusion:**
Inter- and intrapopulation variability in thermal tolerance potentially suggests local adaptation to warming.

**Future Direction:**
Understanding plasticity as an adaptive trait and mechanism of persistence.

# Next steps:

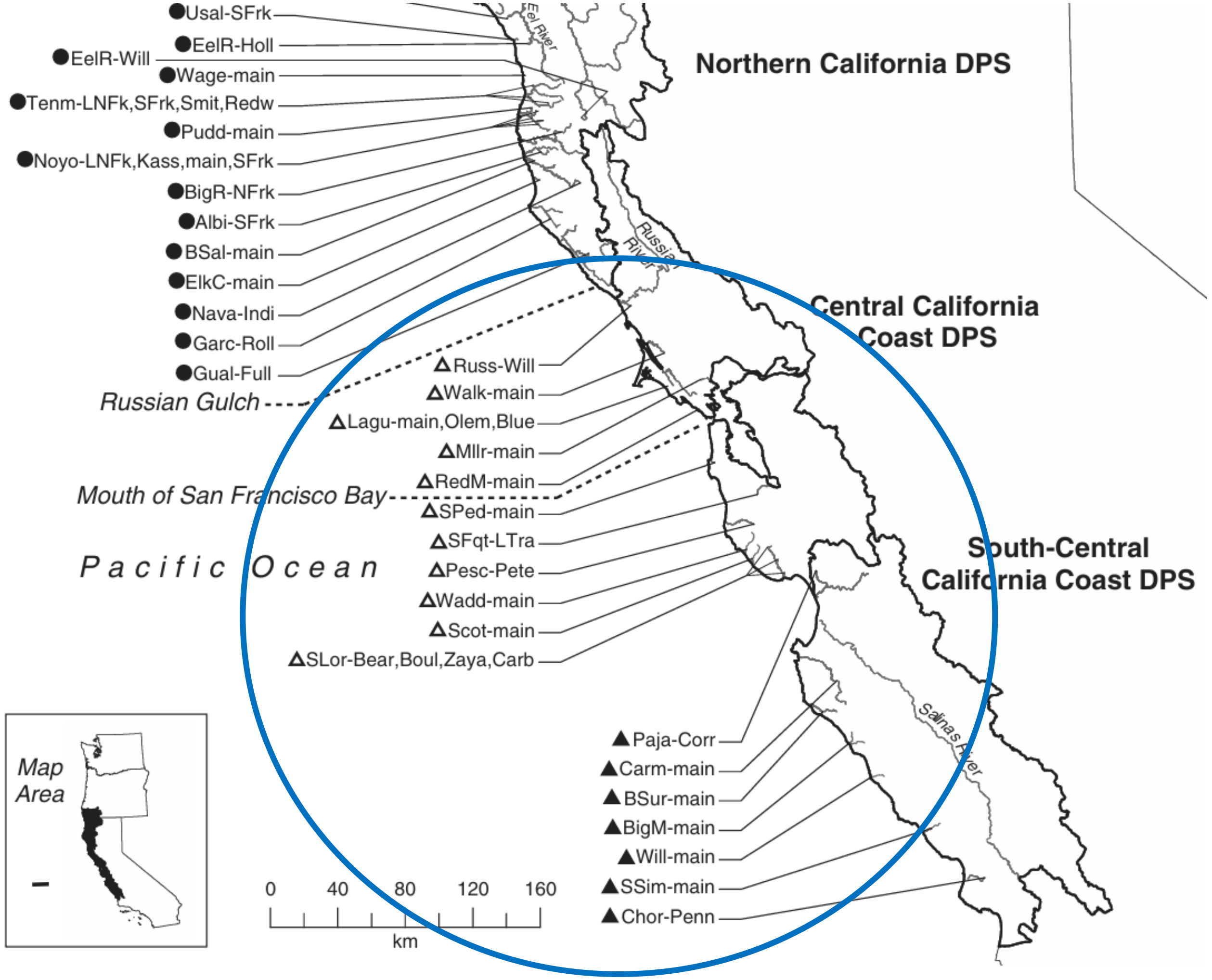



- Select individual candidates for genotyping:
  - Top 10% in thermal tolerance
  - Bottom 10% in thermal tolerance

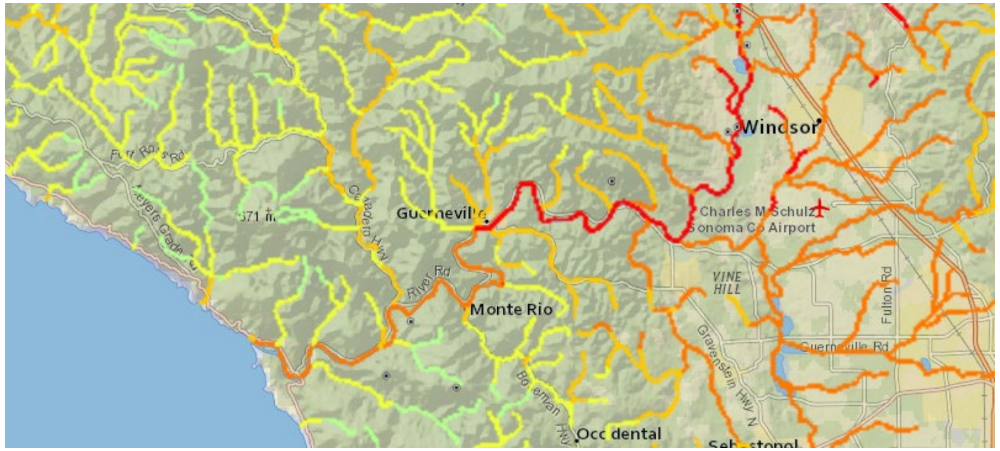



Chen et al., 2018

# Next Steps: developing a dataset that maximizes outcomes




- Select additional field sites that minimize natural genetic variation
  - Within genetic boundaries
  - Within watershed comparisons




NorWeST Stream Temperature Map - USFS RMRS

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# Research Applications and Policy Implications

**Research Outcomes:**

Provide tools for managers to test thermal vulnerability in steelhead populations in climate-risk watersheds.

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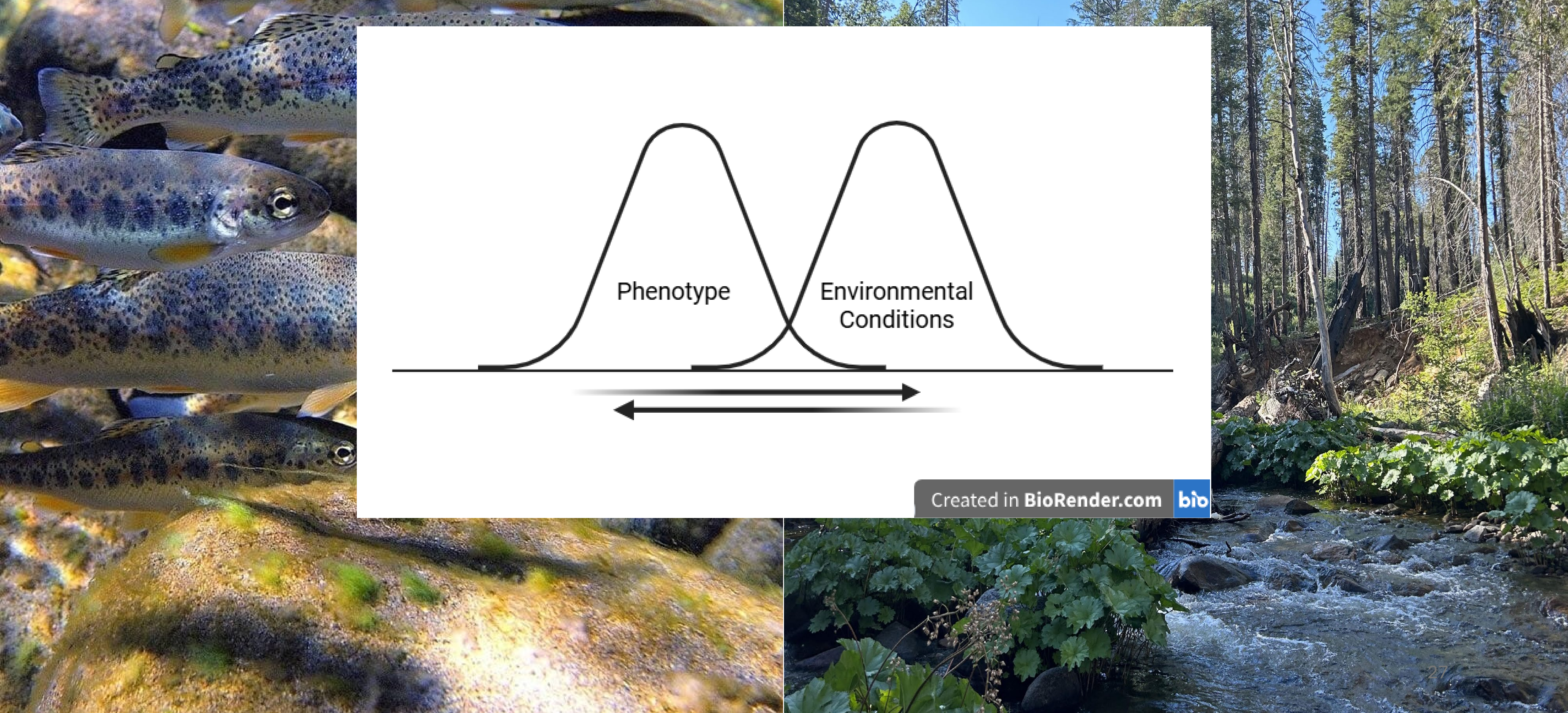
COASTAL SCIENCE AND POLICY

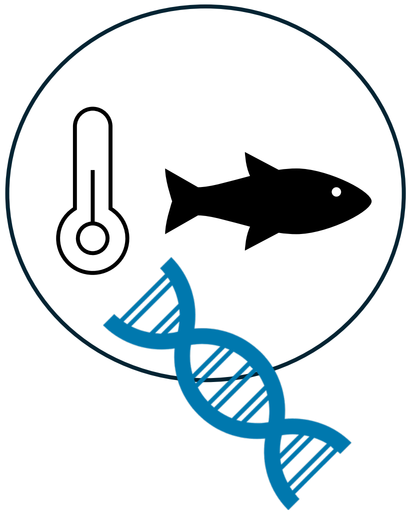
# Aligning Phenotype and Environment

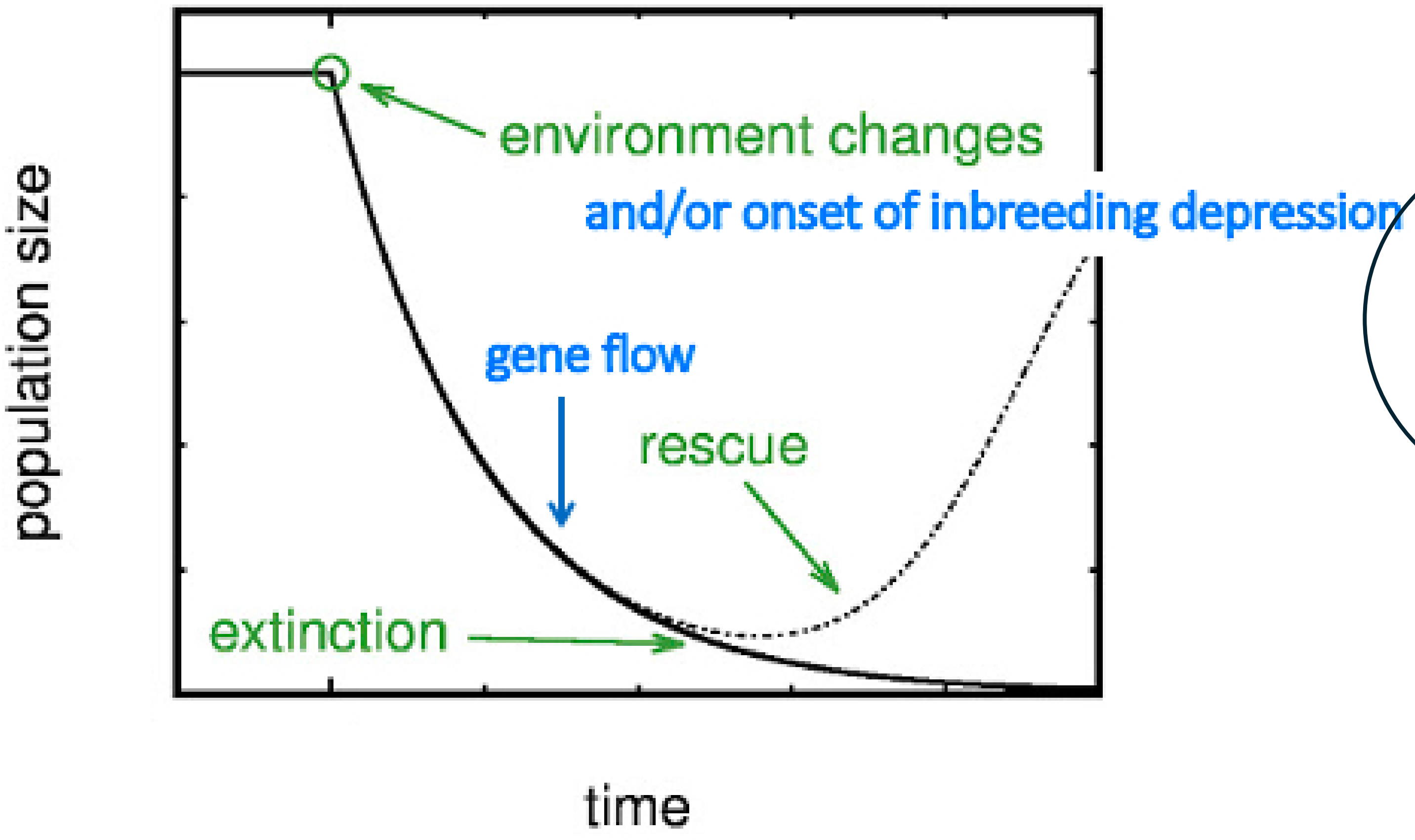


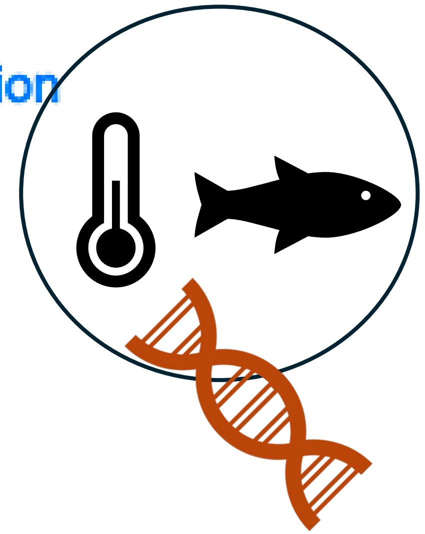
# Targeted Habitat Restoration

- Creating/preserving thermal refuges.
- Informing water management: Keeping water in rivers during the hottest times of the year.

# Example: Genetic Rescue





# Summary

1. Thermal tolerance is plastic, but plasticity has upper limits and may vary between populations.
2. $CT_{max}$ somewhat varies between populations, but within population variation is an important pathway for genetic understanding.
3. Developing tools for managers may provide a crucial pathway for Steelhead conservation.

# Acknowledgements

pogardne@ucsc.edu

**MPWMD**
Cory Hamilton
**Wonderful volunteers!**

UC SANTA CRUZ | Fisheries Collaborative Program
Center for Coastal Climate Resilience UC SANTA CRUZ
CAMINO

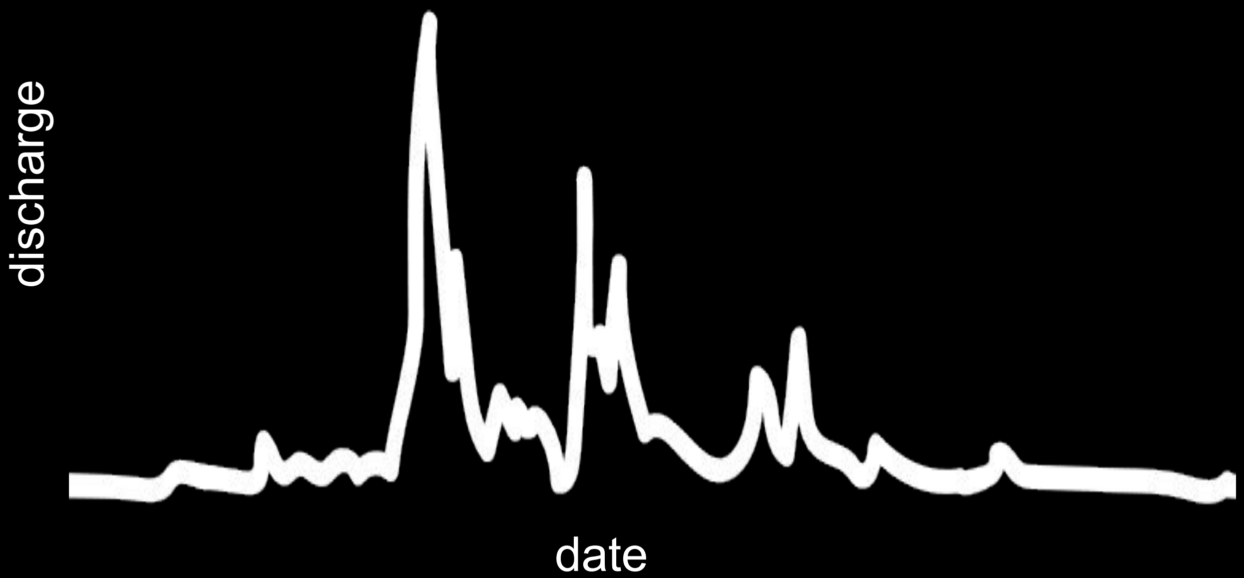
# Spawning distributions through space & time:

## Assessing resilience of an endangered salmon population in coastal California

**Rachael Ryan**, Rachel Johnson, Ted Grantham & Stephanie Carlson

Photo credit: Ramin Rahimian

# Climate change is driving hydrological volatility

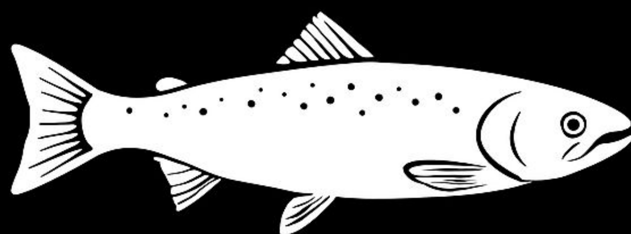




# Volatility adds to challenges facing imperiled salmon populations in highly altered watersheds


How has climate change impacted your watershed?

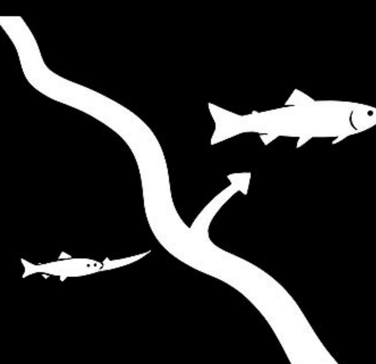
# Hope spots: Salmon use a diversity of strategies that promote resilience



Yearling holdovers

Floodplain users

Fry migrants

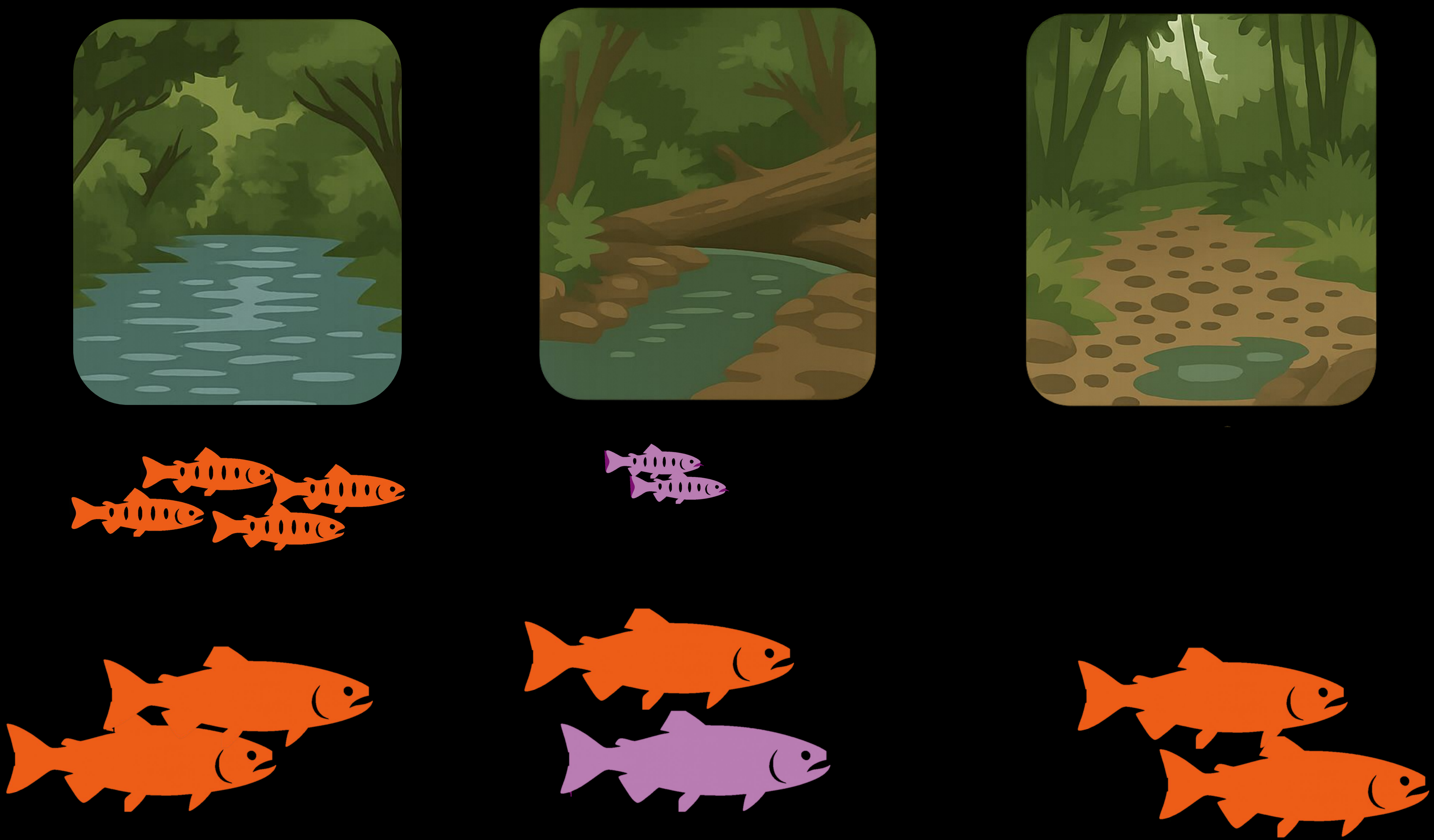


Non-natal rearing

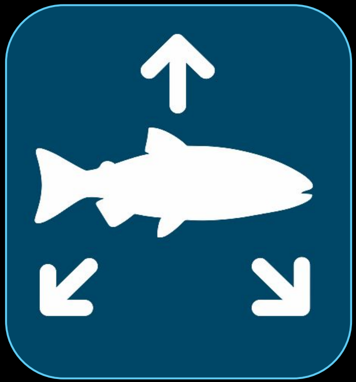
# Mosaic of habitats support diverse strategies that contribute to returning adult population

# Under certain climate conditions, some strategies have higher success

# Dispersal dynamics can support resilience to extreme climate events through recolonization



# Spawning a key life stage that lays the blueprint for the next generation



Recolonization of sink habitats

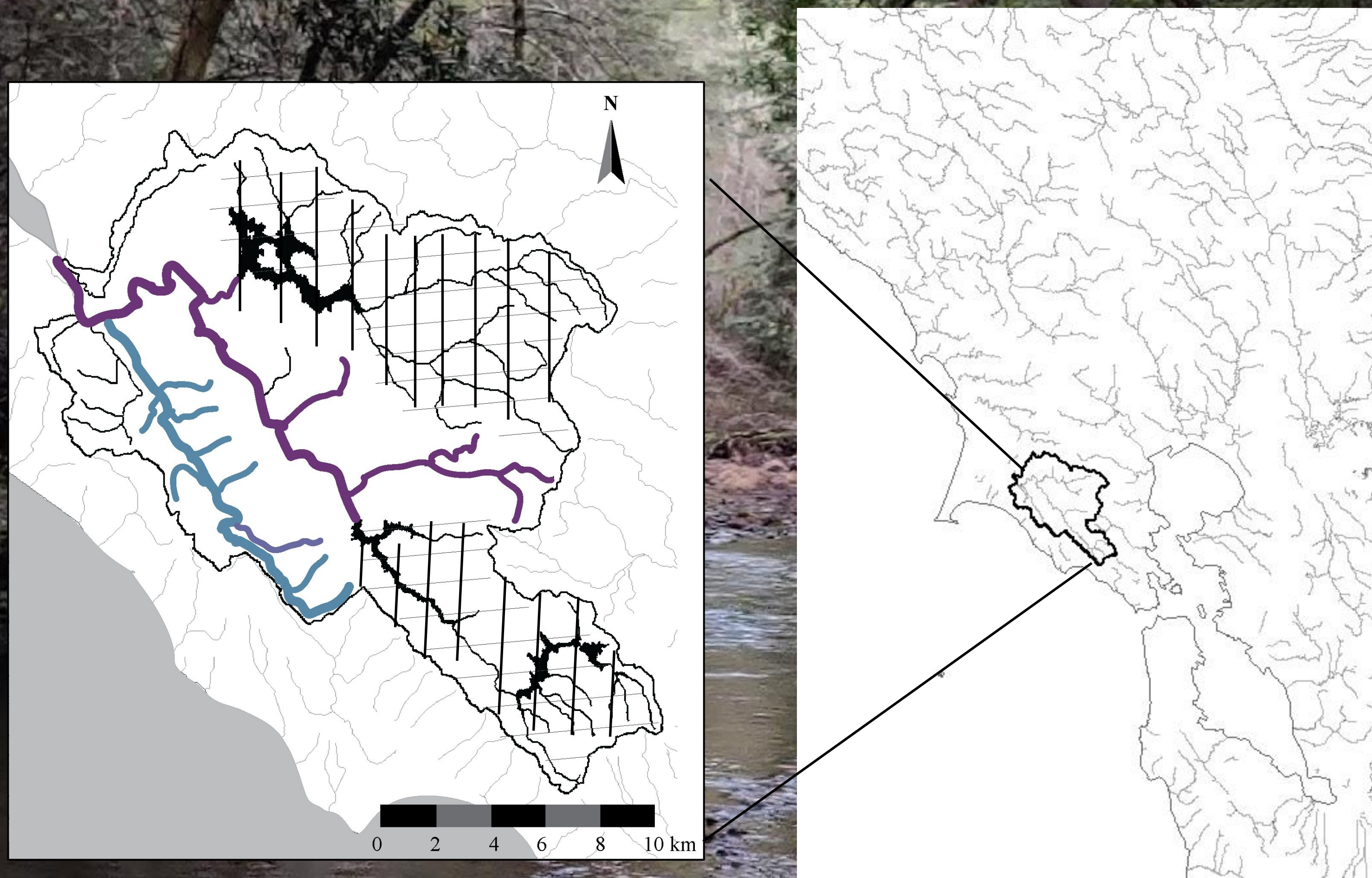
Juvenile habitat, growth and dispersal

Risk of redd scouring or dewatering

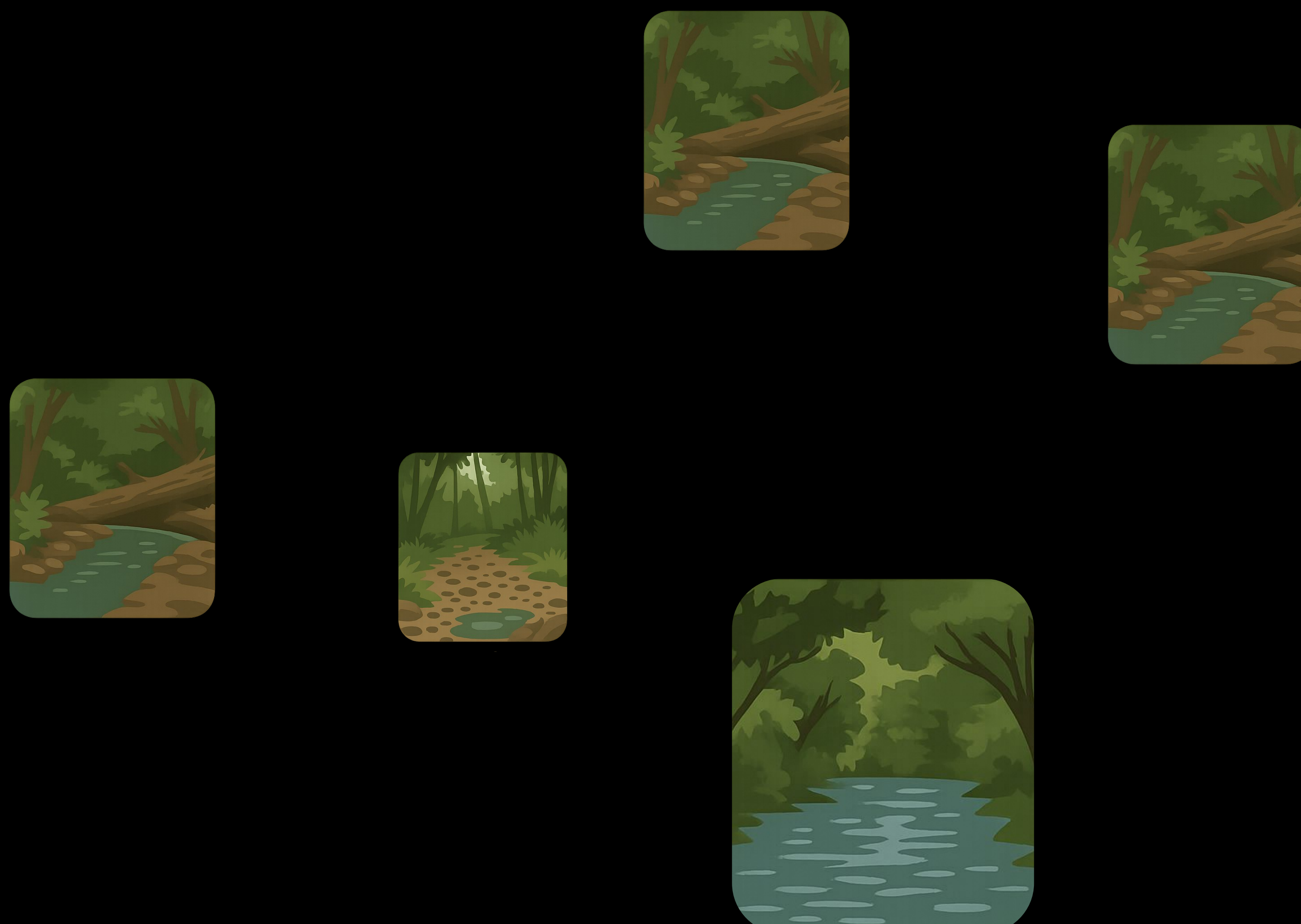
Timing of emergence

Dispersal opportunities

# Coho salmon population in Lagunitas Creek a stronghold for the endangered ESU

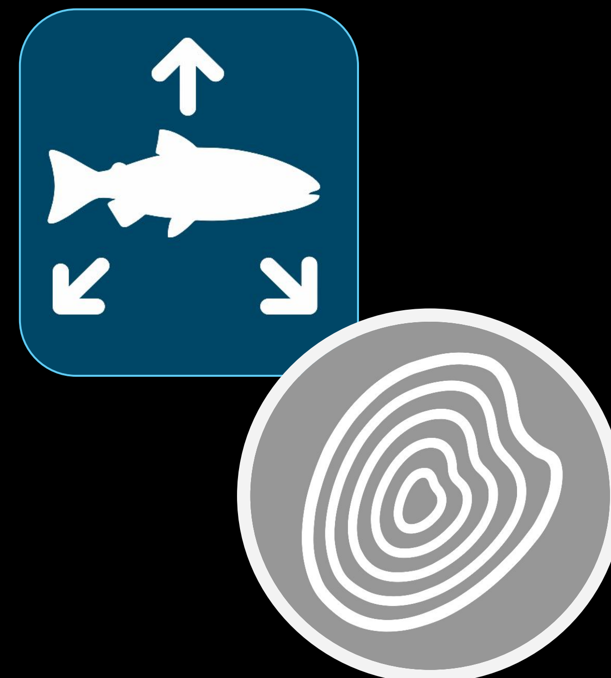


# Mosaic of habitats across the watershed persists, potential for trait variation



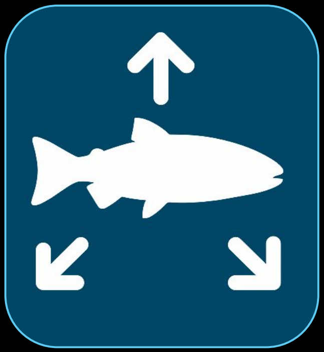
# Mosaic of habitats across the watershed persists, potential for trait variation

# Strong geologic heterogeneity enables exploration of spawner dispersal



# Variation in stream size and flow regulation enables spawning phenology comparison

# Understanding spawning distributions across time and hydrological conditions to assess resilience



Natal origin & spawner location

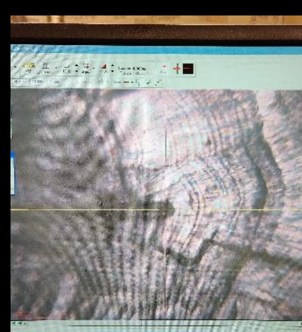
2010-2019

Onset of spawning, peak spawning

2005-2022

# It takes a collaborative effort and suite of tools to uncover spawner dispersal and timing

NATIONAL PARK SERVICE

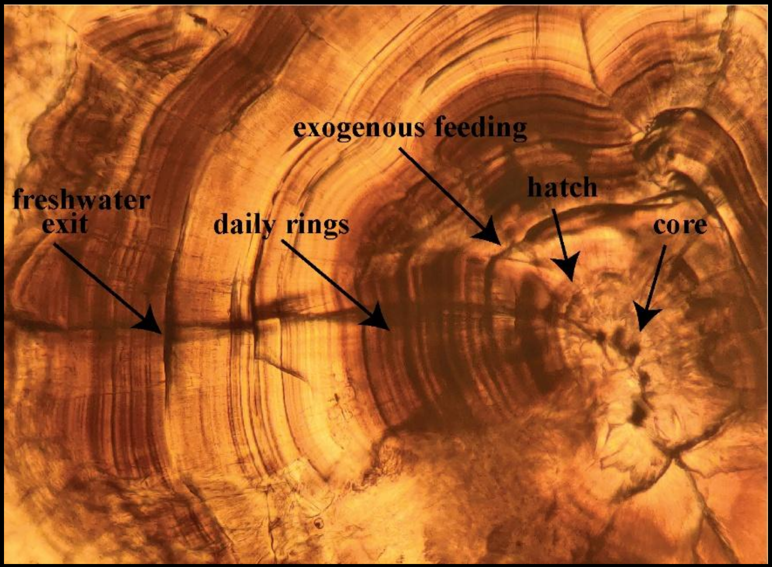


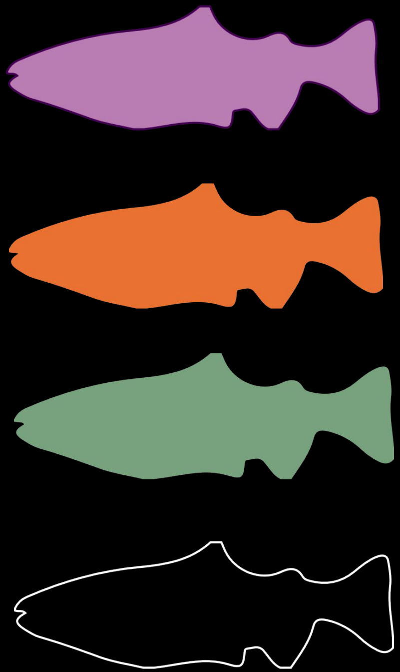
Sea Grant California

THE UNIVERSITY OF CALIFORNIA BERKELEY

THE UNIVERSITY OF CALIFORNIA DAVIS

# Natal origin of spawners can reveal key habitats, dispersal dynamics



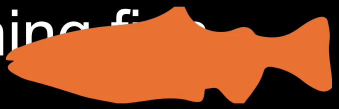
streams have a chemical “fingerprint”

fish incorporate the fingerprint into their otoliths (ear stones)

can assign fish origin, compare to where they returned to

# Lagunitas Creek is the major source population for the watershed

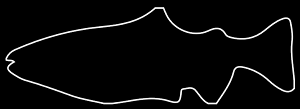
63% otoliths recovered in Lagunitas basin, 70% of returning fi



In all years (except 2019)

made up 10-57% redds in Olema basin

< 4% fish from out of watershed



# Intermittent streams play out outsized role in successful adults in some years

*Return year 2012-2013*

Intermittent stream = 23% of redds in Olema basin (2010), made up 60% of returns in Olema basin

# Intermittent streams contribute to successful adults even in drought

*Return year 2017-2018*

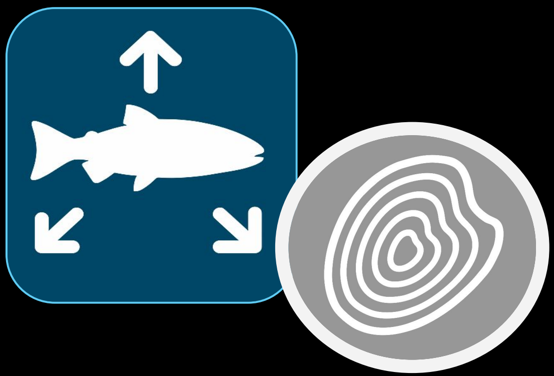
Intermittent stream = 50% of redds in Olema basin (2015), made up 50% of 3-year old returns in Olema basin

# Diversity of habitats, age structure, important for metapopulation recovery following drought

“jacks” only spent 1 year in the ocean

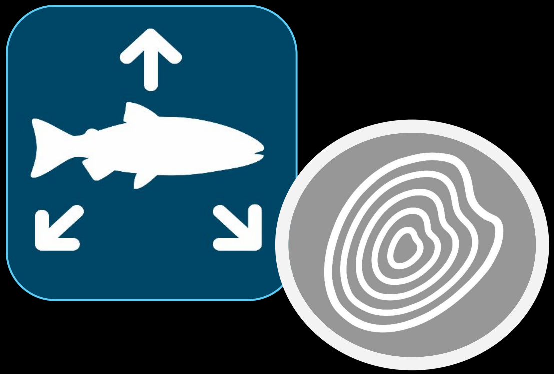
*Return year 2014-2015*

# Dispersal between habitats key to reactivating habitat mosaic after drought



Diverse habitats & dispersal contributing to resilience

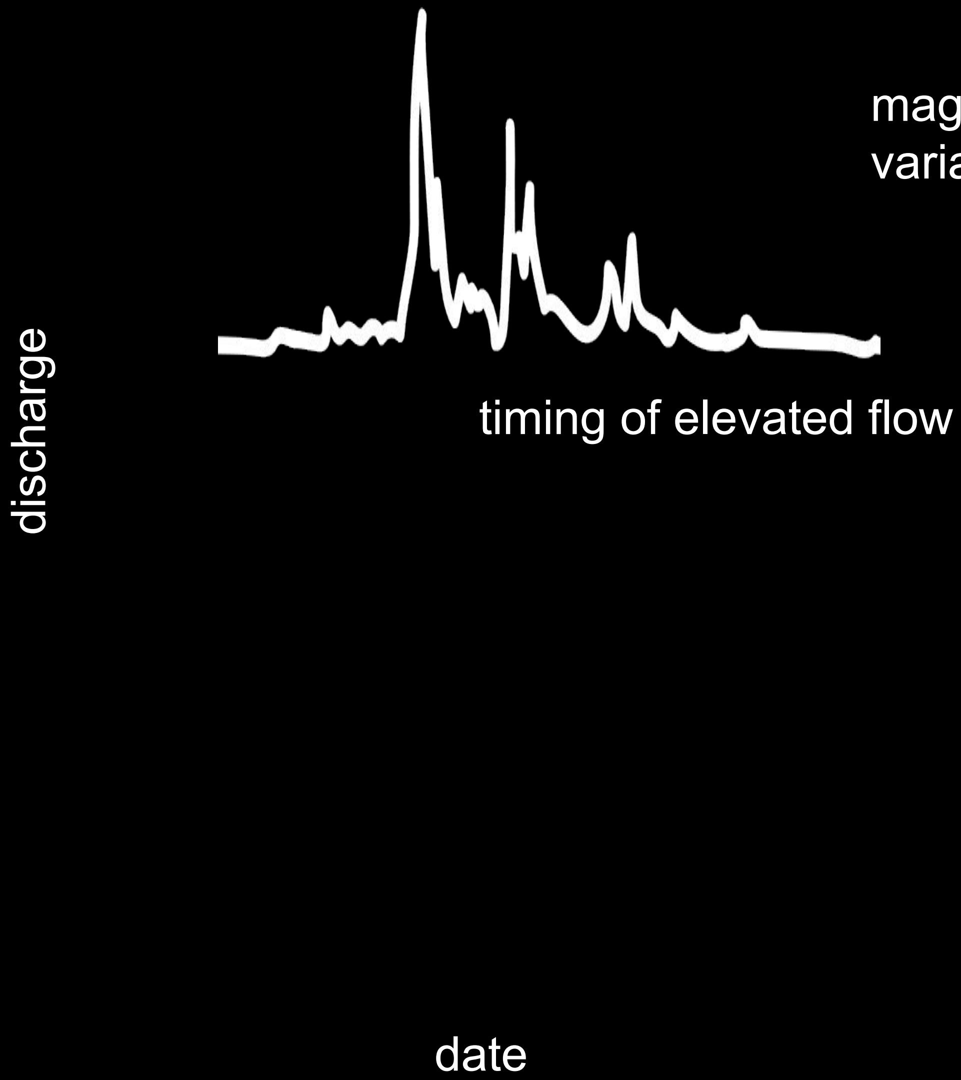
# Otoliths as a tool reveal contributions of key habitats to returns and recolonization



Diverse habitats & dispersal contributing to resilience

Tool for *uncovering* resilience

# Spawn timing driven by hydrological cues from winter precipitation



# Flow regulation can decouple flow from precipitation in dry years

magnitude of flow
variability of flow

timing of elevated flow

discharge

increased magnitude
decreased variability

earlier
timing

date

# Flow regulation can decouple flow from precipitation in dry years

discharge

date

# Variation in flow regulation may lead to differences in drivers of timing

Differences in onset

Differences in peak

Onset day

Peak spawn day

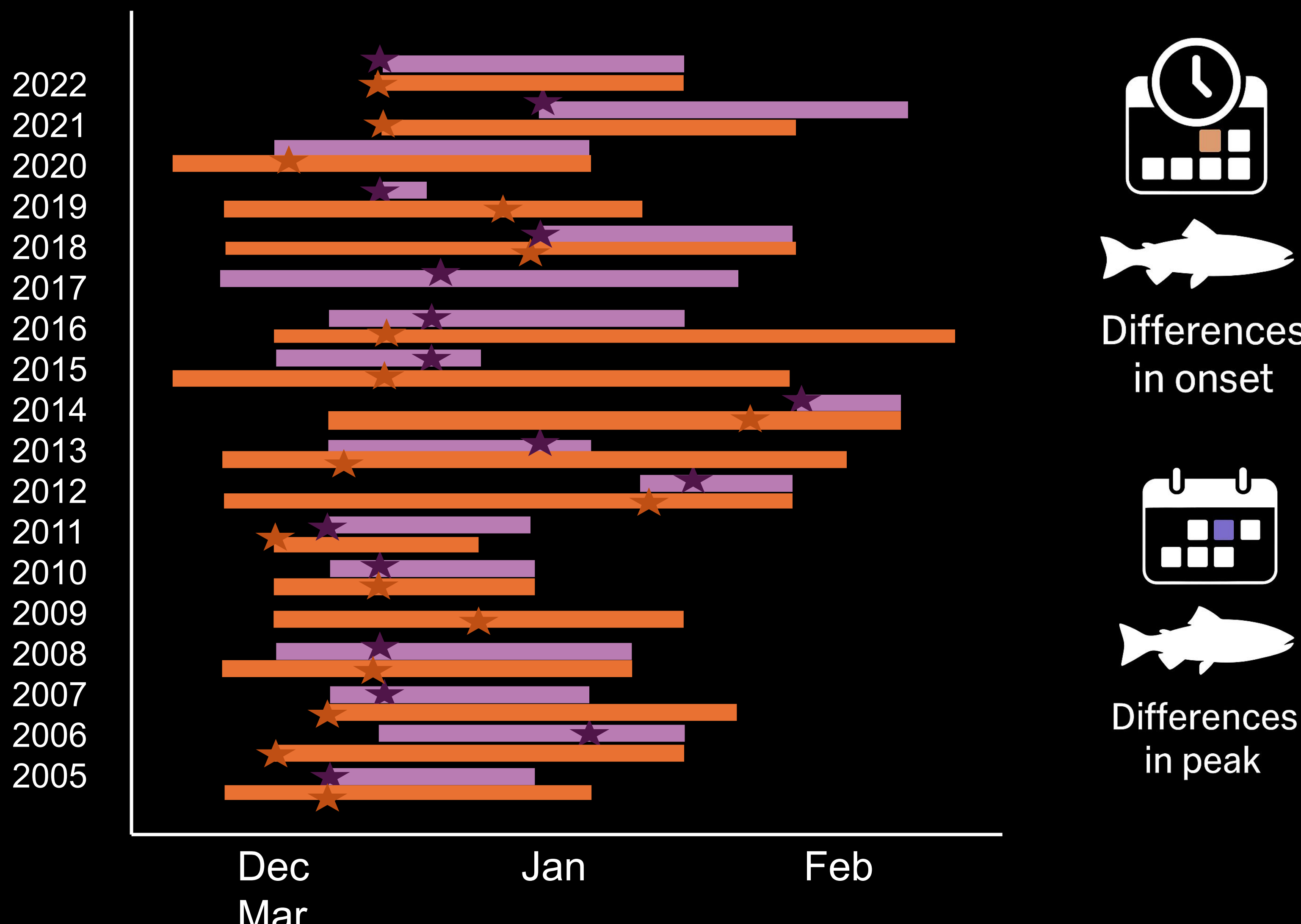
Wet season start

Flow variability

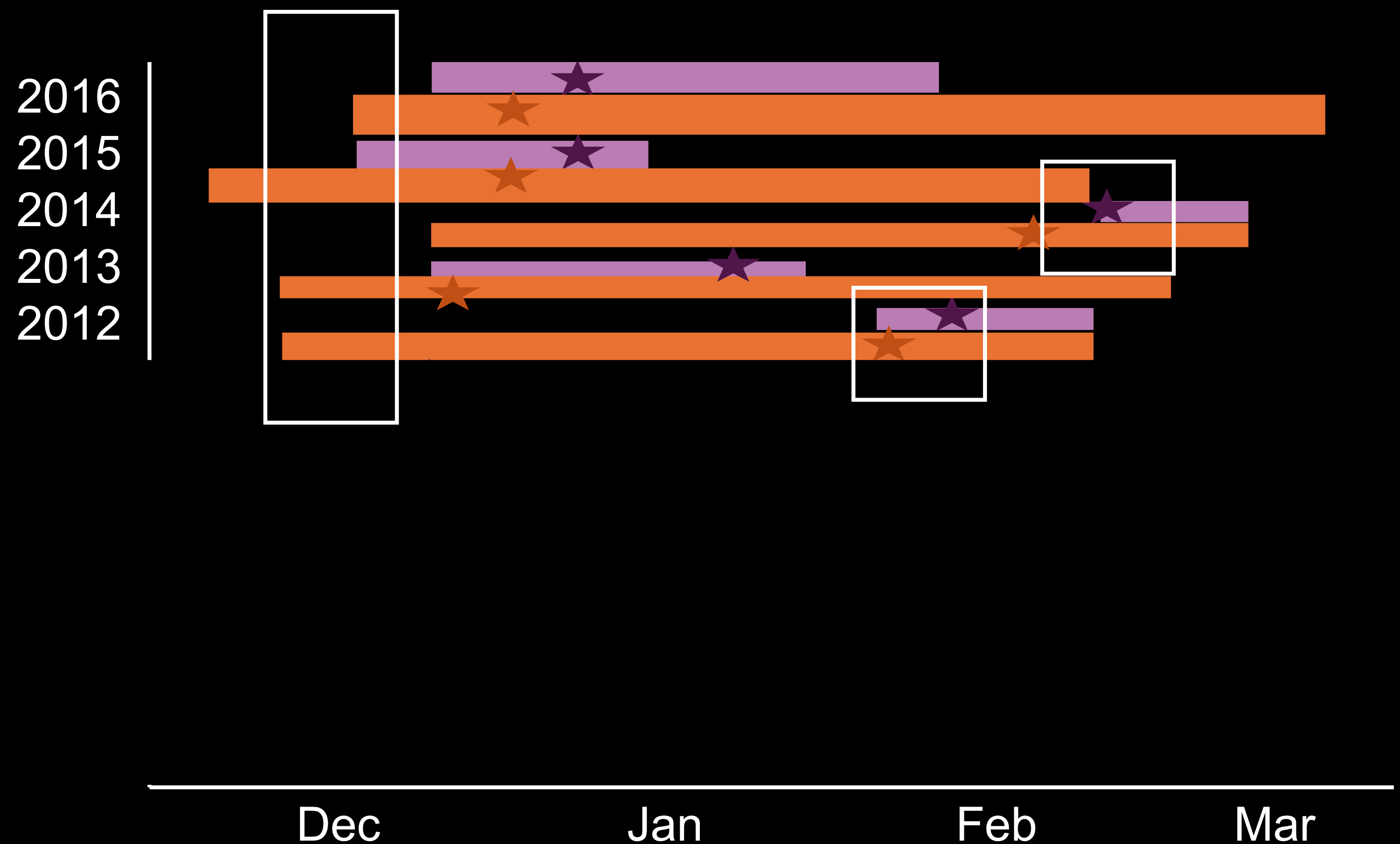
Day of peak flow

Magnitude

# Onset of spawning is earlier in mainstem, peak spawning conserved



# During drought, onset of spawning very delayed in unregulated tributary



# Flow variability, wet season timing drive differences in onset of timing

Onset day

Wet season start

Flow variability

Median flow

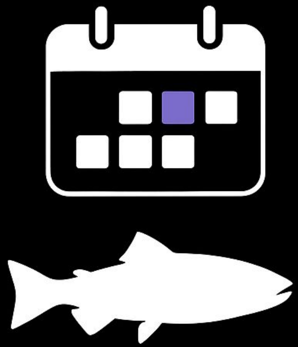
Differences in onset

# Peak spawning driven by large precipitation events across the watershed

Peak spawn day

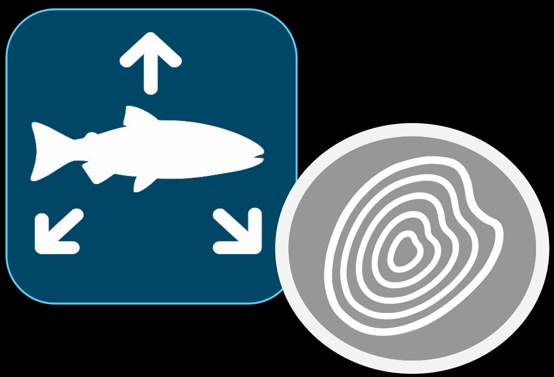
Day of peak flow

Magnitude



Differences in peak

# Variation in flow cues drives some phenological diversity in spawning, especially in drought

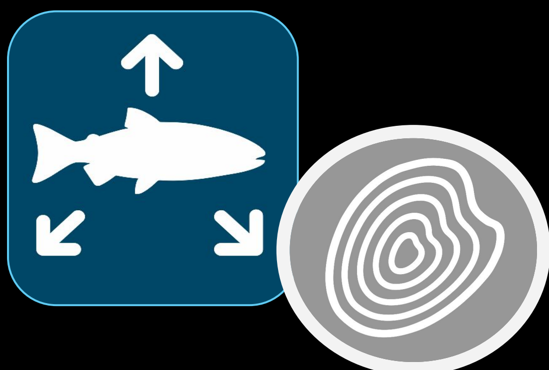


Diverse habitats & dispersal contributing to resilience

Tool for *uncovering* resilience

Phenological diversity contributing to resilience

# Environmental flows as a *possible* tool to buffer impacts of drought



Diverse habitats & dispersal contributing to resilience

Tool for *uncovering* resilience

Phenological diversity contributing to resilience

Tool for *enhancing* resilience

Connected mosaic of habitats provides resilience in endangered population

We can leverage tools to read salmon stories & buffer climate volatility

# A collaborative effort!

Stephanie Carlson, Ted Grantham, Albert Ruhi & Berkeley Freshwater Lab!

**Mentors, Collaborators, Research Assistants** – Rachel Johnson & Johnson Lab, Eric Ettlinger & Marin Water, Michael Reichmuth, Brentley McNeill & NPS staff, Justin Glessner, Alie Smith, Noor Harwell, Elena Campell, Emily Chen

**Funders -** Point Reyes National Seashore Association Grant, ESPM Continuing Fellowships & Awards, California Sea Grant Graduate Research Fellowship

# A Model-Based Investigation Of Early Marine Growth And Survival For California Chinook Salmon

Authors: **K. Vasbinder**, J. Fiechter, J. Santora, N. Mantua, S. Lindley, D. Huff, and B. Wells

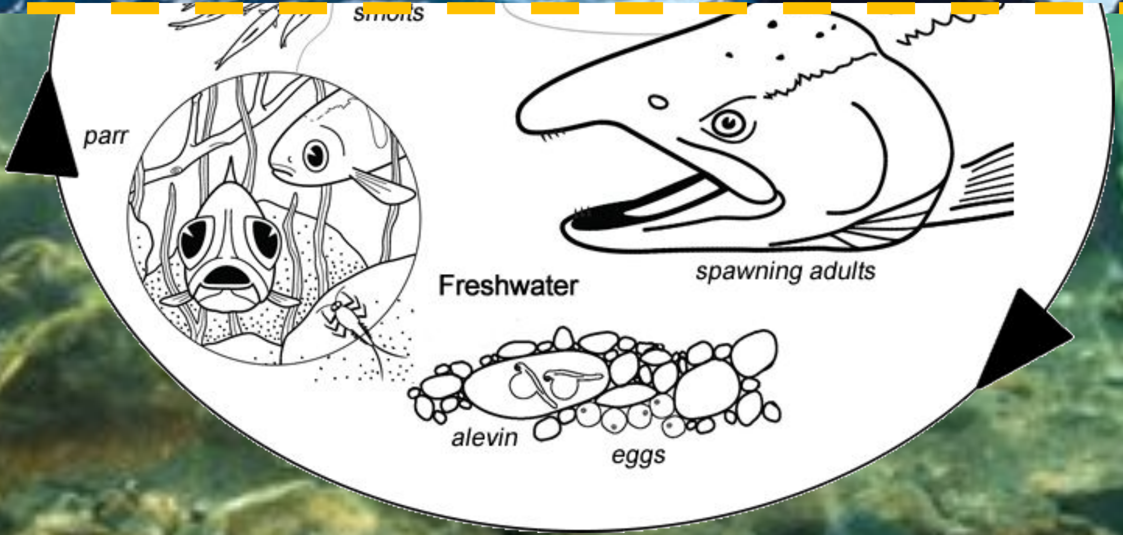
University of California Santa Cruz, SWFSC Fisheries Ecology Division, NWFSC Fish Ecology Division

UC SANTA CRUZ

Funding: NOAA SWFSC Santa Cruz CIMEC award 22694-443861-BICVEP (Central Valley Salmon)

# Lifecycle of Chinook Salmon

Ocean



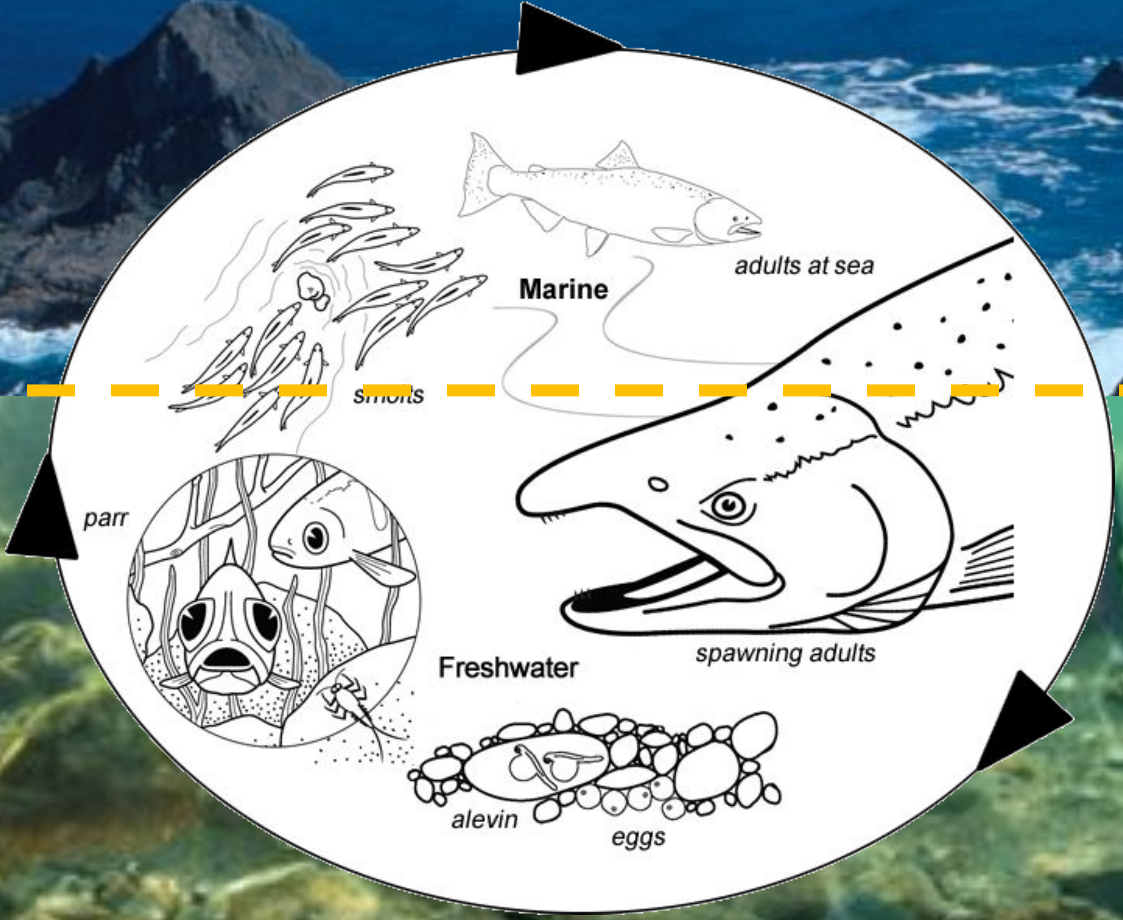

Freshwater
and Estuaries

Life Cycle Image Credit: US Fish and Wildlife Service

# Lifecycle of Chinook Salmon

Ocean

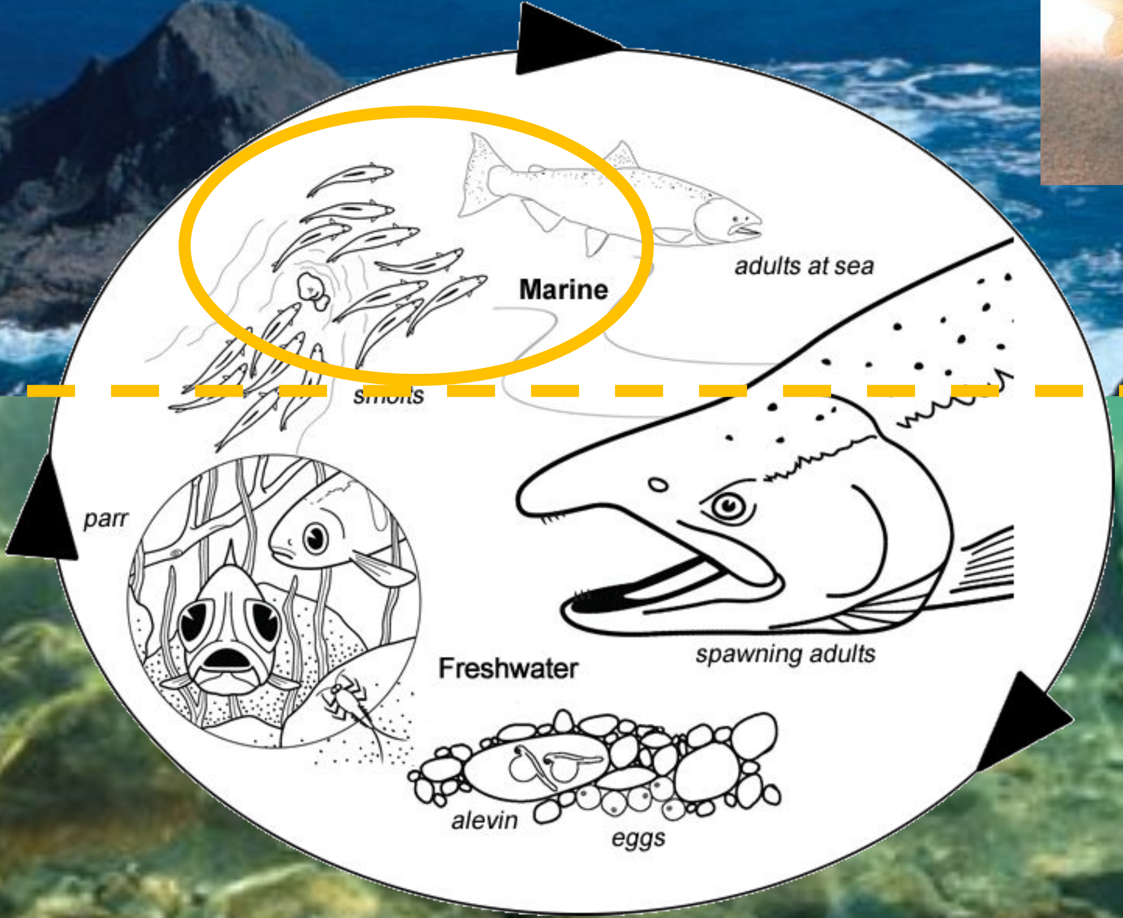
Freshwater
and Estuaries




Life Cycle Image Credit: US Fish and Wildlife Service

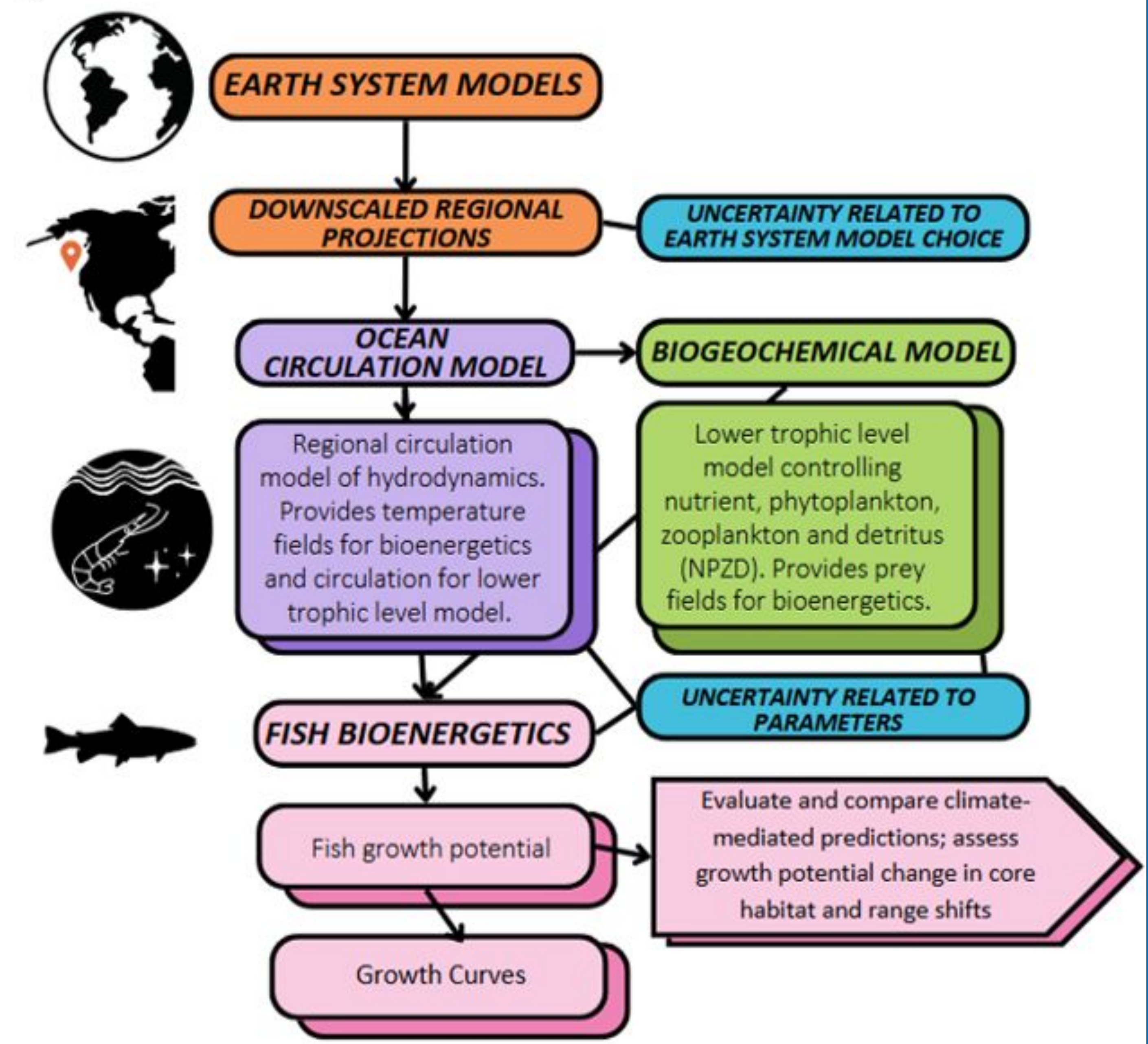
# Lifecycle of Chinook Salmon

Ocean



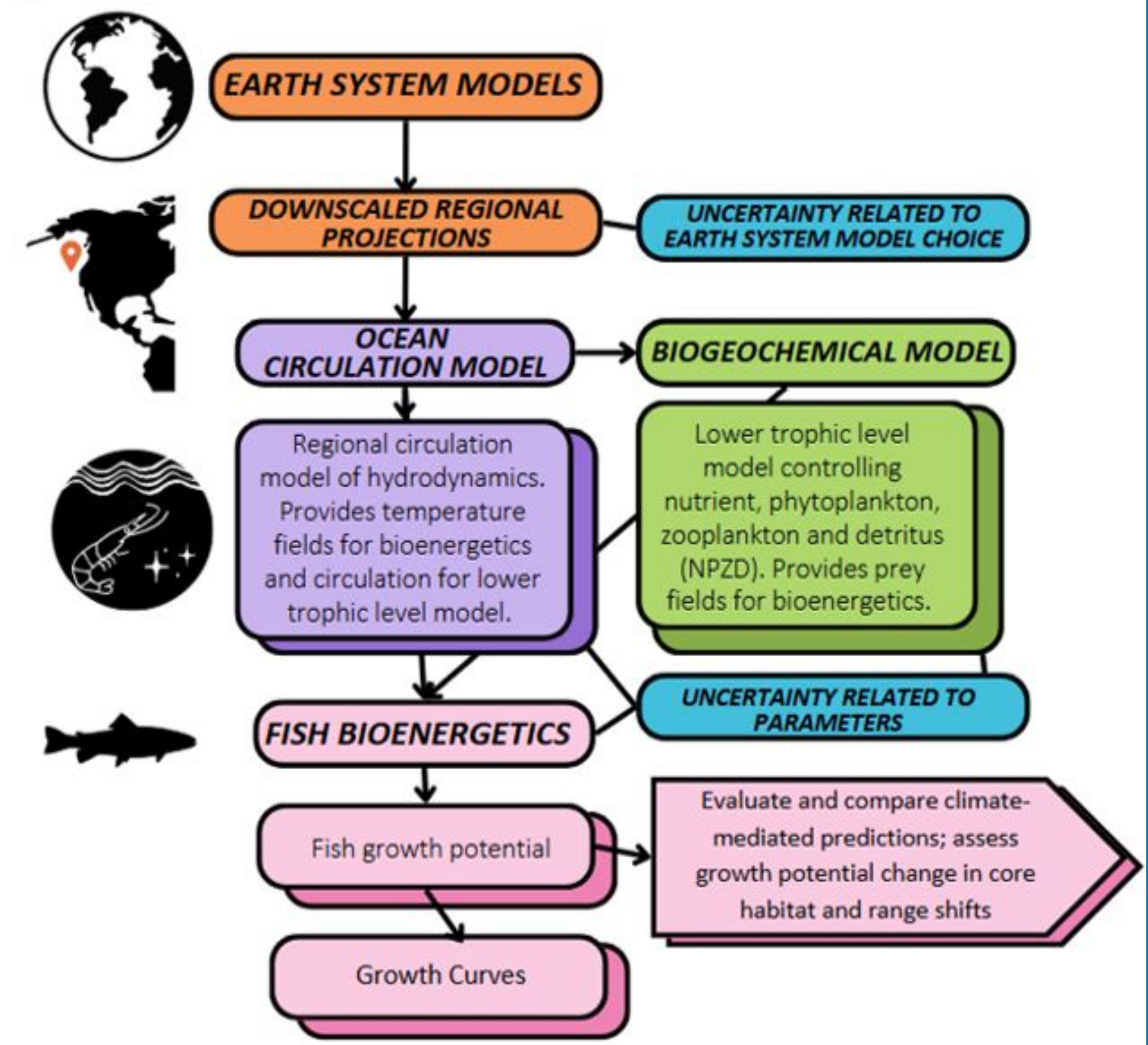

Freshwater
and Estuaries

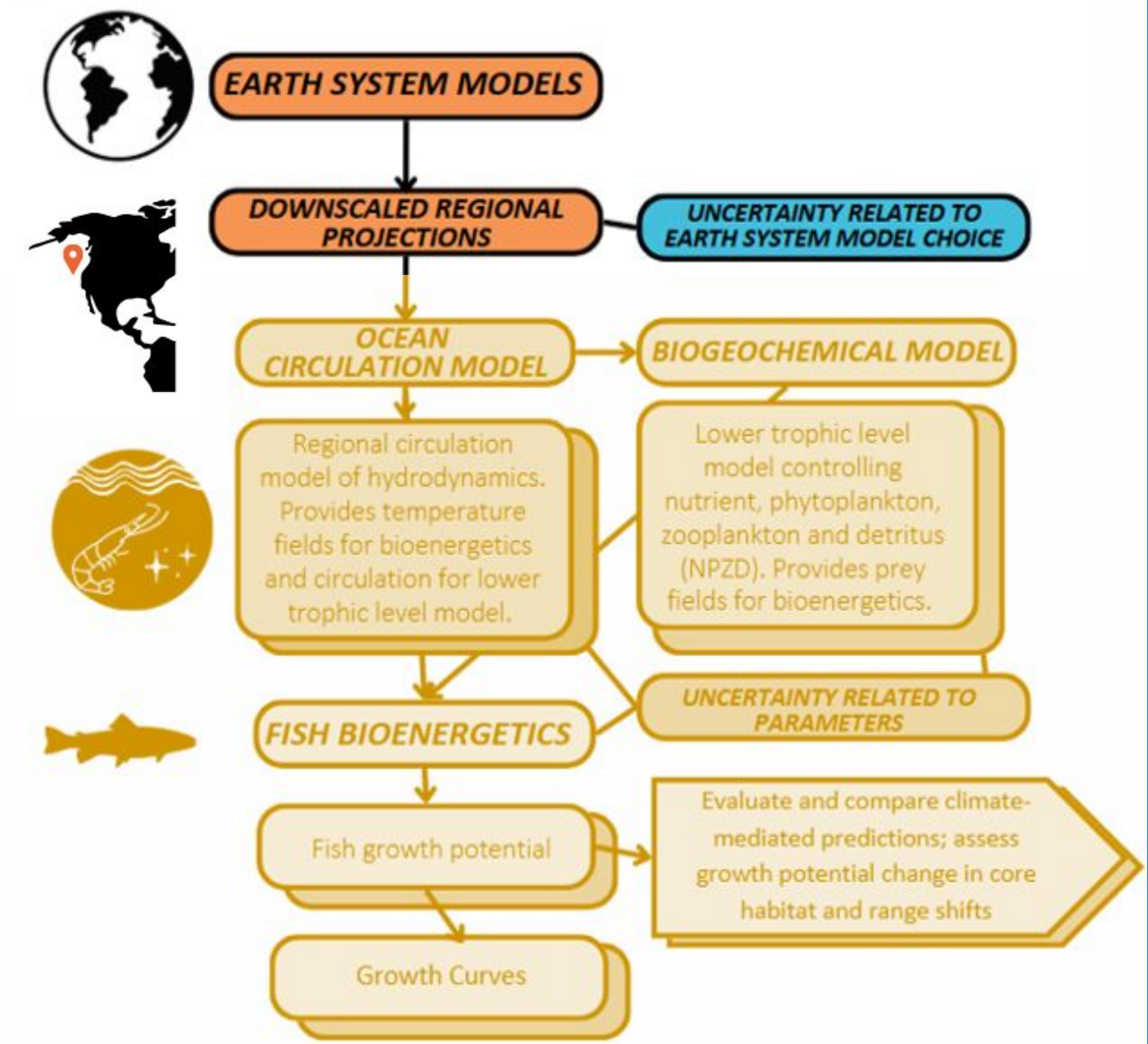
Life Cycle Image Credit: US Fish and Wildlife Service

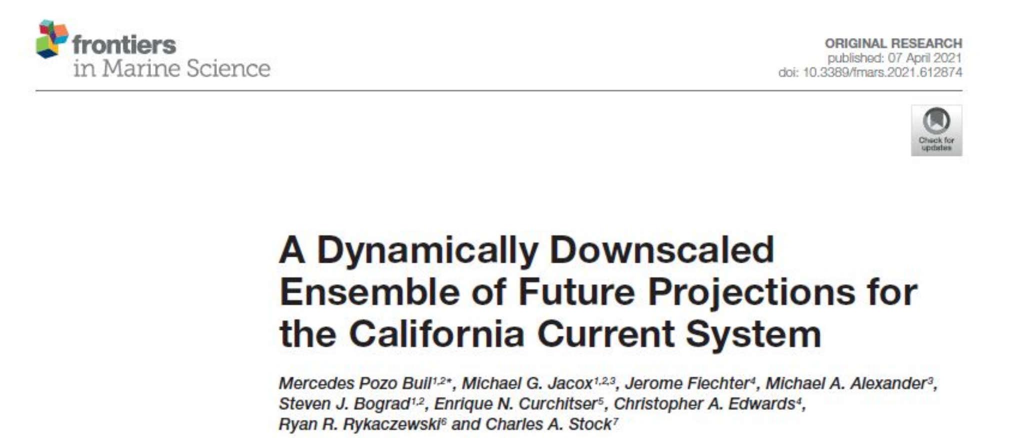



# How will this system react to changes in climate?

# Collaborative Modeling Framework







frontiers in Marine Science
ORIGINAL RESEARCH
published: 07 April 2021
doi: 10.3389/fmars.2021.612874

A Dynamically Downscaled Ensemble of Future Projections for the California Current System

Mercedes Pozo Buil[1,2]*, Michael G. Jacox[1,2,3], Jerome Fiechter[4], Michael A. Alexander[3], Steven J. Bograd[1,2], Enrique N. Curchitser[5], Christopher A. Edwards[4], Ryan R. Rykaczewski[6] and Charles A. Stock[7]

We chose earth system models (ESMs) to show spread for temperature and primary production under the RCP8.5 high emissions scenario (Pozo-Buil et al. 2021).

**HADL** = high warming rate

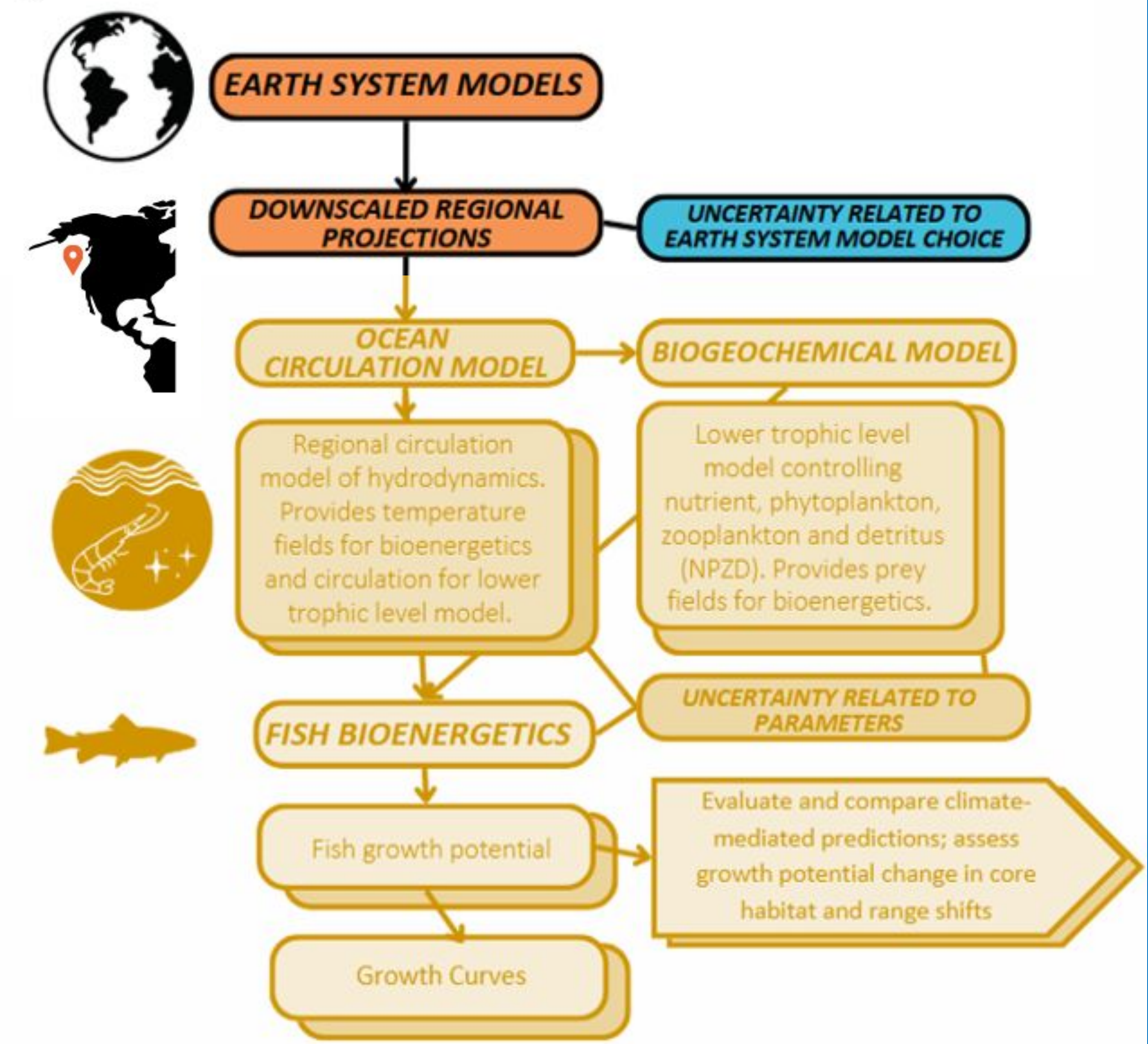
**IPSL** = moderate warming rate

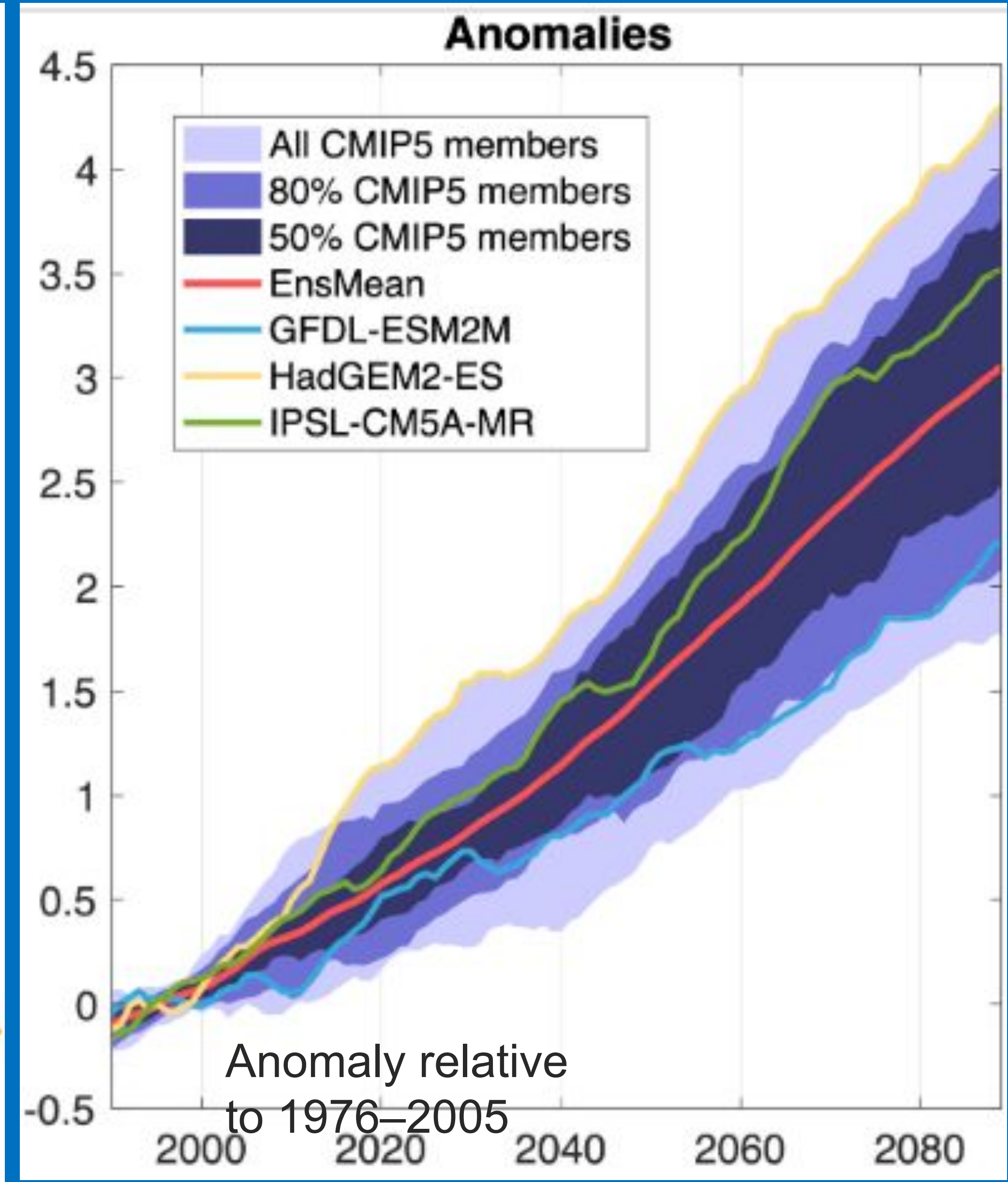
**GFDL** = low warming rate

We assess the impacts of RCP8.5 over the course of a century by creating an ensemble of the driving variables from the ESMs.



Pozo Buil et al. 2021. Frontiers in Marine Science

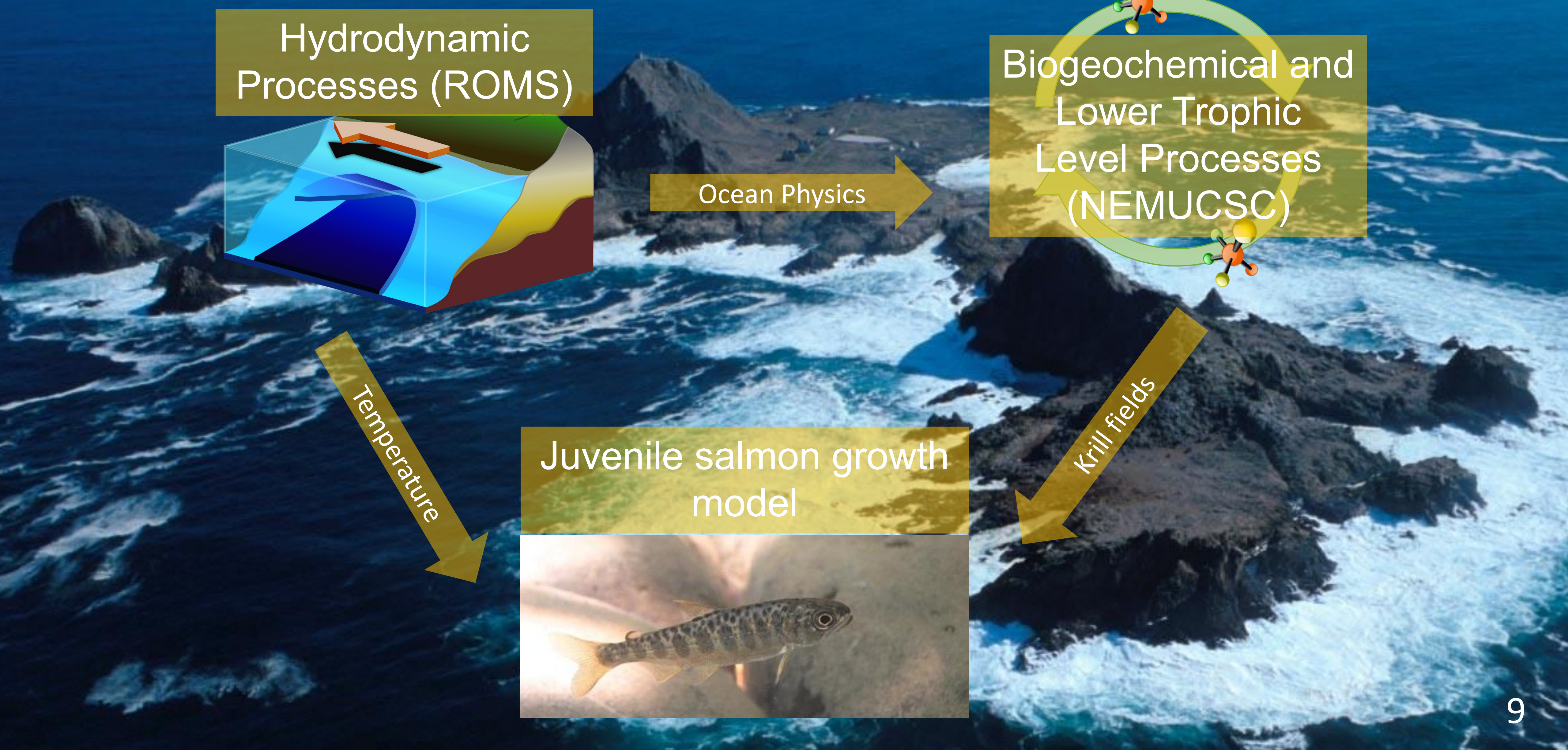


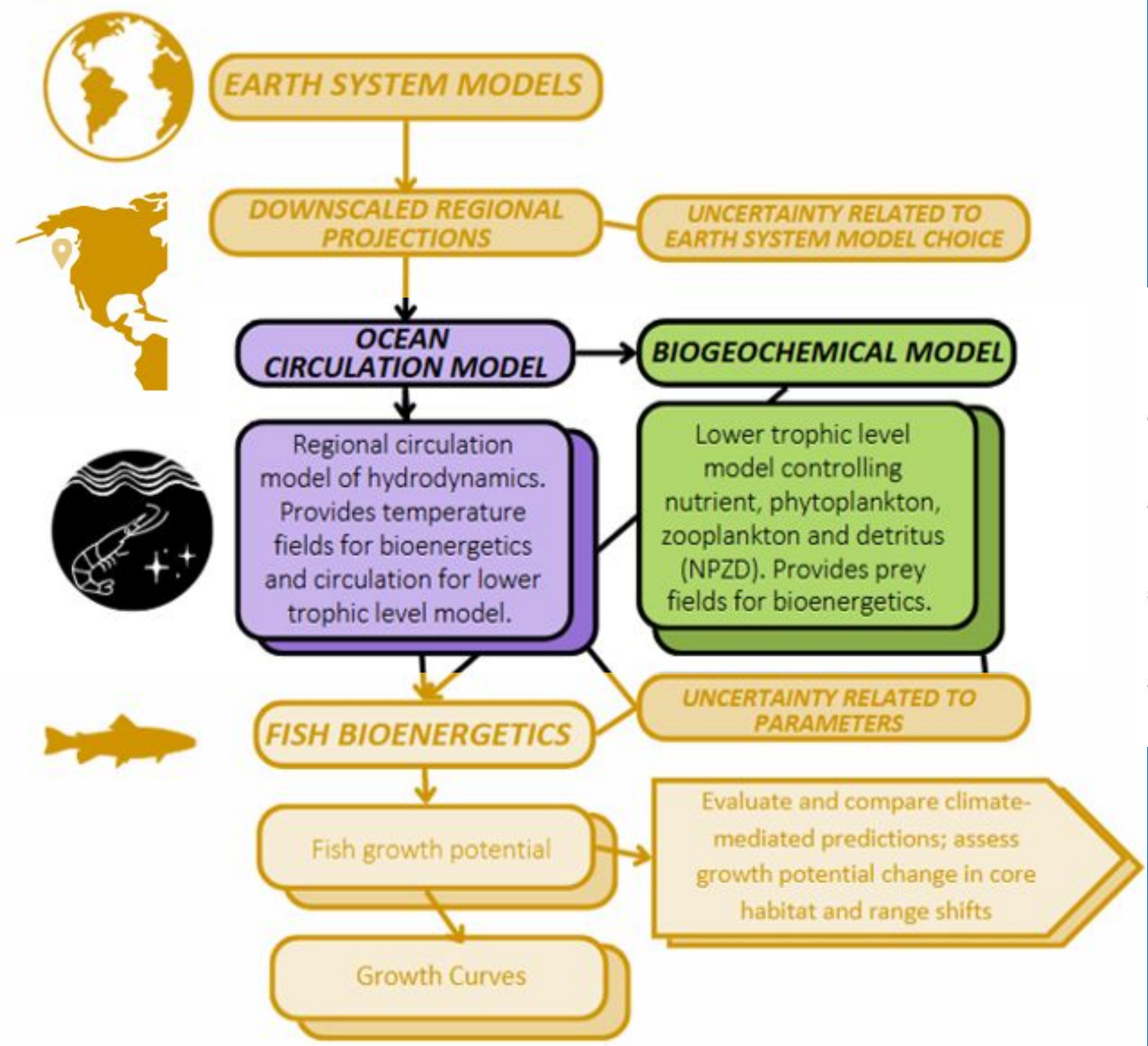



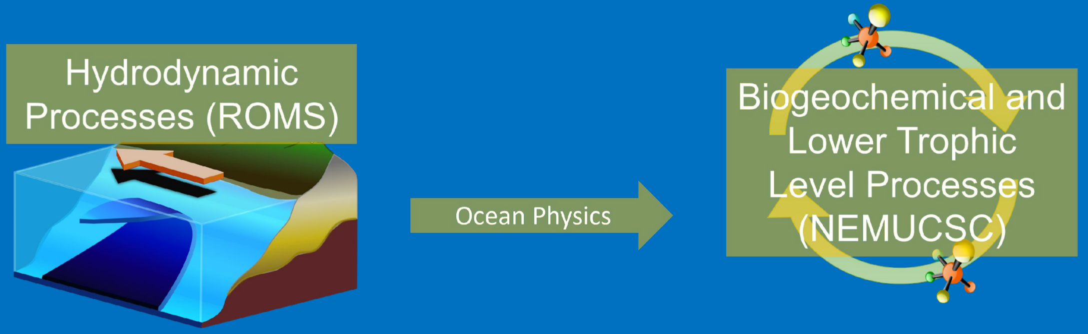


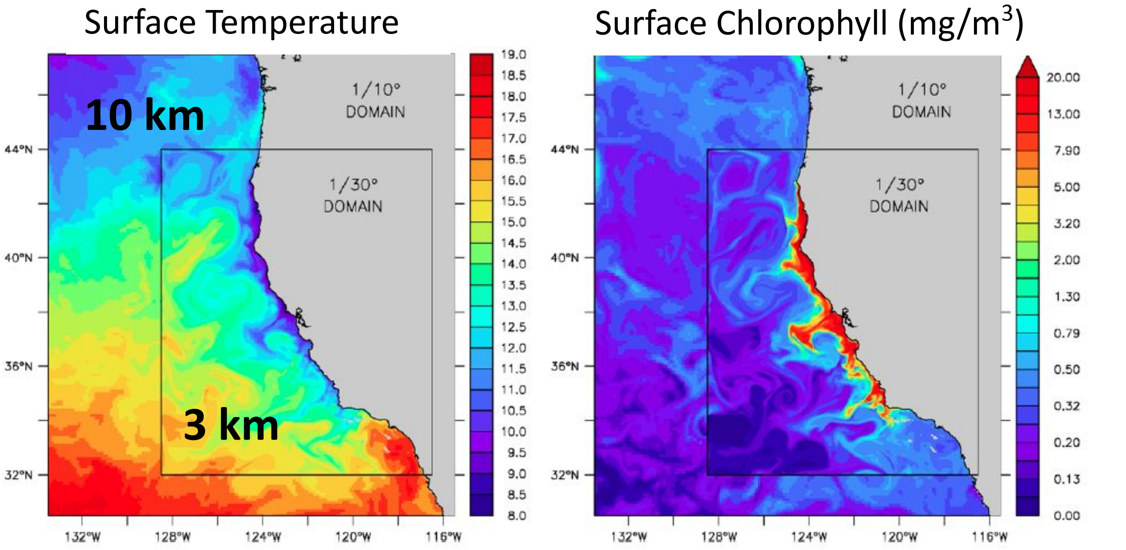

Pozo Buil et al. 2021. Frontiers in Marine Science

# Ecosystem Modeling Framework





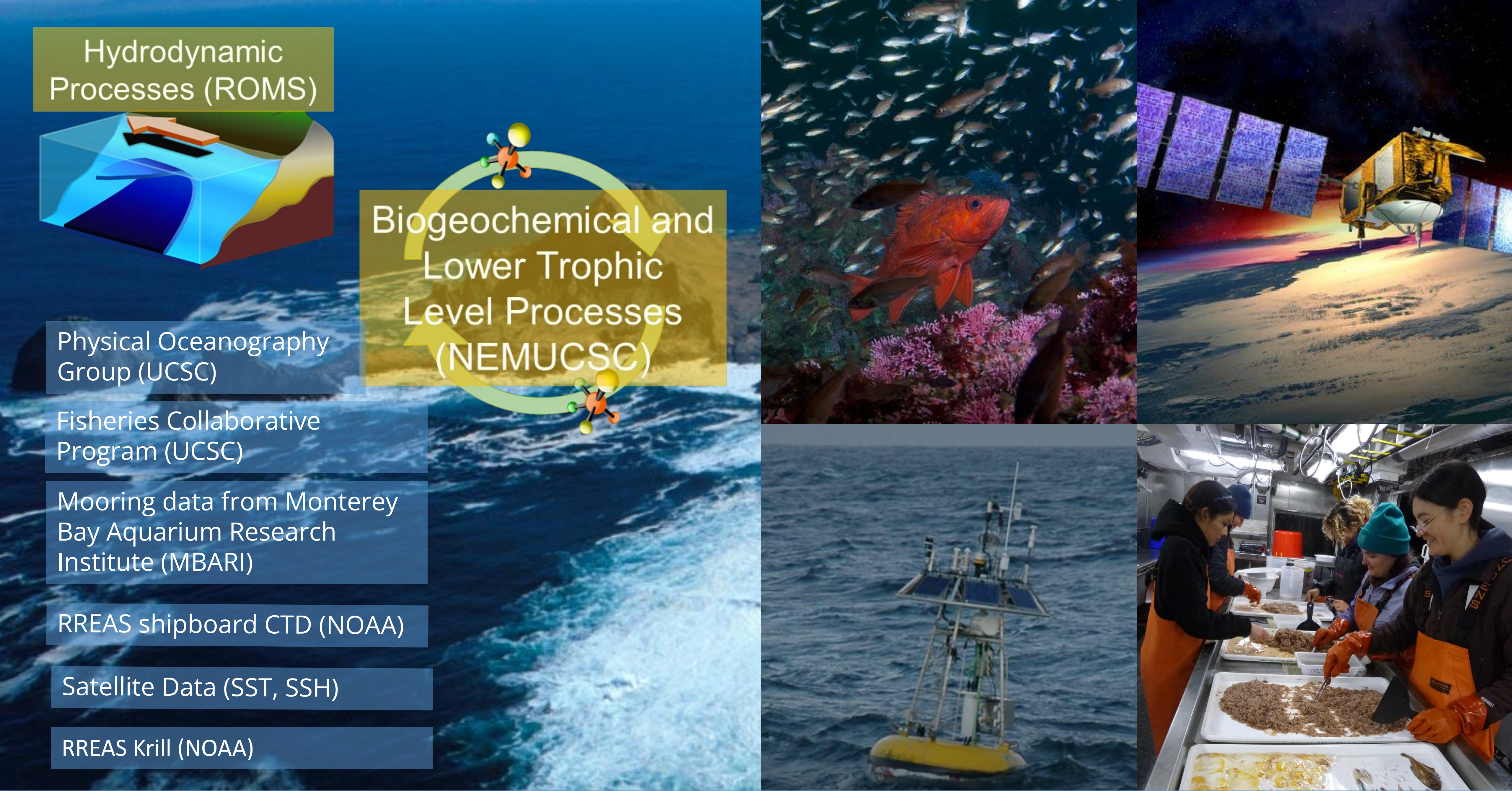

**ROMS:** Regional Ocean Modeling System: 1/30° high-resolution nested domain within 1/10° dynamically-downscaled climate projections for the broader California Current region

**NEMUCSC:** North Pacific Ecosystem Model for Understanding Regional Oceanography (NEMURO) customized for the California Current (NEMUCSC) for biogeochemical interactions and generation of the prey (krill) field

Brinton 1962; n.d.; Lavaniegos and Ohman 2007; Fiechter et al. 2018, 2020

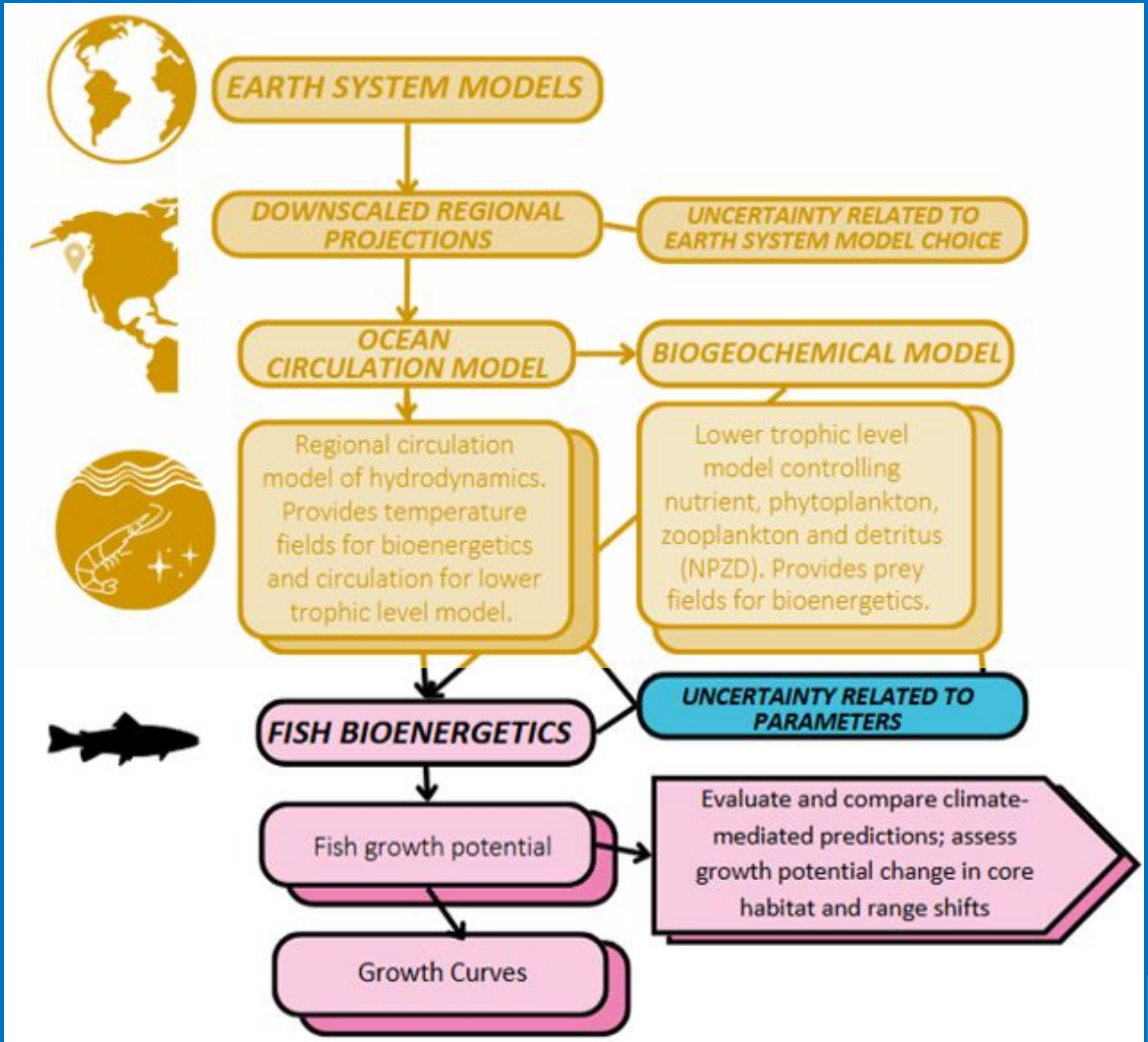
# Environmental variables and krill validated on empirical data

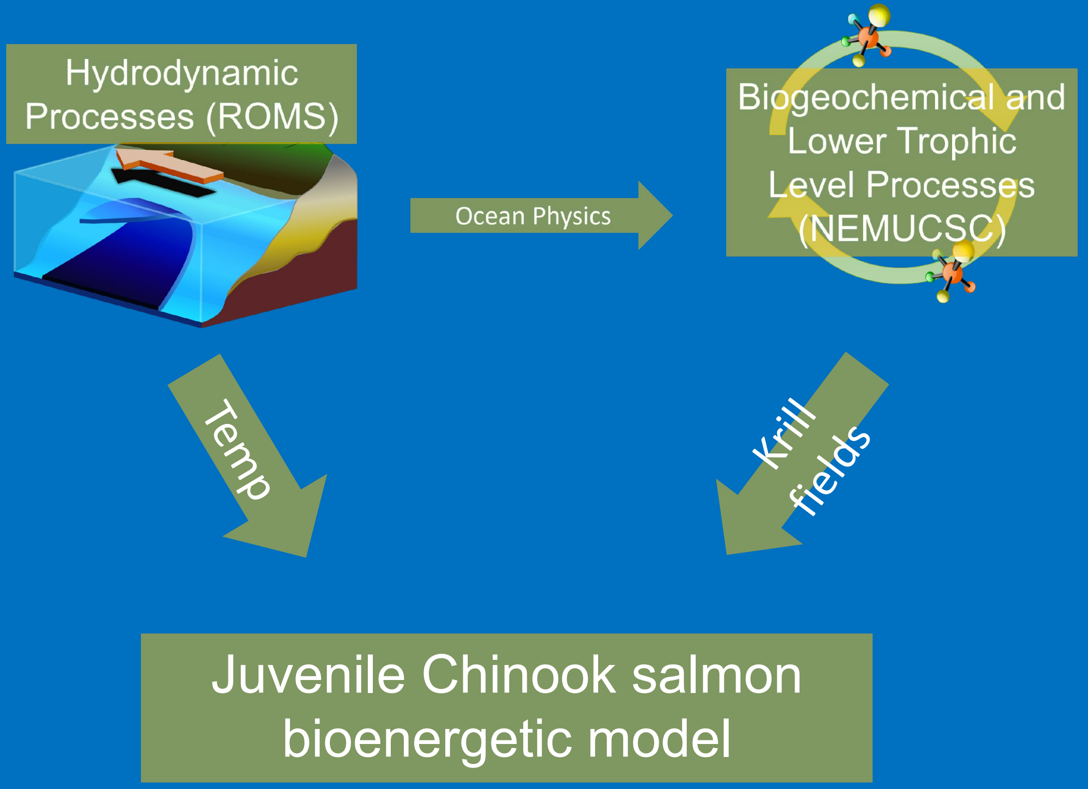
Photos: MBARI, RREAS Survey Team, NASA, Robert Lee



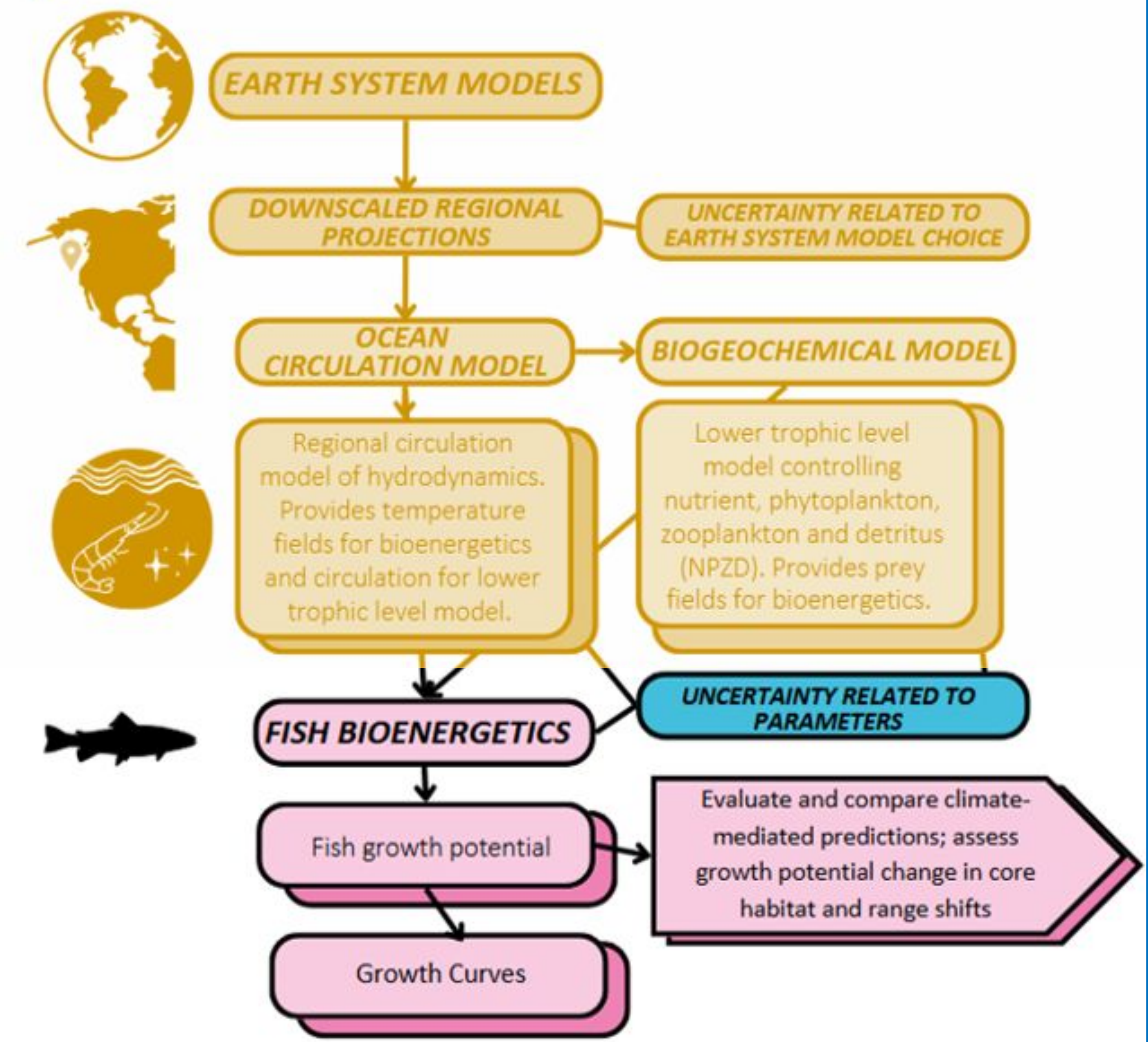

Schroeder et al. 2014 (environmental variables), Cimino et al. 2020 (field survey sampling of krill), Fiechter et al. 2020 (modeled krill hotspots match observed hotspots) , Sakuma et al. 2006 (Krill sampling methods)

Photos: MBARI, RREAS Survey Team, NASA, Robert Lee



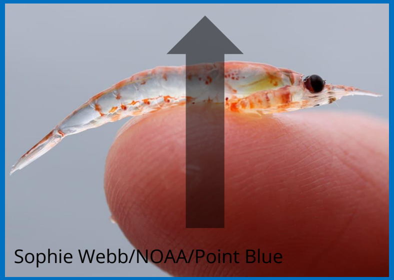

Fiechter, J et al. (2015) *Geophysical Research Letters*
Vasbinder et al. (2024) *Fisheries Oceanography*




**Growth = conversion efficiency x (Biomass Assimilation - Maintenance Metabolism - Swimming Costs)**

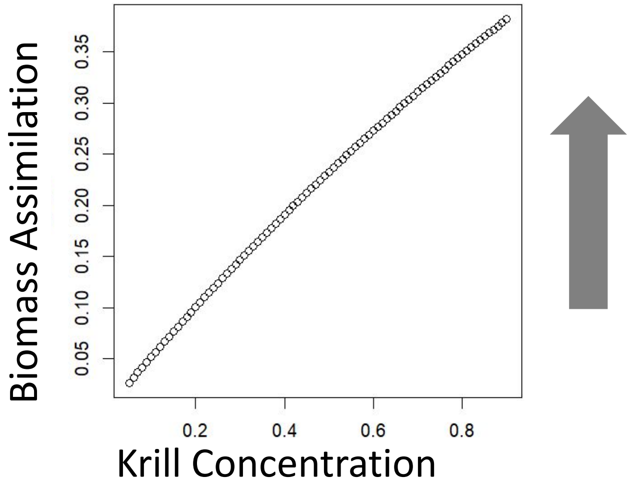
Fiechter, J et al. (2015) *Geophysical Research Letters*

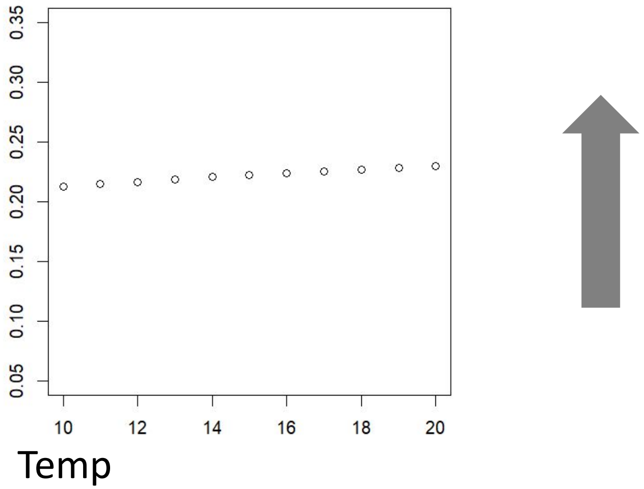
Growth = conversion efficiency x (**Biomass Assimilation - Maintenance Metabolism** - Swimming Costs)




# Bioenergetic Tradeoffs

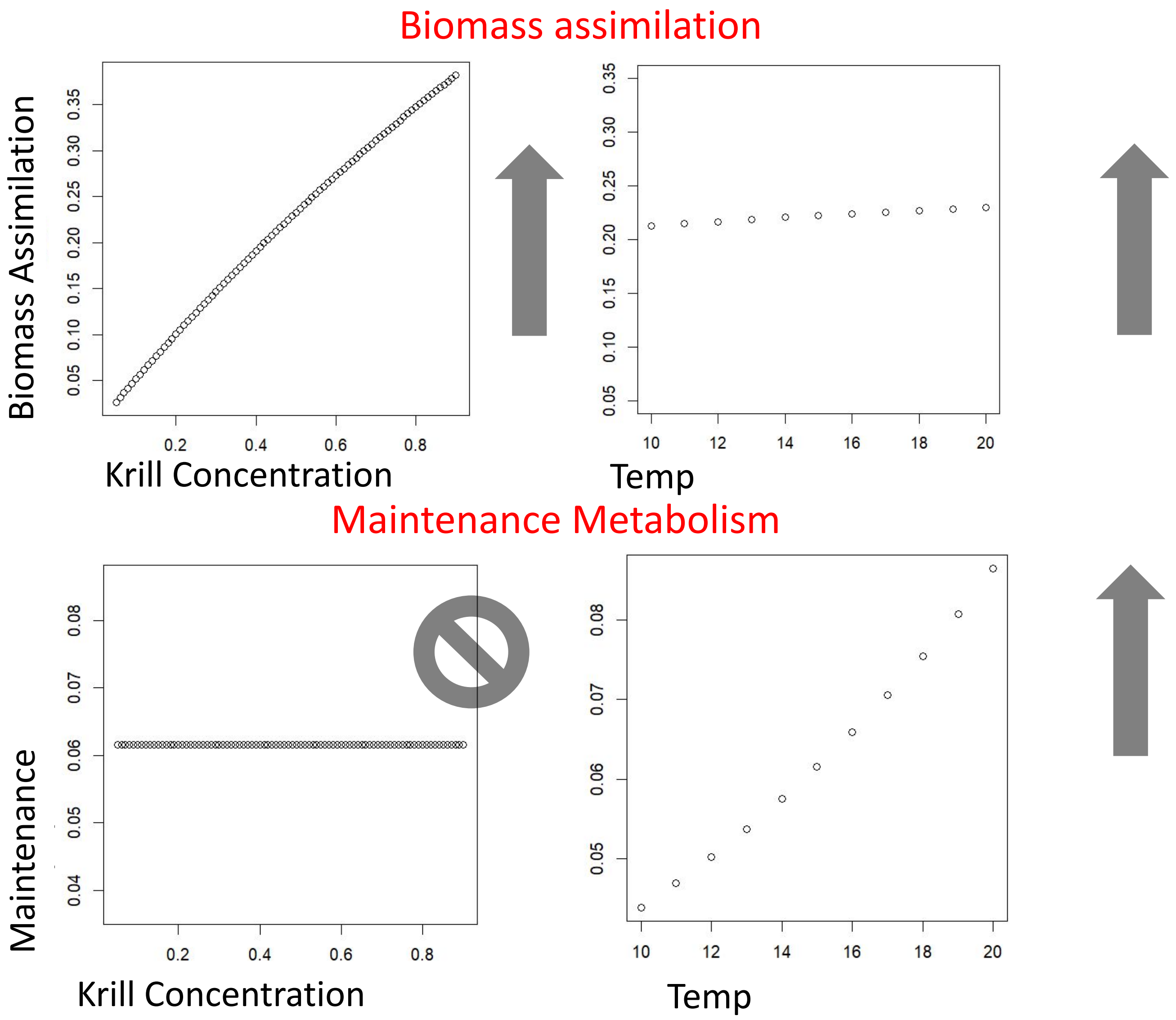
Biomass assimilation

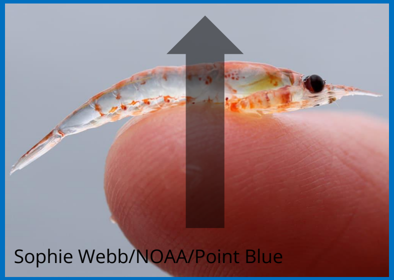



# Bioenergetic Tradeoffs

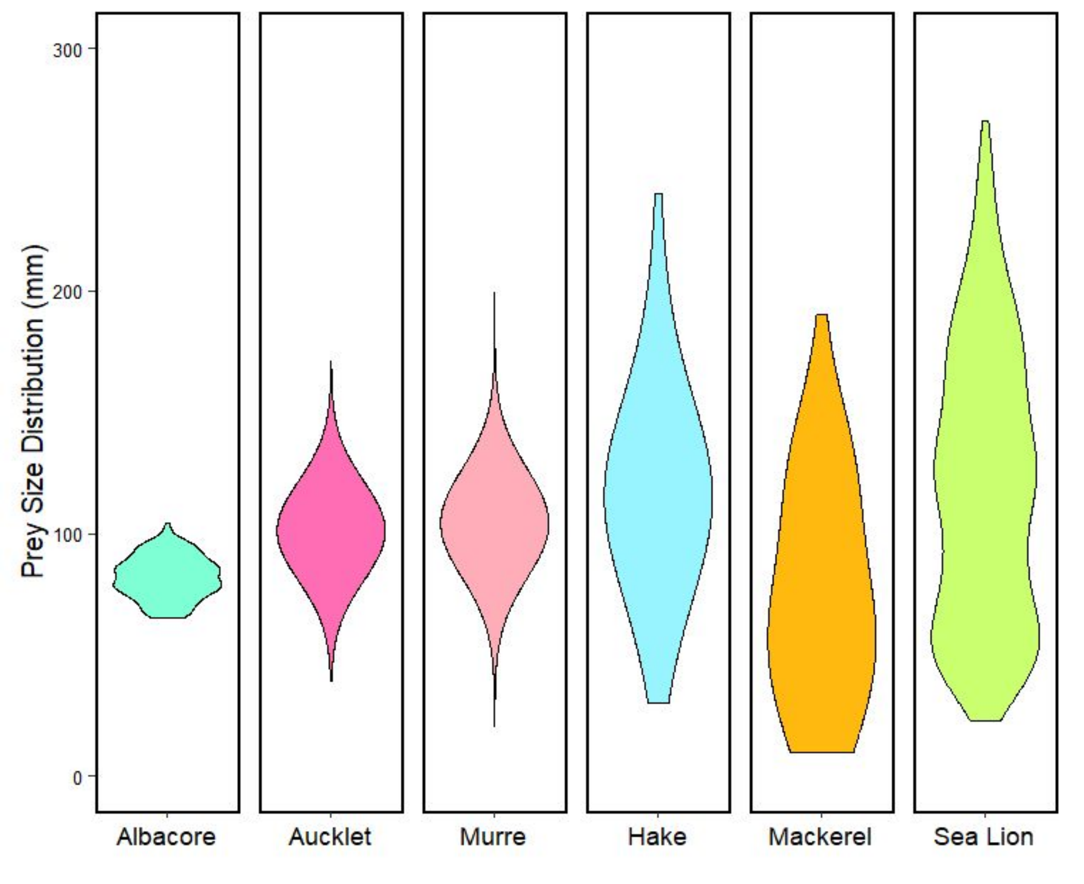
**Growth = conversion efficiency x (Biomass Assimilation - Maintenance Metabolism - Swimming Costs)**

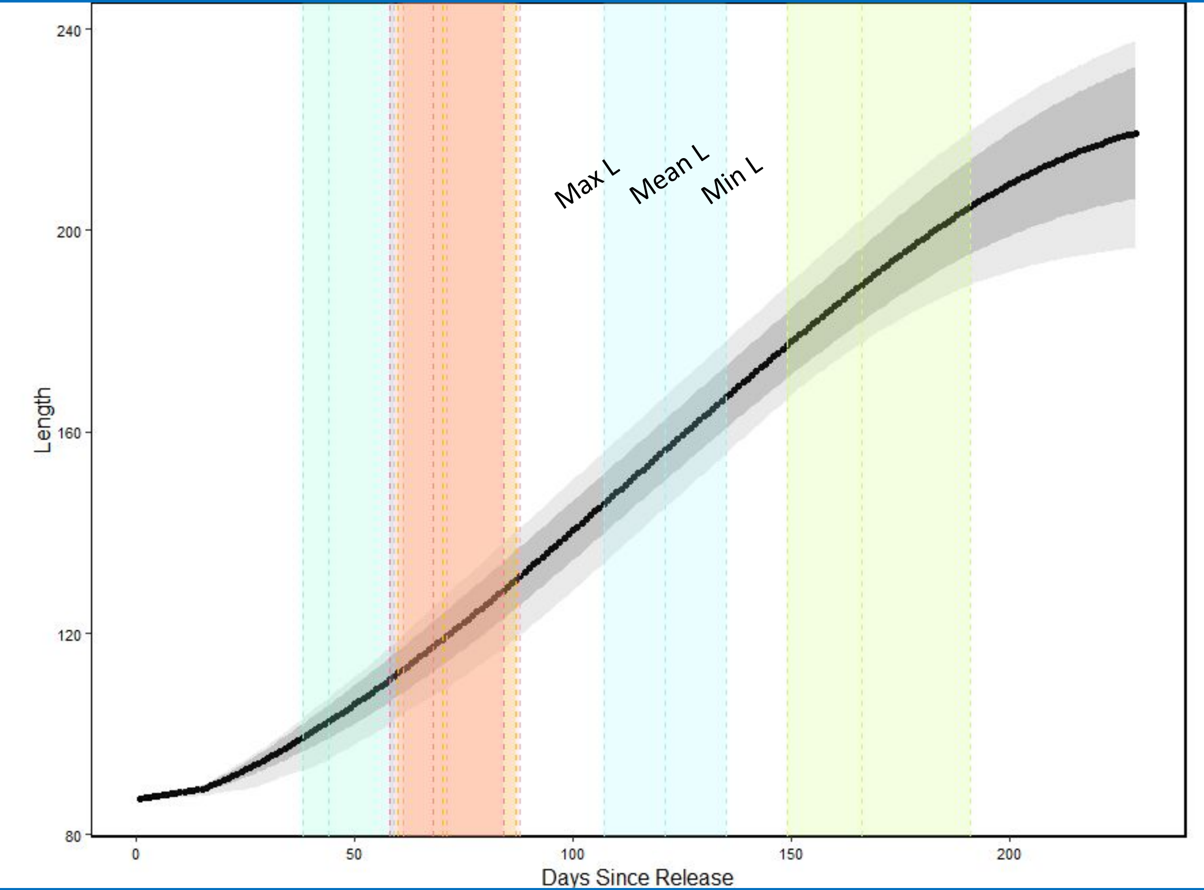


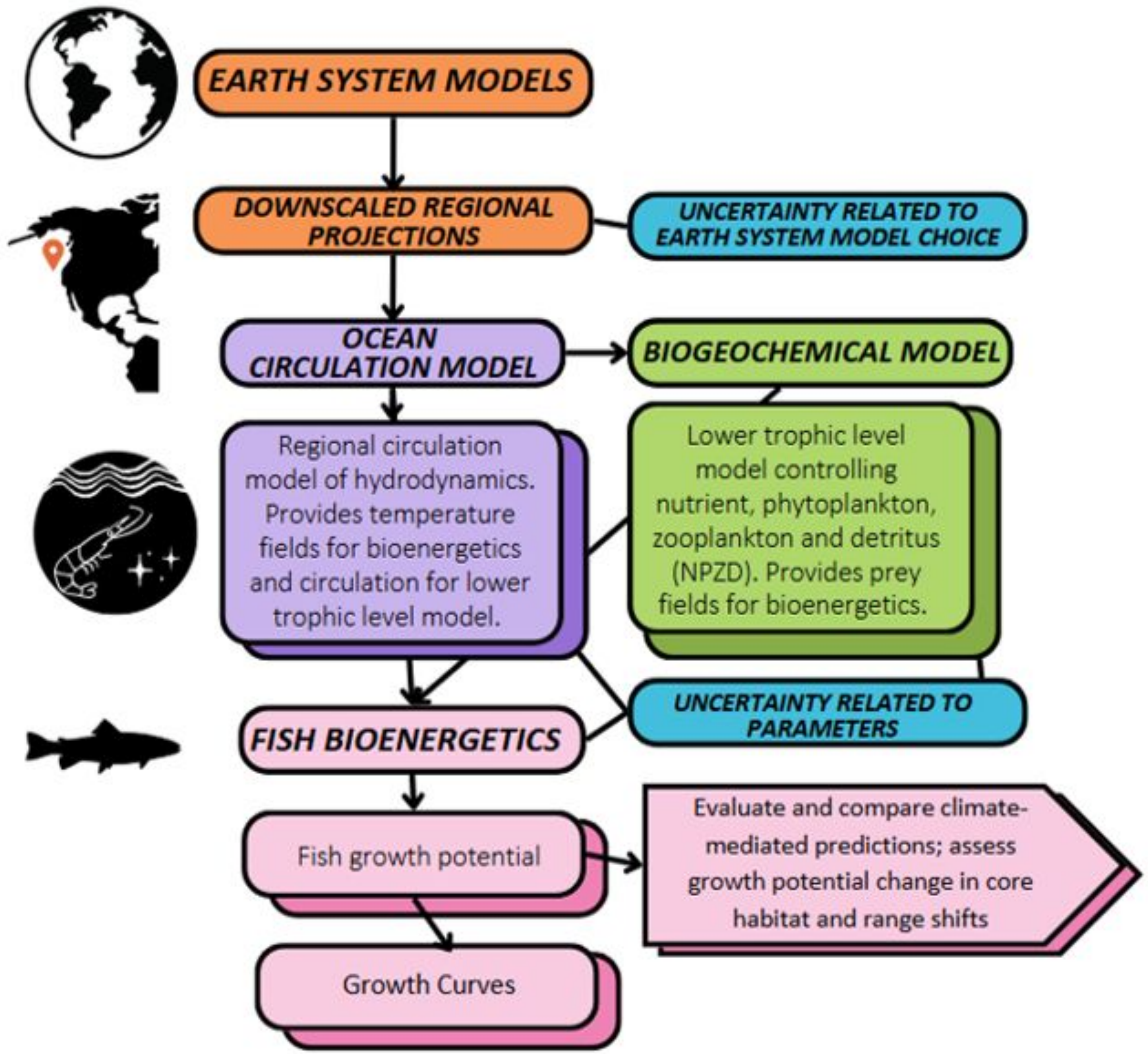

Growth potential in the future depends on the rate at which metabolic needs outpace assimilation

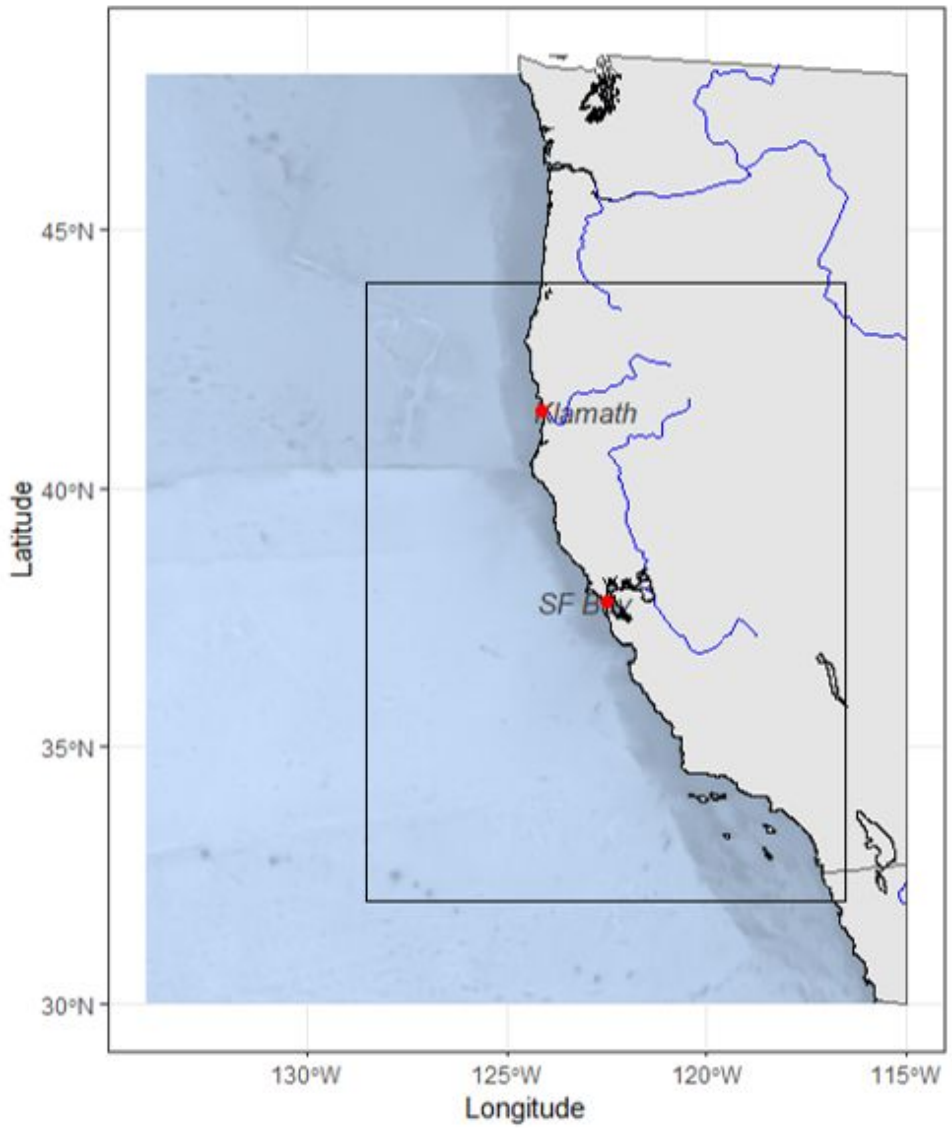
# Why does it matter how well you grow?




Days for smallest, largest, and mean size smolt to escape the mean+1SD prey size distribution of predators. Note that as smolt grow out of the range of albacore, they grow into the range for seabirds, and as they grow out of the range for seabirds, they grow into the range of larger fish predators and pinnipeds.

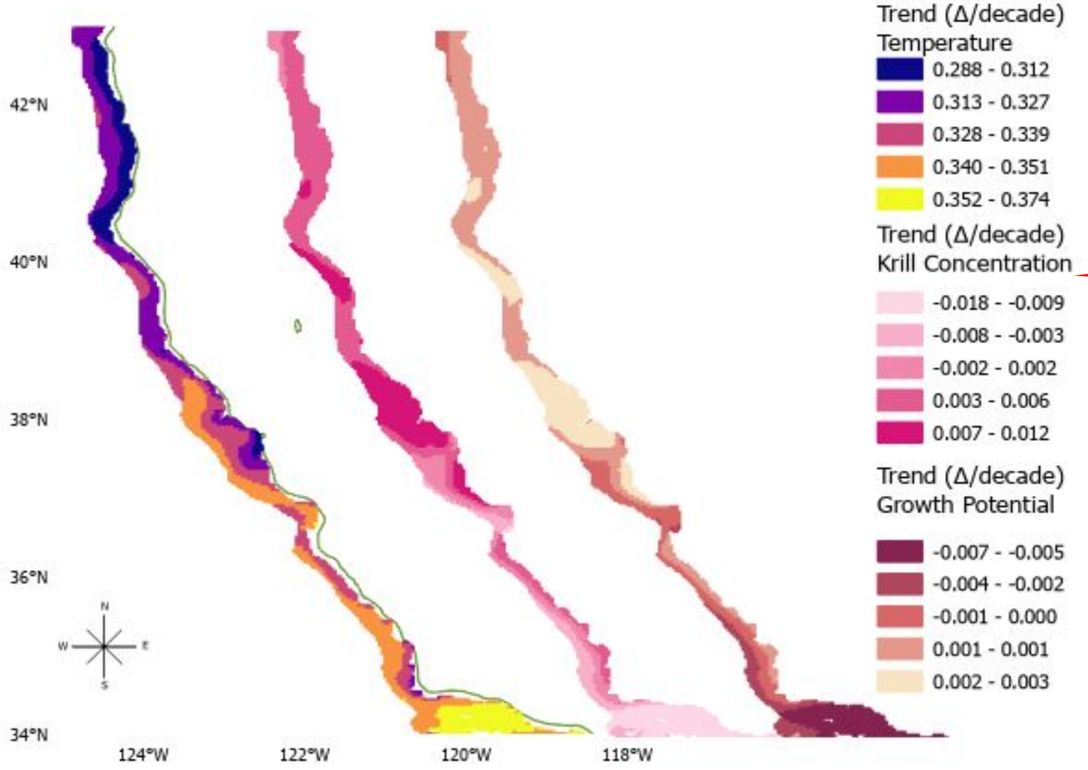

EARTH SYSTEM MODELS
DOWNSCALED REGIONAL PROJECTIONS
UNCERTAINTY RELATED TO EARTH SYSTEM MODEL CHOICE
OCEAN CIRCULATION MODEL
BIOGEOCHEMICAL MODEL
Regional circulation model of hydrodynamics. Provides temperature fields for bioenergetics and circulation for lower trophic level model.
Lower trophic level model controlling nutrient, phytoplankton, zooplankton and detritus (NPZD). Provides prey fields for bioenergetics.
UNCERTAINTY RELATED TO PARAMETERS
FISH BIOENERGETICS
Fish growth potential
Evaluate and compare climate-mediated predictions; assess growth potential change in core habitat and range shifts
Growth Curves

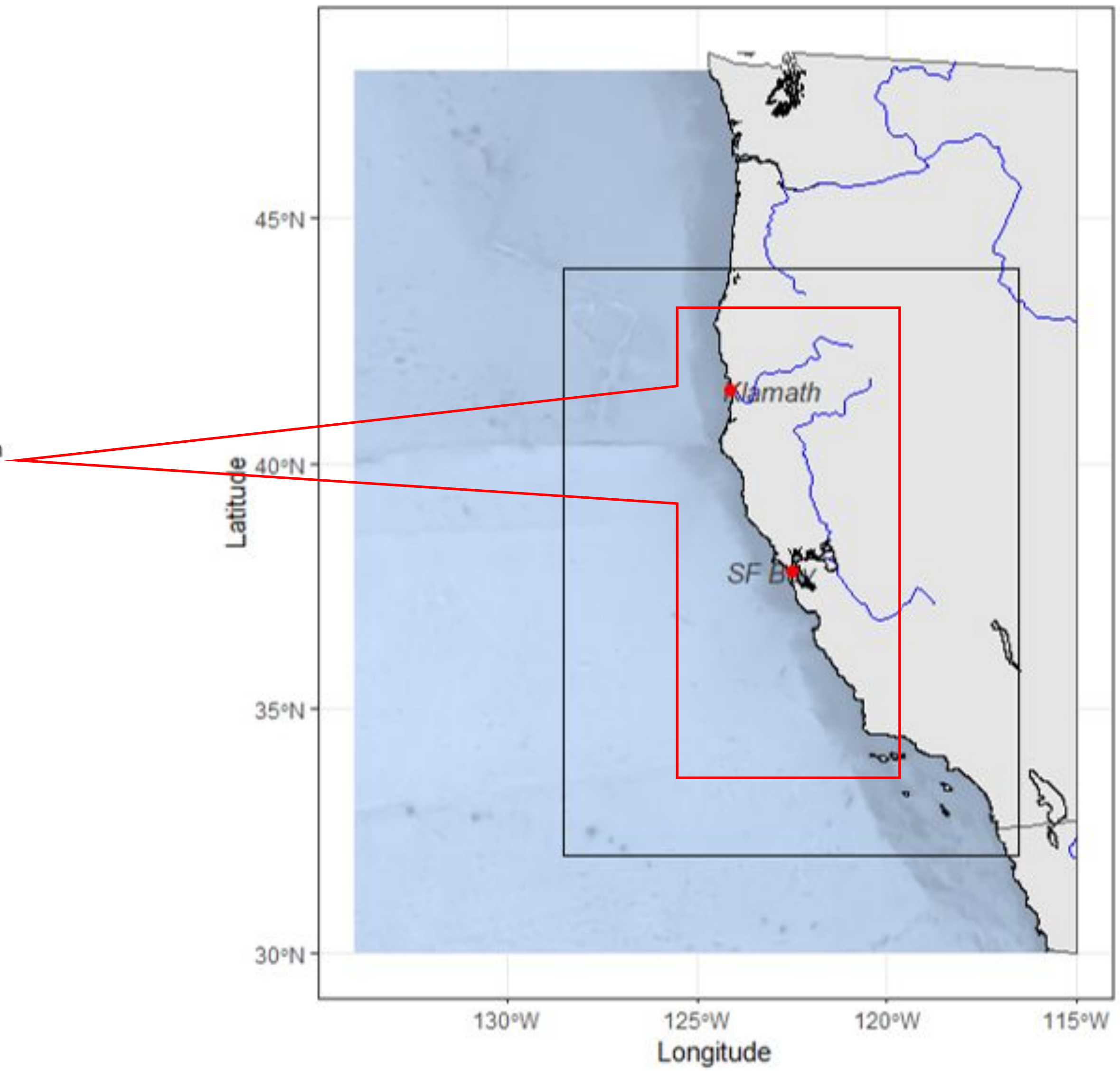

45°N
40°N
35°N
30°N
Latitude
Klamath
SF Bay
130°W
125°W
120°W
115°W
Longitude

Ensemble Trend in May Temp 2000-2100

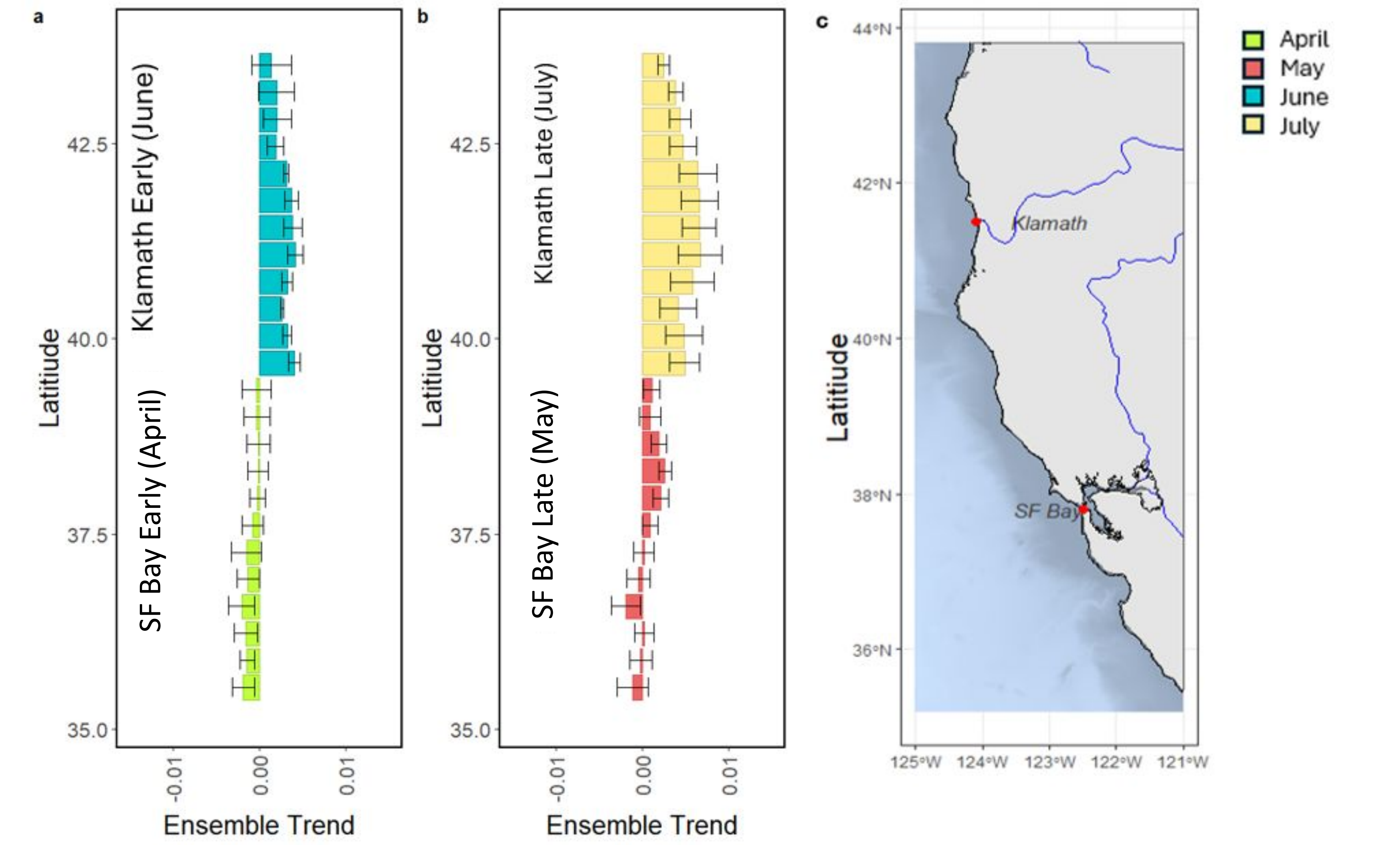
Ensemble Trend in May Krill 2000-2100

Ensemble Trend in May Growth 2000-2100

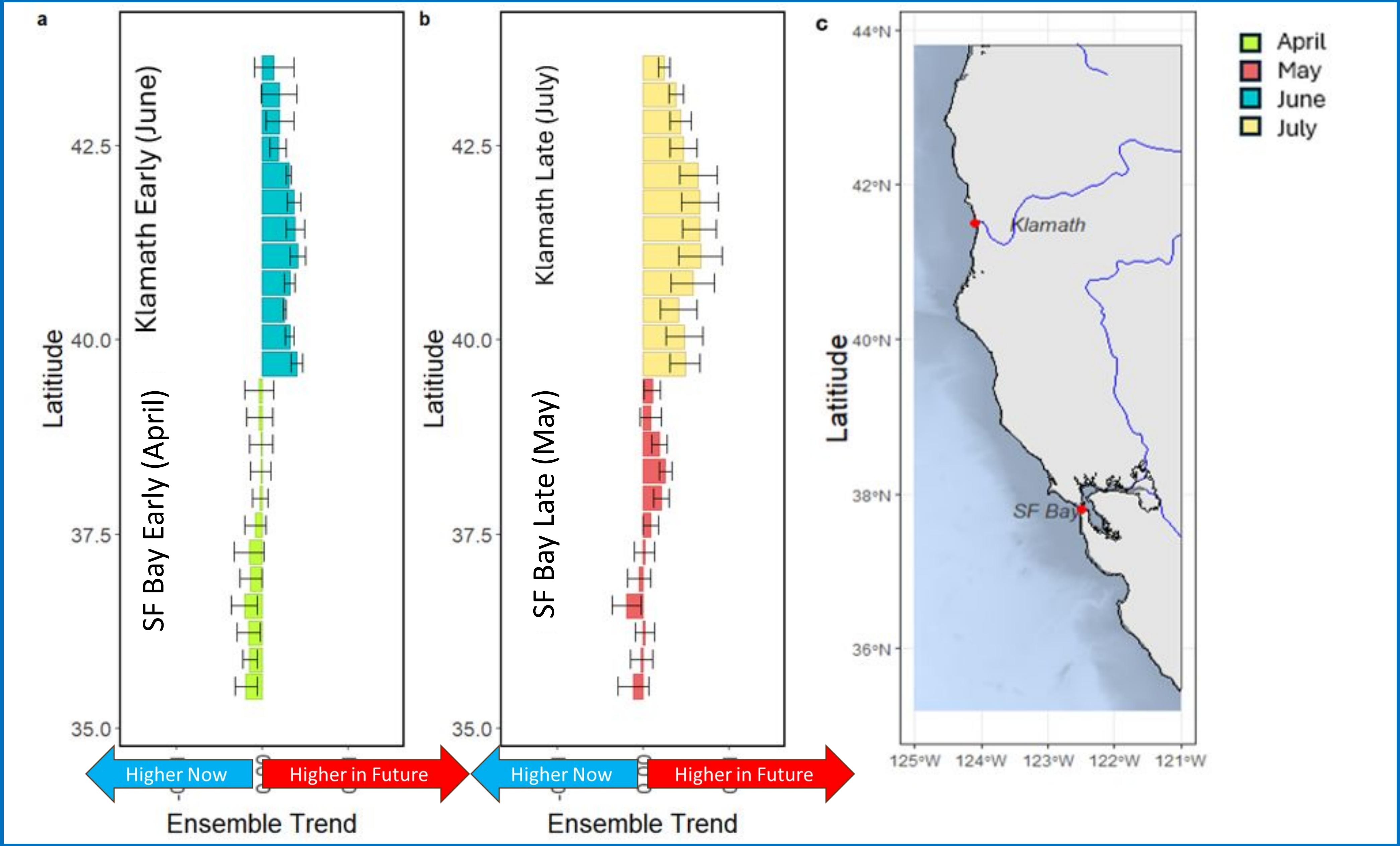


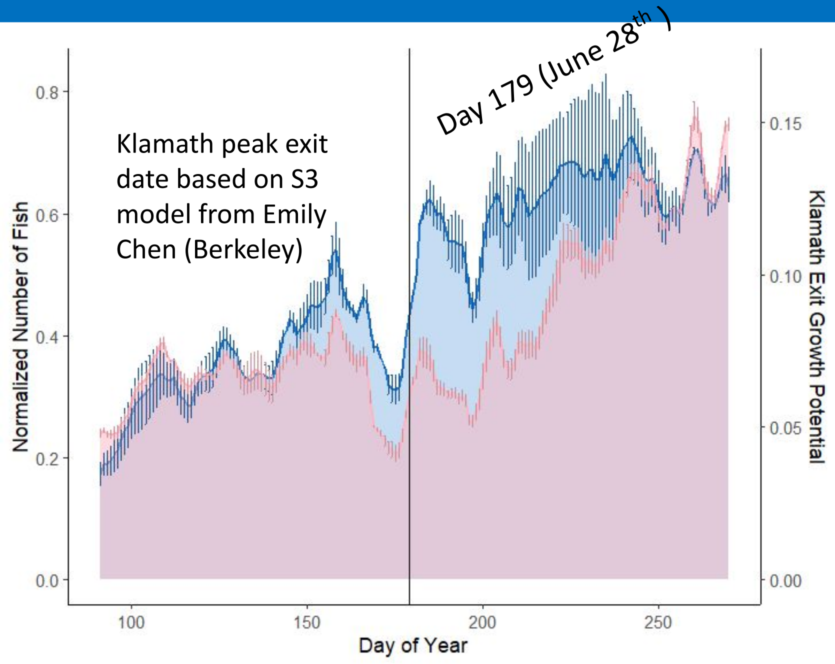



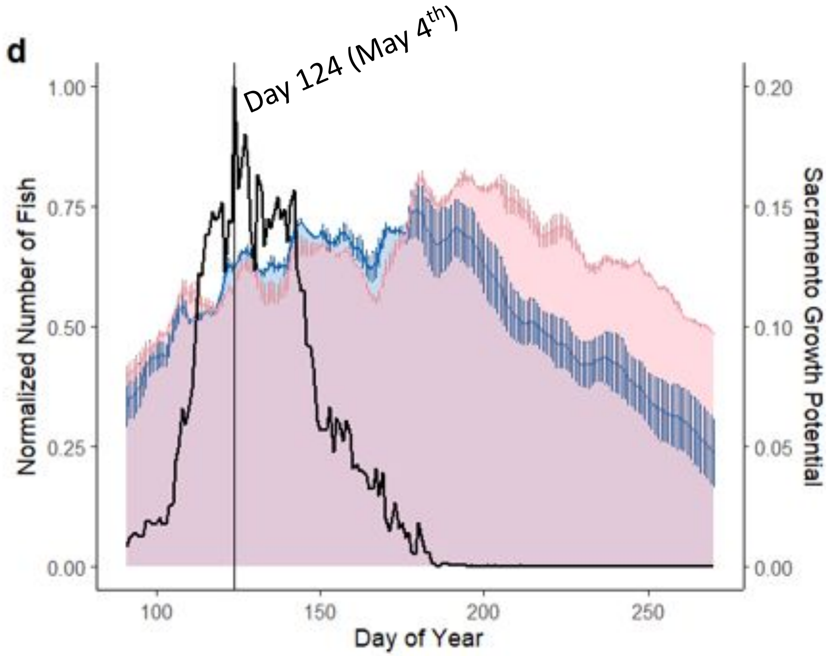
# Century Trends: Ensemble Trend and Spread

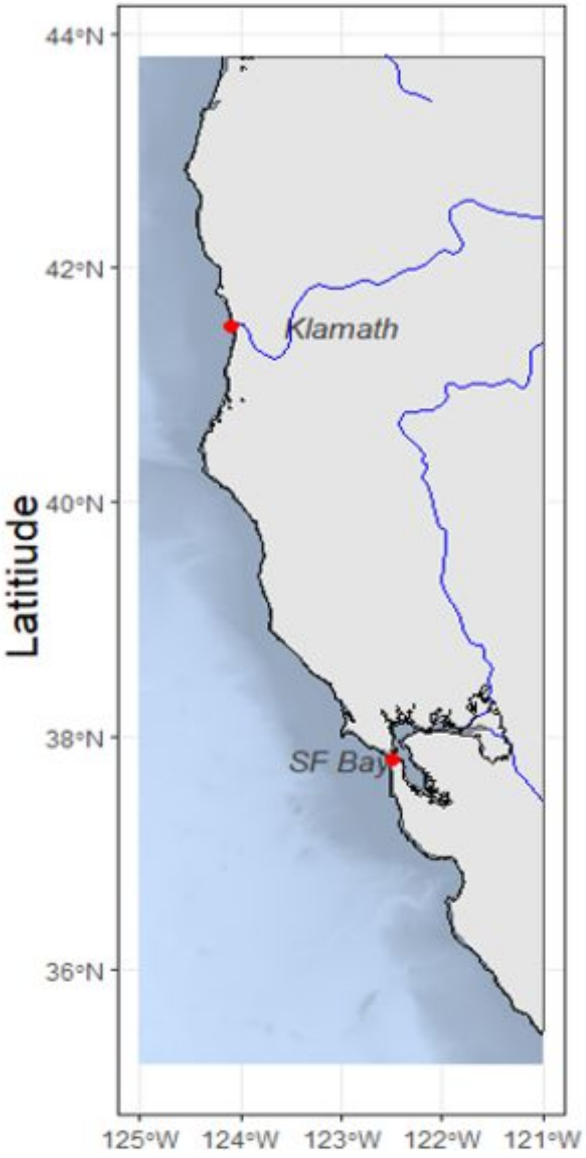


# Century Trends: Ensemble Trend and Spread

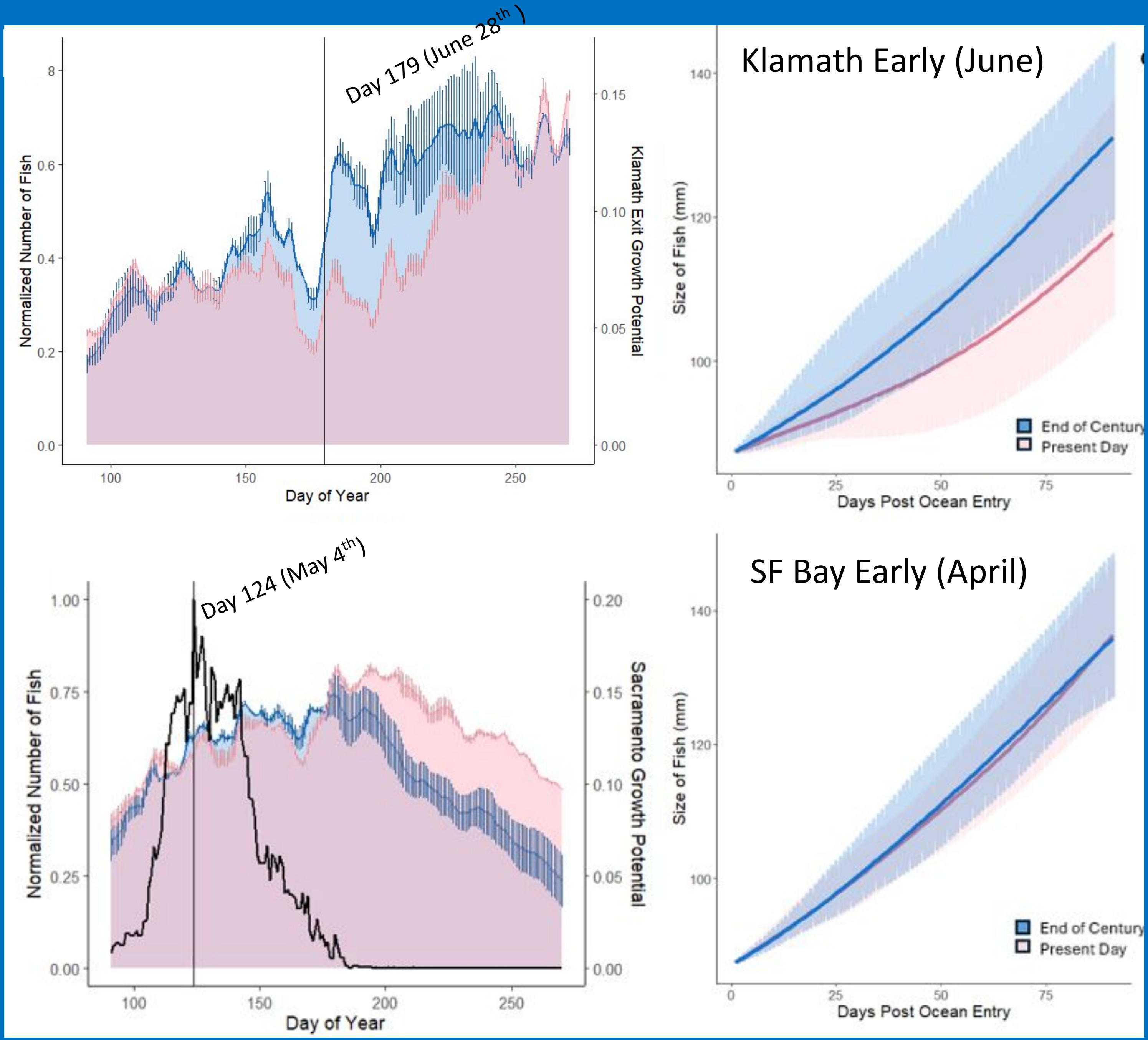



Klamath peak exit date based on S3 model from Emily Chen (Berkeley)
Day 179 (June 28th )
Normalized Number of Fish
Klamath Exit Growth Potential
Day of Year
0.0
0.2
0.4
0.6
0.8
0.00
0.05
0.10
0.15
100
150
200
250

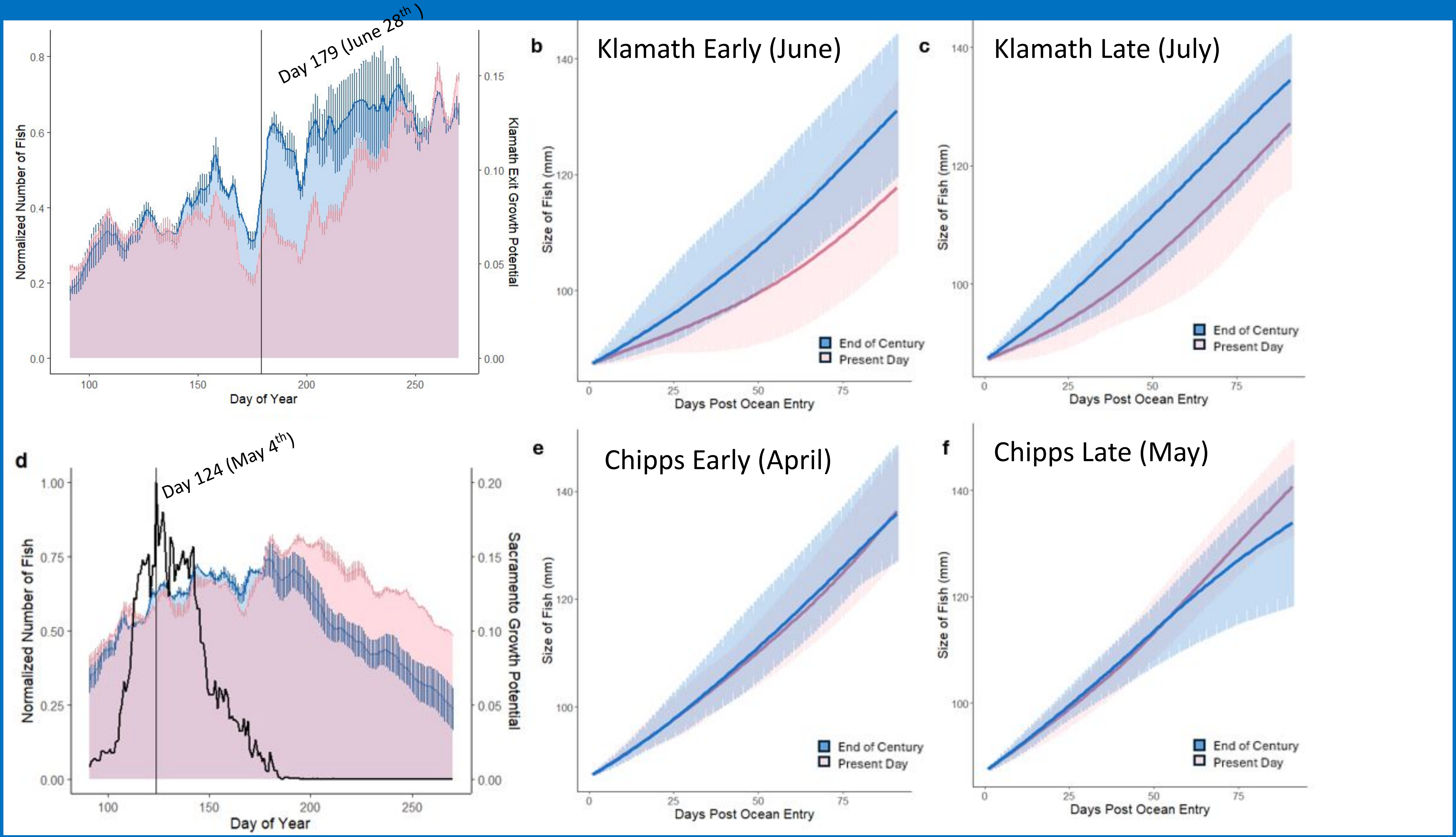

d
Day 124 (May 4th)
Normalized Number of Fish
Sacramento Growth Potential
Day of Year
0.00
0.25
0.50
0.75
1.00
0.00
0.05
0.10
0.15
0.20
100
150
200
250

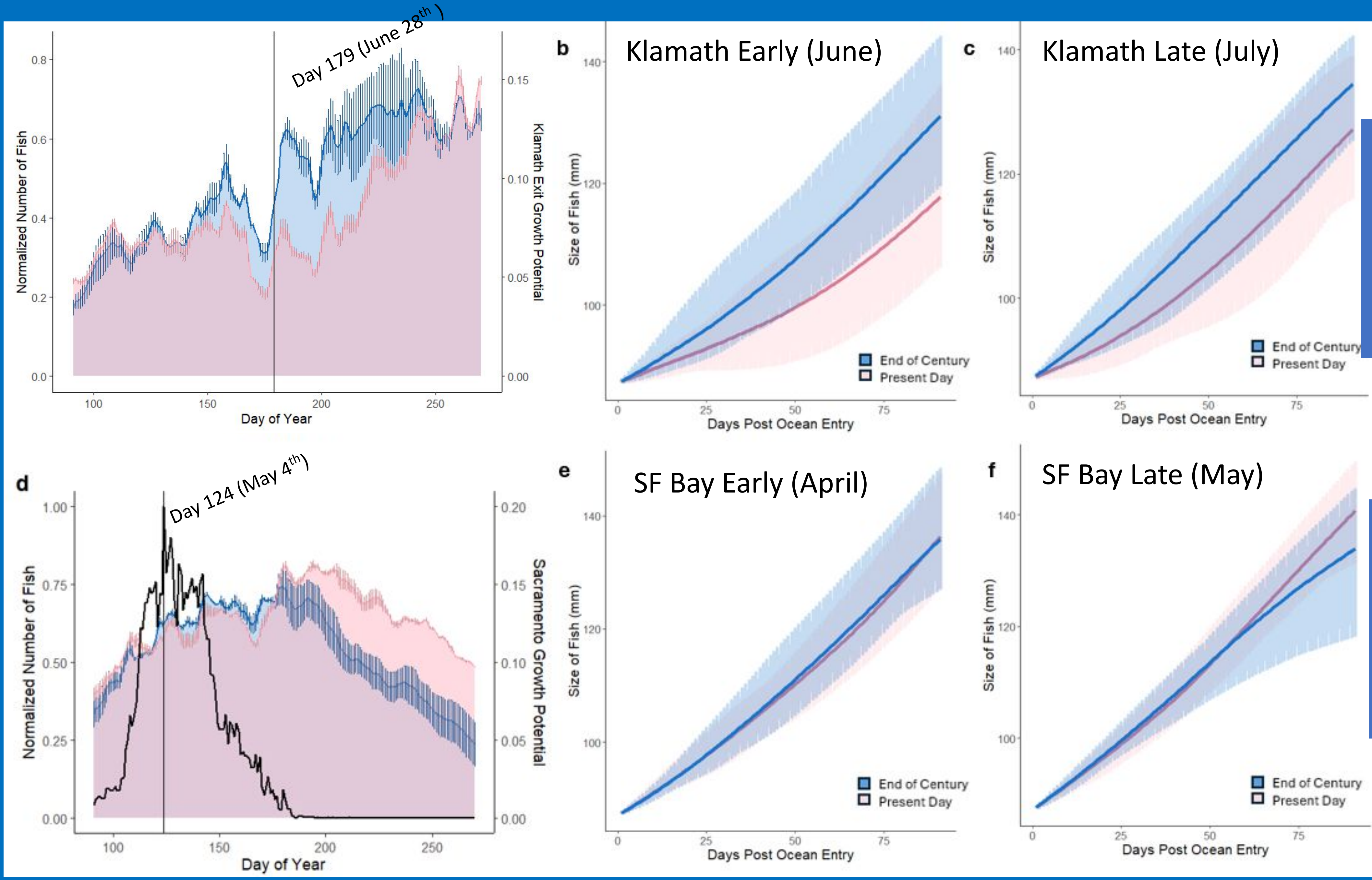

Latitude
44°N
42°N
40°N
38°N
36°N
125°W
124°W
123°W
122°W
121°W
Klamath
SF Bay


Roger Tabor/USFWS


Day 179 (June 28th)
Normalized Number of Fish
Klamath Exit Growth Potential
Day of Year
Klamath Early (June)
Size of Fish (mm)
Days Post Ocean Entry
End of Century
Present Day
Day 124 (May 4th)
Normalized Number of Fish
Sacramento Growth Potential
Day of Year
SF Bay Early (April)
Size of Fish (mm)
Days Post Ocean Entry
End of Century
Present Day


Roger Tabor/USFWS

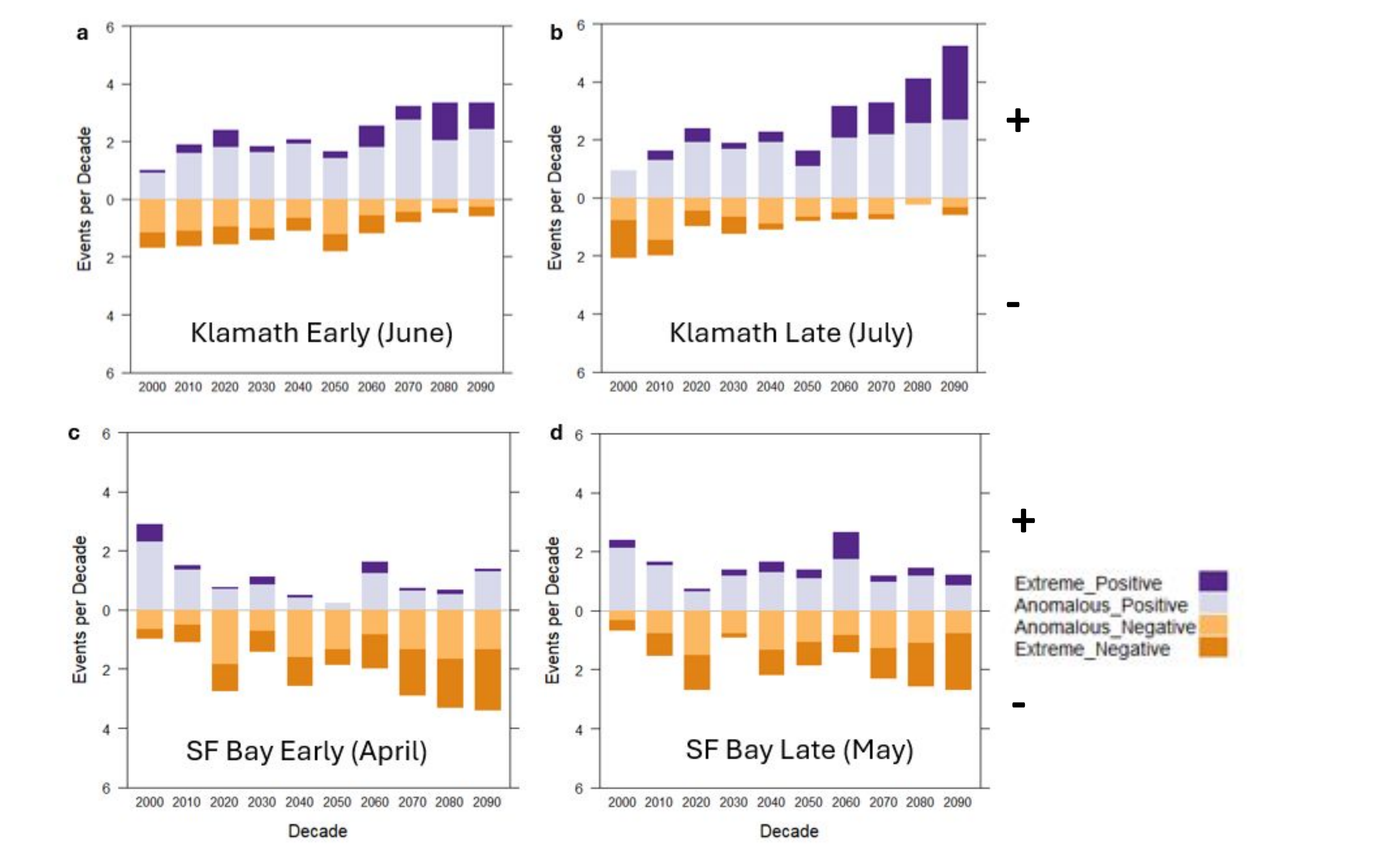

Day 179 (June 28th)
Normalized Number of Fish
Klamath Exit Growth Potential
Day of Year
b
Klamath Early (June)
Size of Fish (mm)
Days Post Ocean Entry
End of Century
Present Day
c
Klamath Late (July)
Size of Fish (mm)
Days Post Ocean Entry
End of Century
Present Day
d
Day 124 (May 4th)
Normalized Number of Fish
Sacramento Growth Potential
Day of Year
e
Chipps Early (April)
Size of Fish (mm)
Days Post Ocean Entry
End of Century
Present Day
f
Chipps Late (May)
Size of Fish (mm)
Days Post Ocean Entry
End of Century
Present Day



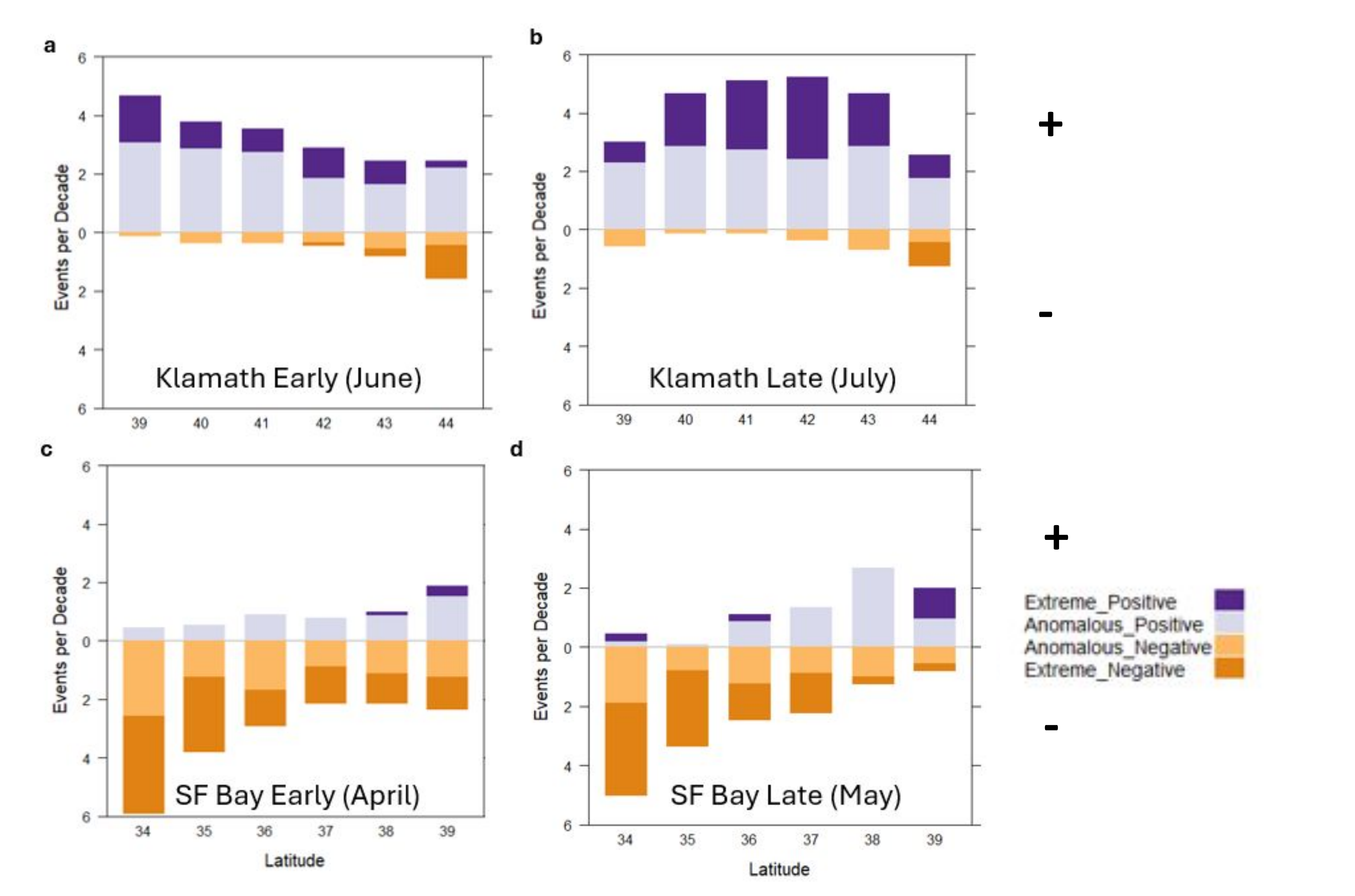

Klamath exit fish grow larger, faster at the end of the century than today

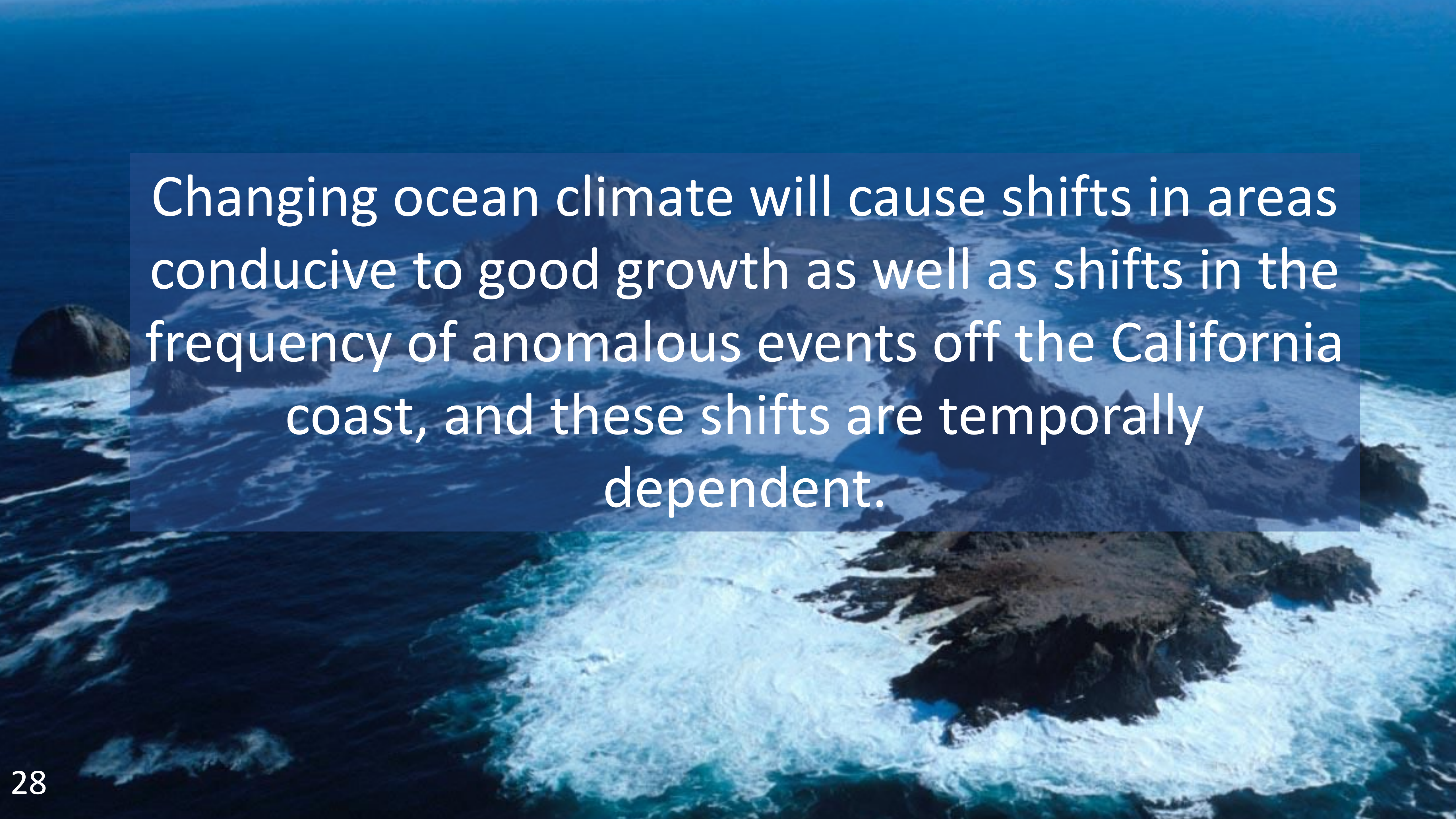
SF Bay exit fish grow slower at the end of the century than today if they enter later

# But what about years that don’t follow the expected pattern?



# But what about years that don’t follow the expected pattern?





Changing ocean climate will cause shifts in areas conducive to good growth as well as shifts in the frequency of anomalous events off the California coast, and these shifts are temporally dependent.

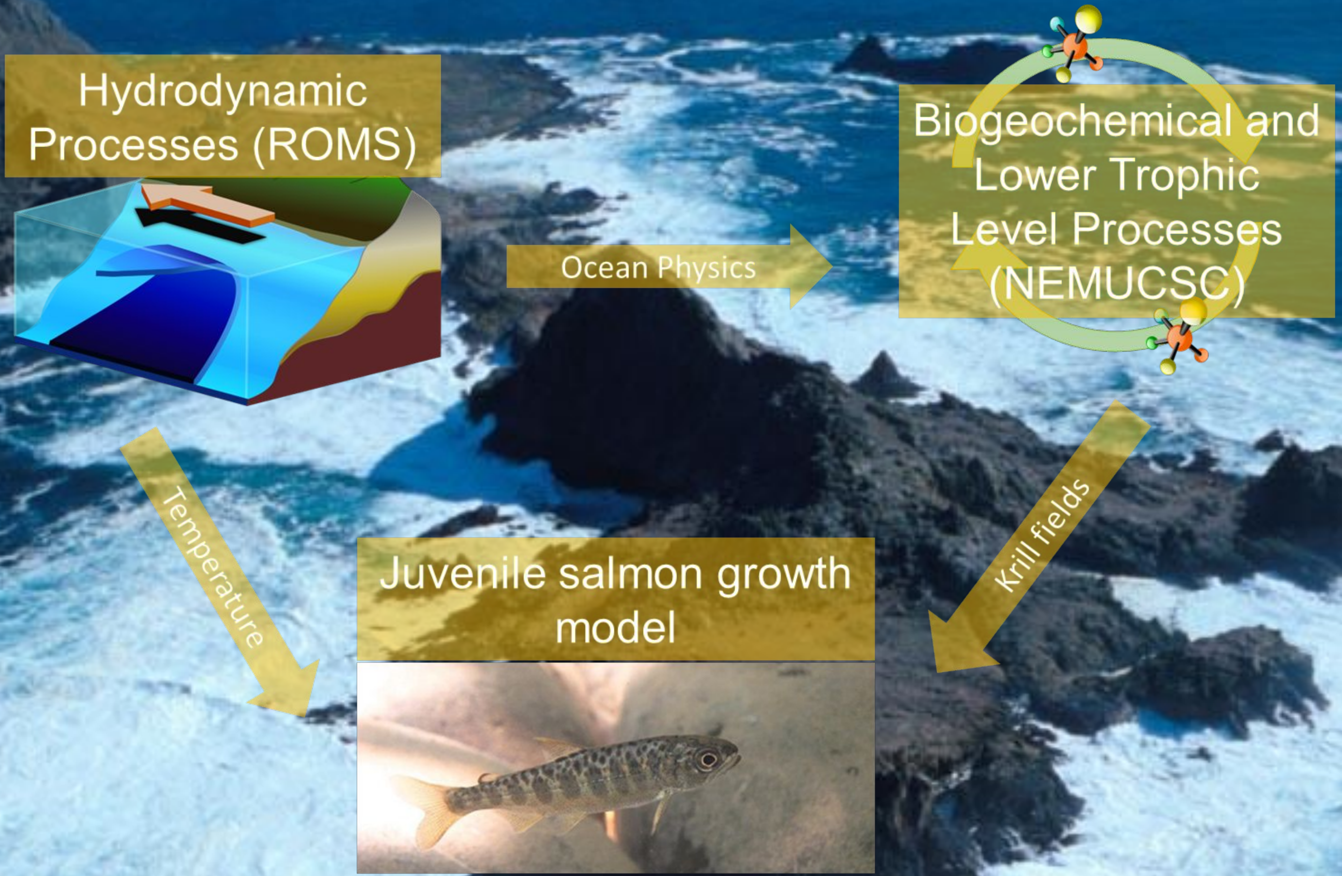
# What are our goals for ecological forecasting?


Steve Martarano, USFWS


NOAA Fisheries

**“generational management” on the timescales of fish and fishermen, local and regional modeling and management**

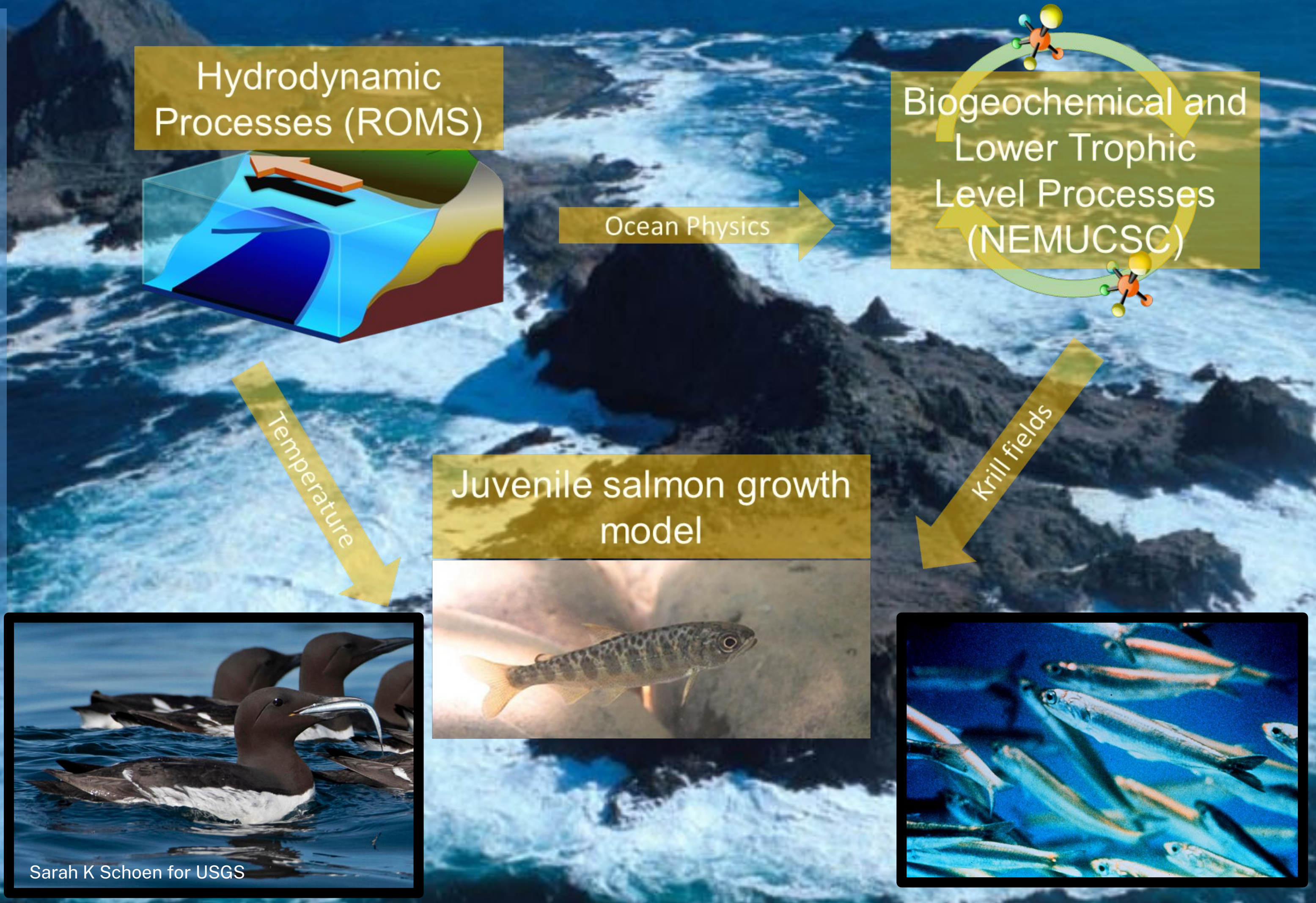
# What’s the future of our collaborative modeling framework?



# What's the future of our collaborative modeling framework?

**Developing functionality for new IBM plug ins:**

- **Bird models that simulate predator distributions**
- **Alternative prey relationships that use forage fish data**
- **Possibility for forage fish models to plug in as inputs**
- **Possibility to collaborate with bioenergetics teams assessing future of salmon metabolic rates**



# Thank you!
# Questions?

Contact me at:

kvasbind@ucsc.edu

kelly.vasbinder@noaa.gov