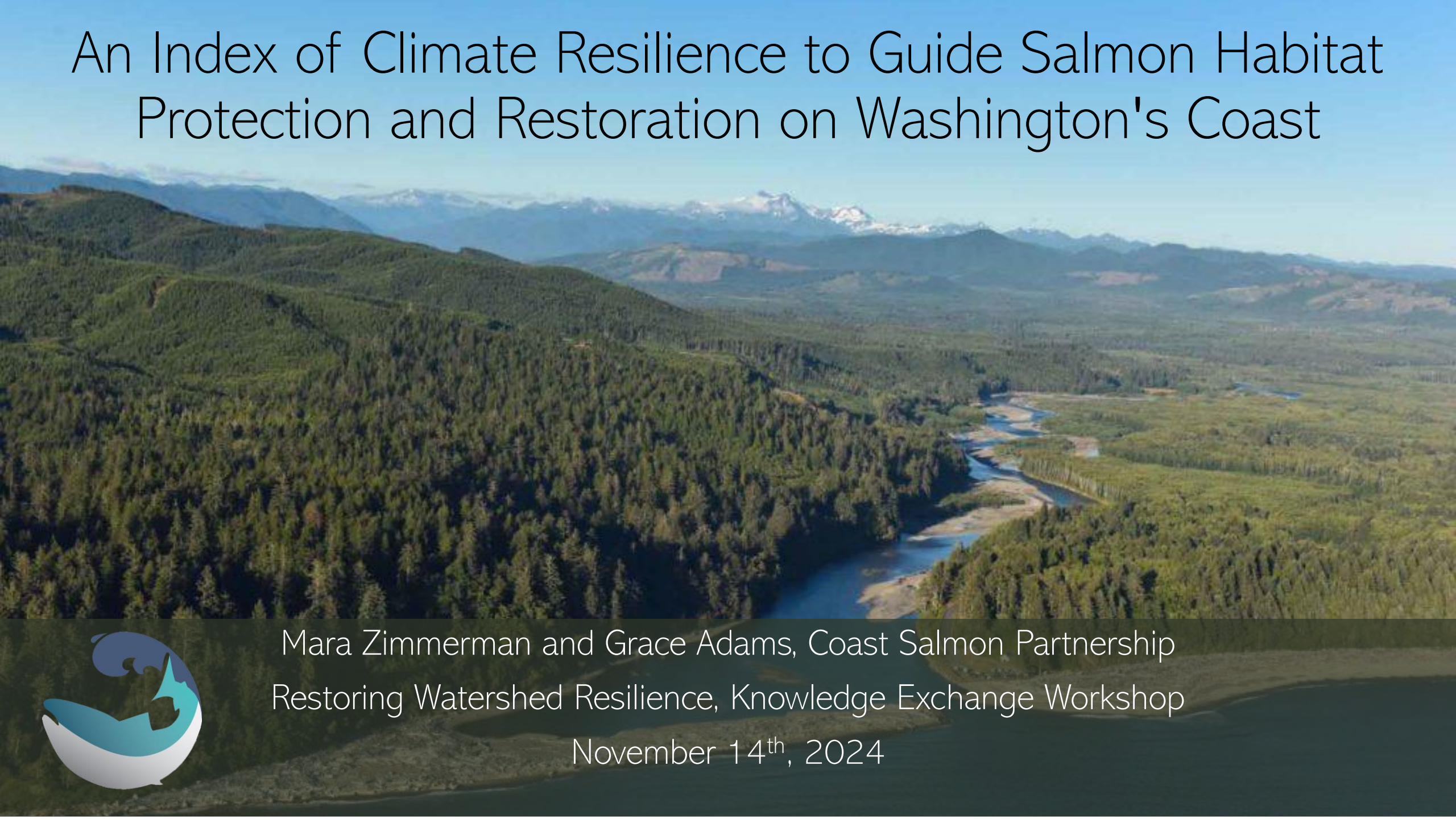
# An Index of Climate Resilience to Guide Salmon Habitat Protection and Restoration on Washington's Coast



Mara Zimmerman and Grace Adams, Coast Salmon Partnership

Restoring Watershed Resilience, Knowledge Exchange Workshop

November 14th, 2024

# Acknowledgements


## Core Team

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- Pete Bisson, SRFB Science Panel
- Ned Pittman, Coast Salmon Partnership
- Matt Sloat, Wild Salmon Center
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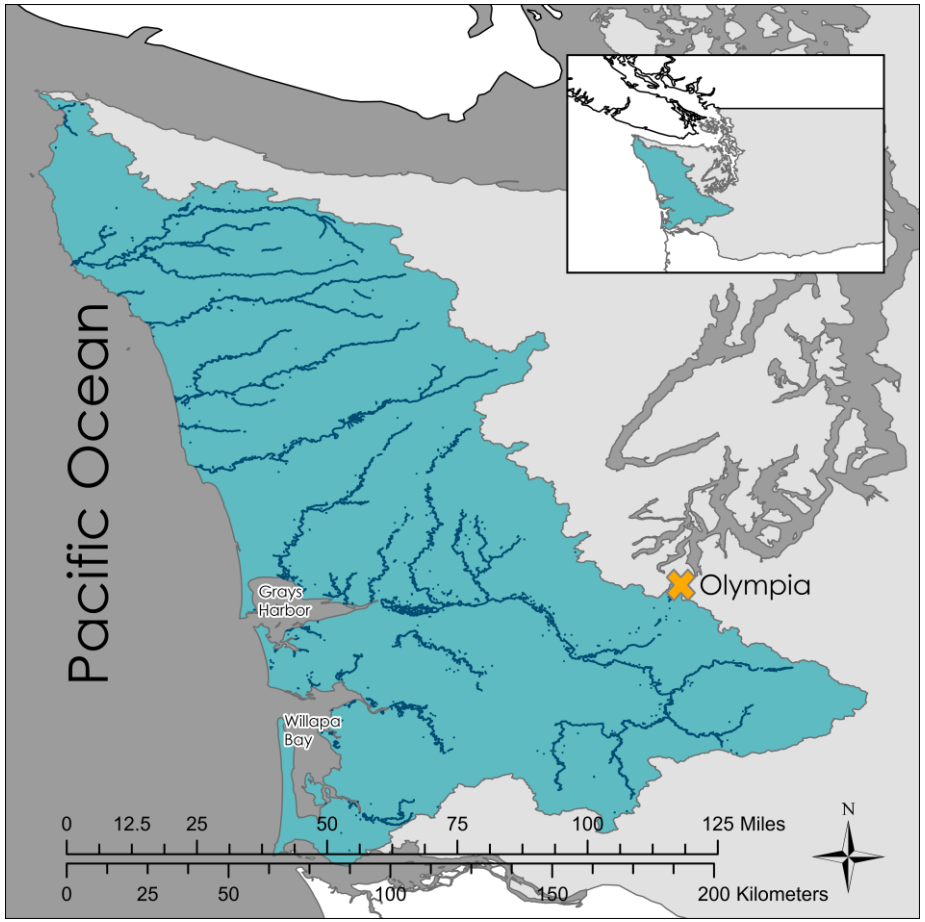
- Megan Tuttle, WDFW

# Climate Adaption & Salmon Restoration

- Coast Salmon Partnership
- Climate Adaptation Framework
- Climate Resilience Index
- Application
- Next Steps

# Washington's Pacific Coast

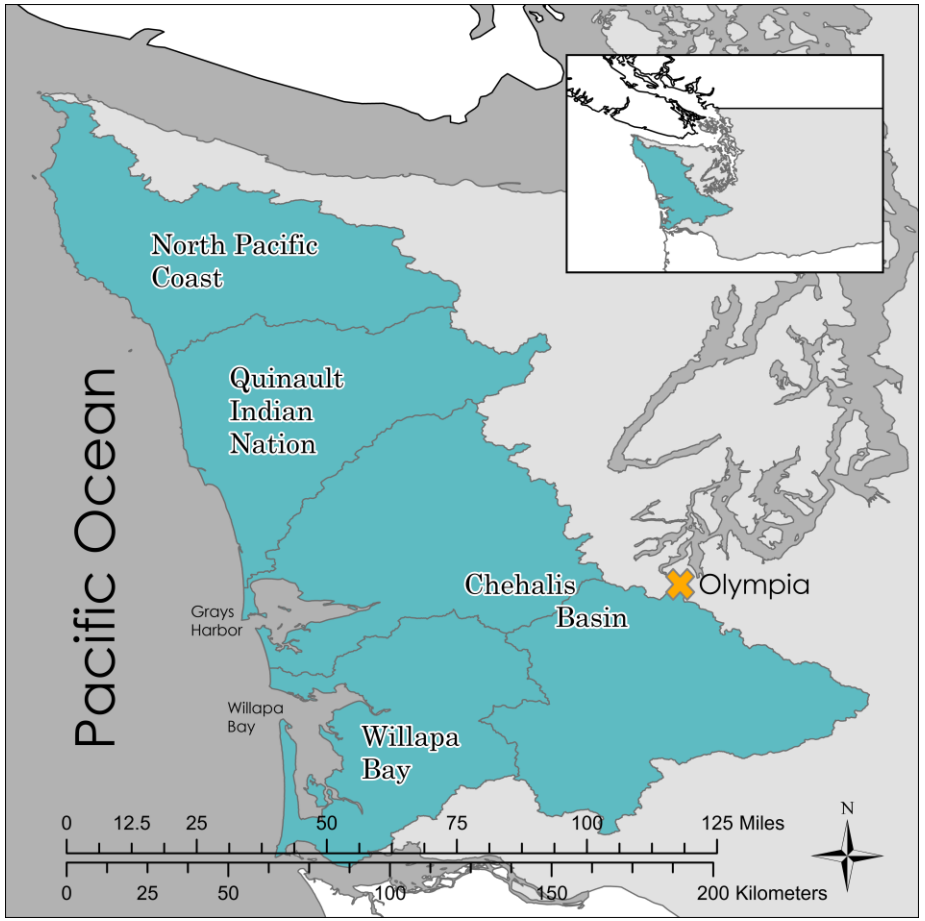
- Watersheds drain directly to the Pacific Ocean (3.75M acres)
- Population ~200,000
- Six federally recognized tribes
- 133 populations of salmon, steelhead, trout, and char



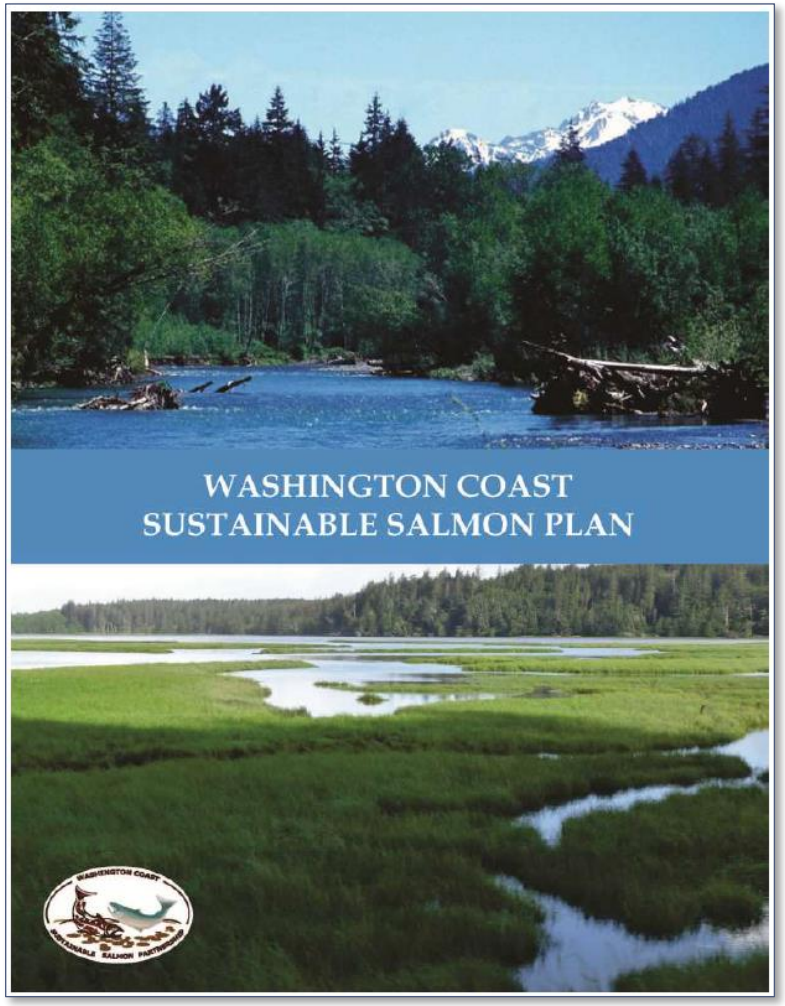
# Coast Salmon Partnership

- Regional salmon recovery organization (RCW 77.85)
- Formed by interlocal agreement among Tribes, counties, cities, and port districts
- Oversight by board of directors

Facilitate collaborative decision making in support of salmon restoration and sustainability on the Washington Coast



# Regional Salmon Plan




Strategy B1. The Coast Salmon Partnership aims to use habitat protection and restoration tools and techniques to maintain or restore in-channel salmon habitats that are key when considering climate change.

# Climate Adaptation Framework

# Climate Adaptation Framework

## Purpose

Climate vulnerabilities of salmon are generally understood

***But…***

Climate adaptation strategies are just starting to emerge

***Our Goal…***

Give practitioners and planners a forward-looking perspective on how their actions can contribute to future resilience of habitat for salmon, steelhead, trout, and char in the region

## Warming Summer Stream Temperature

Photo: Mara Zimmerman

## Decreasing Summer Low Flows

Photo: Betsy Krier

## Increasing Winter Floods

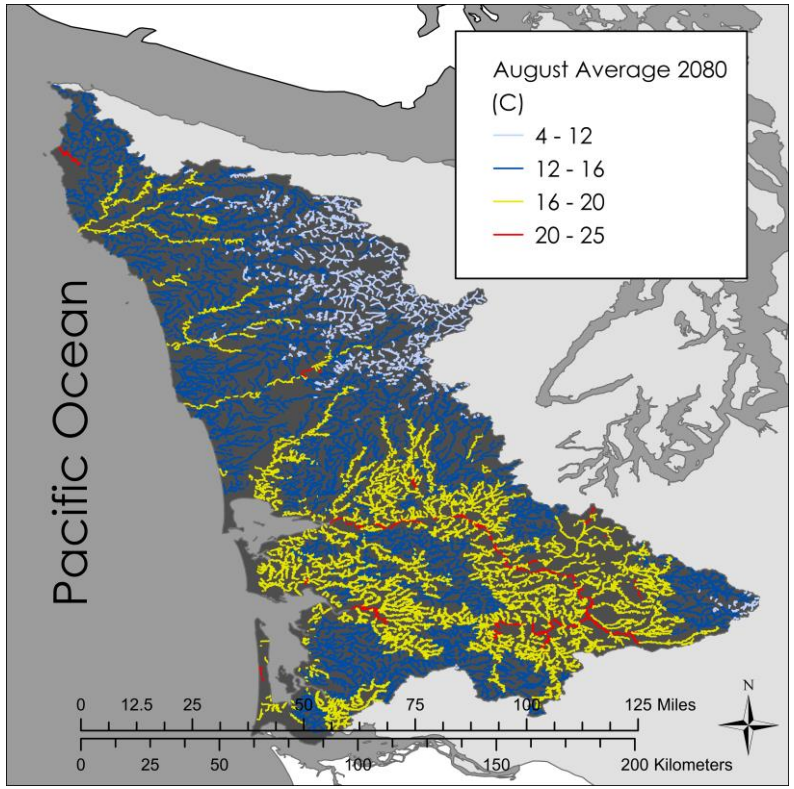
Photo: Lea Ronne

## Increasing Sea Level and Coastal Erosion

Photo: Mara Zimmerman

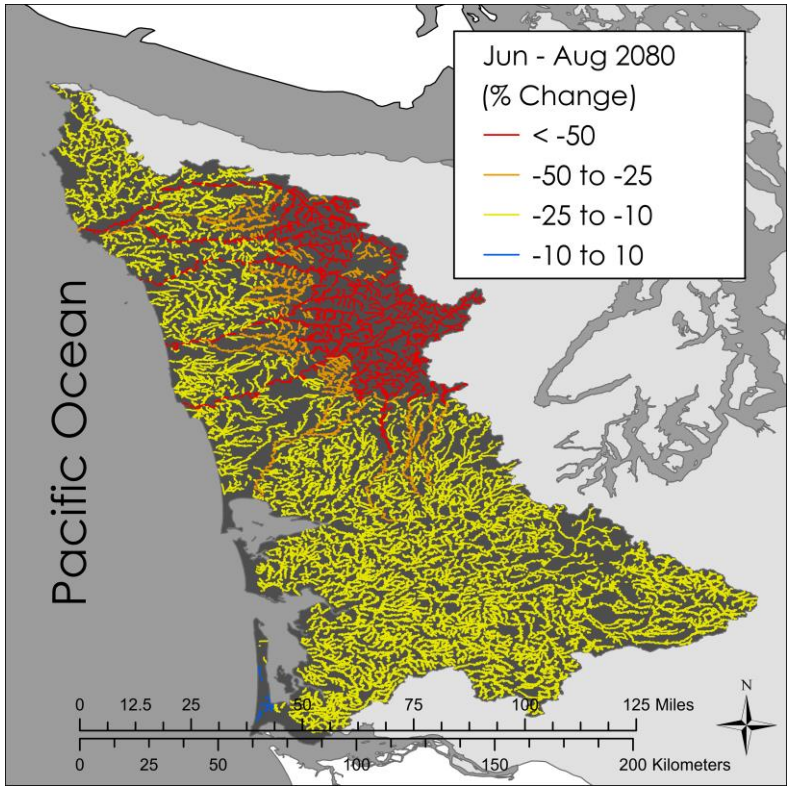
# Climate Impacted Projected for Region

## Summer Temperature



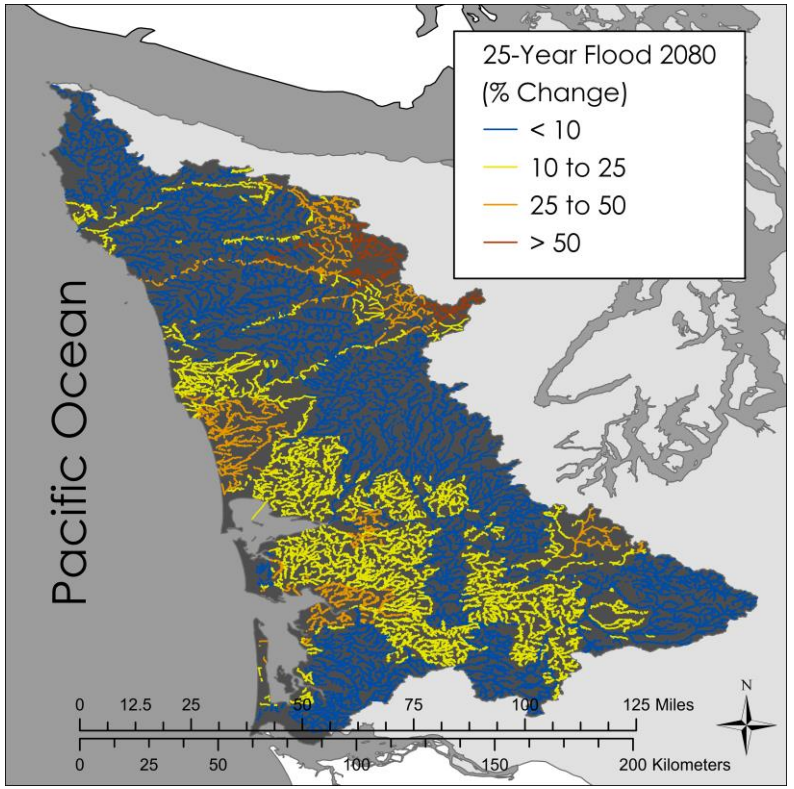

WA Dept Fish & Wildlife
Coastal Thermalscape

## Summer Low Flow




U.S. Forest Service
Western U.S. Stream Flow (VIC)

## Winter Peak Flow




U.S. Forest Service
Western U.S. Stream Flow (VIC)

# Climate Resilience Index

# Climate Resilience

## Definition

**Climate Resilience** is the ability of a species or habitat to recover from a disturbance or change without significant loss of function

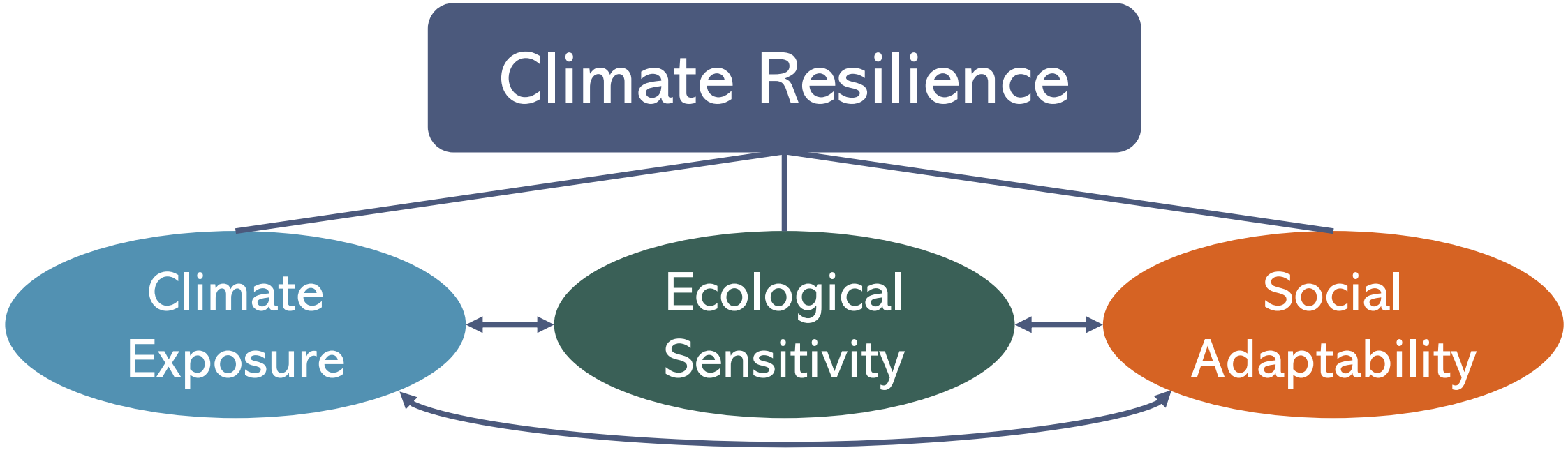
Gunderson, 2000; Glick et al., 2011

**Climate-Resilient Habitat** occurs where ecological processes to support the salmonid life cycle remain intact when exposed to climate impacts.

Working definition for Coast Salmon Partnership

# Climate Resilience

## Components




The physical, chemical, biological, and other changes occurring due to broader shifts in climate

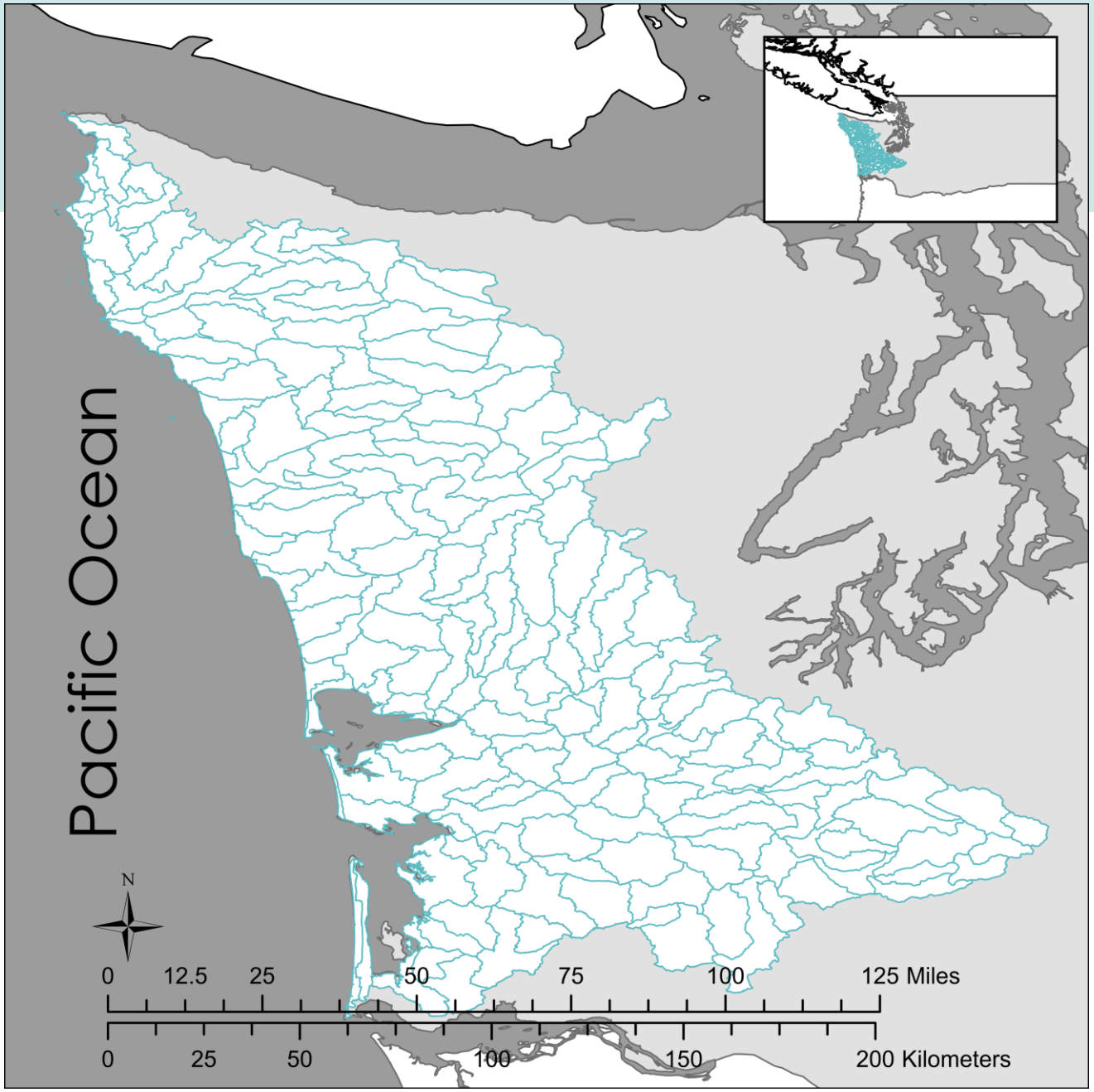
Watershed characteristics that influence the extent climate impacts will be felt in an area

The capacity of human systems to respond to changing conditions

# Climate Resilience

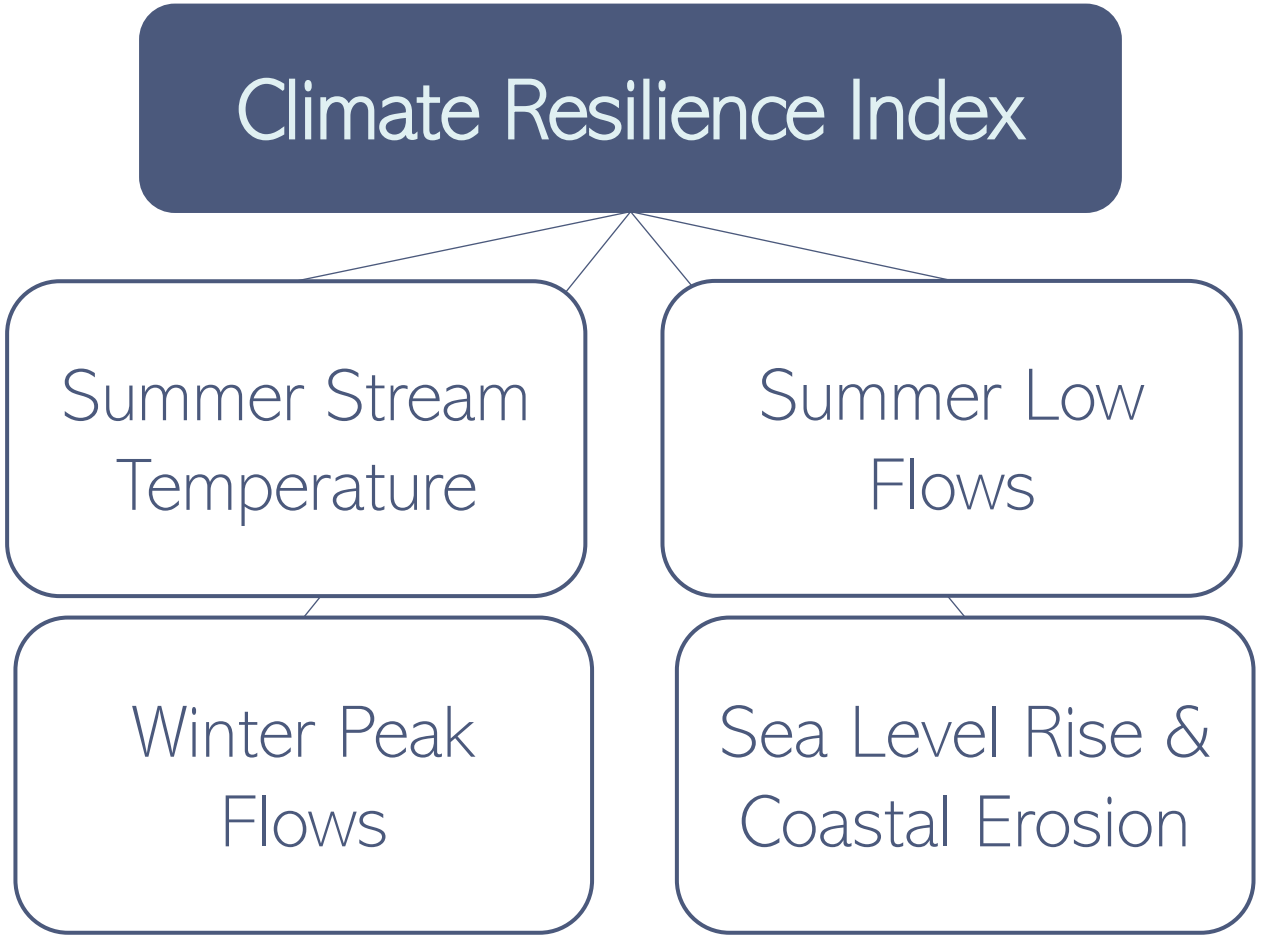
## Scale of Calculation

- **Climate Resilience**
  - Climate Exposure
  - Ecological Sensitivity
  - Social Adaptability



# Climate Resilience Index

## Organized by Climate Stressor



# Climate Resilience Index

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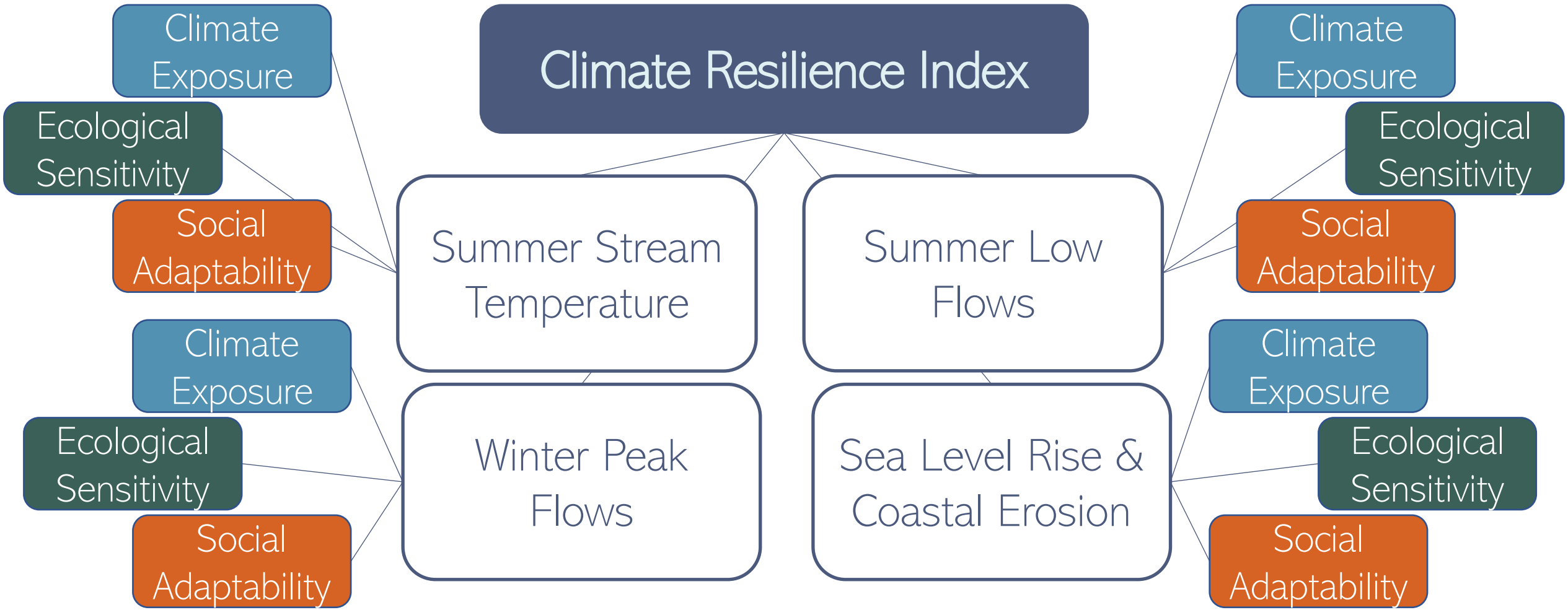
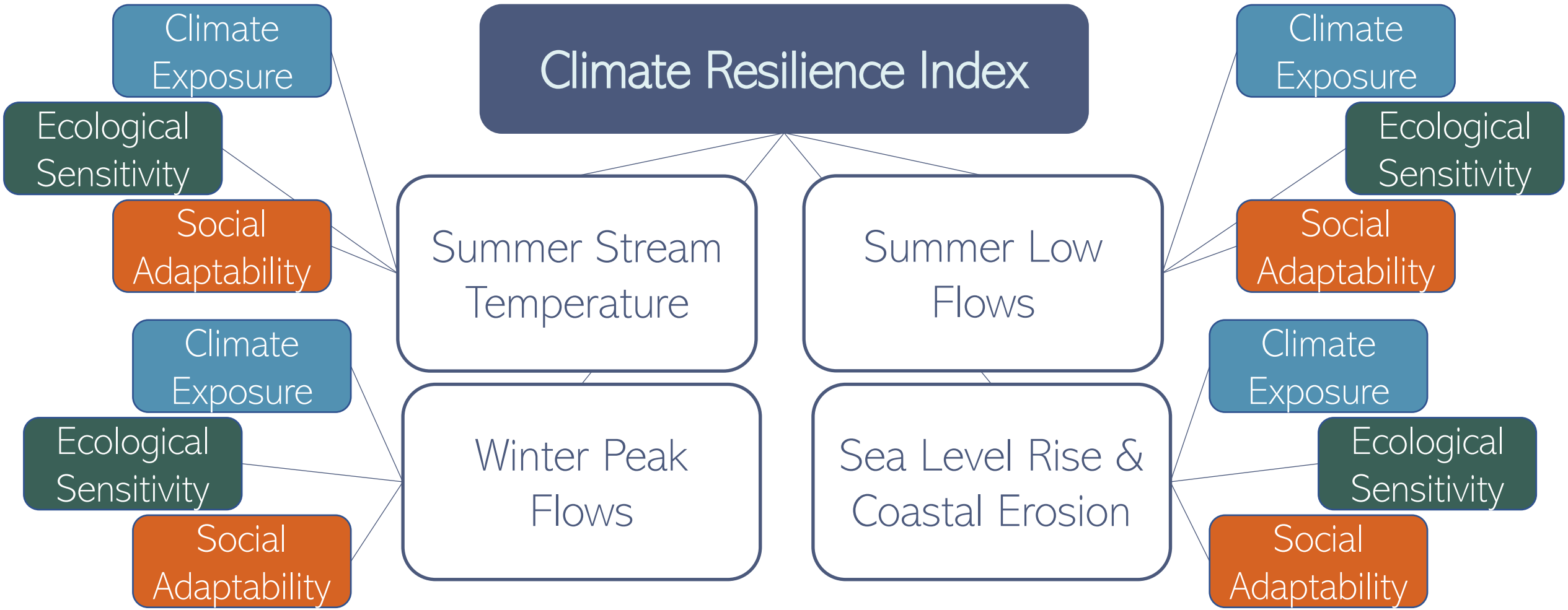


$$CRI = a*CRI_{SST} + b*CRI_{SLF} + c*CRI_{WiPF} + d*CRI_{SLR}$$



# Climate Resilience Index

## Metrics

Climate Exposure | Ecological Sensitivity | Social Adaptability

### Summer Stream Temp

- Mean August Temperature
- Base Flow Index
- Wetland Density
- Wetland Intactness
- Riparian Intactness
- Invasive Plant Index
- Regulatory Effectiveness
- Voluntary Receptivity

### Summer Low Flow

- Mean June-August Flow
- Mean September Flow
- Minimum Weekly Flow
- Base Flow Index
- Wetland Density
- Wetland Intactness
- Water Use Index
- Invasive Plant Index
- Regulatory Effectiveness
- Voluntary Receptivity

### Winter Peak Flows

- Bankfull Flow (Q1.5 Yr.)
- Peak Flow (Q25 Yr.)
- Forest Cover
- Valley Constraint
- Road Density
- Landslide Risk
- Regulatory Effectiveness
- Voluntary Receptivity

### Sea Level Rise

- Anadromous Habitat
- Upland Migration Potential
- Regulatory Effectiveness
- Voluntary Receptivity

# Climate Resilience Index

## Social Adaptability Metrics

Participatory workgroup process

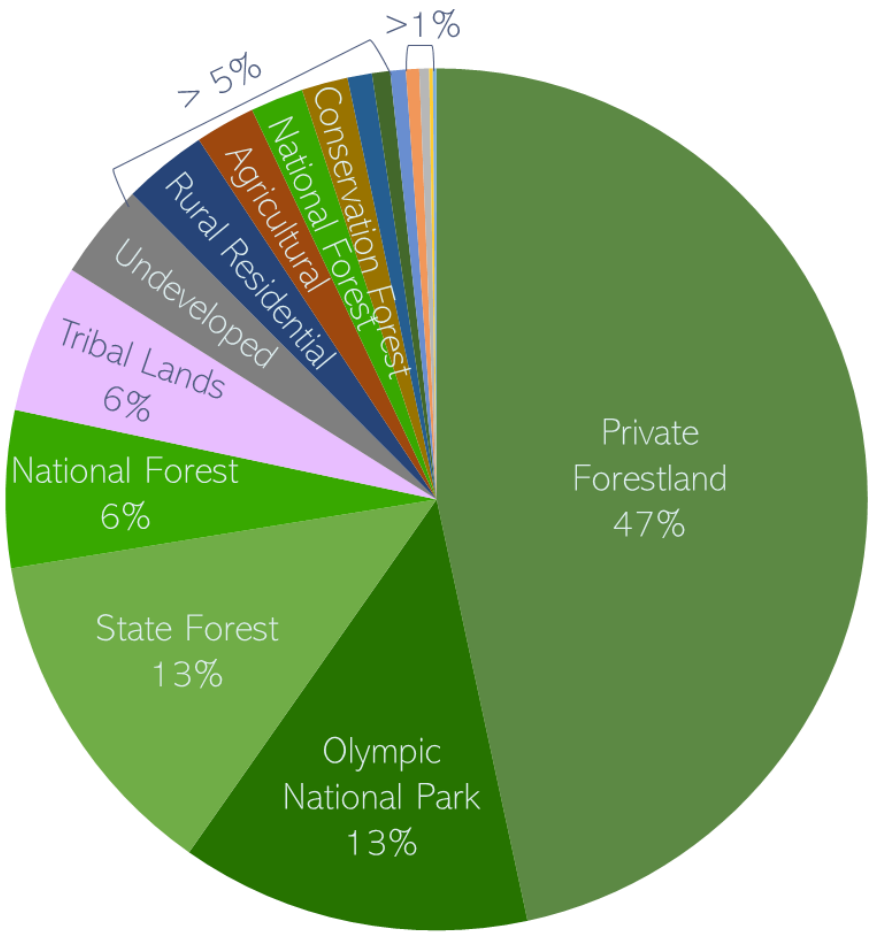
Parcels organized by land type (use, ownership)

Identify regulatory and voluntary programs

Each land type scored 1 to 5:

1. **Regulatory effectiveness**
2. **Voluntary receptivity**

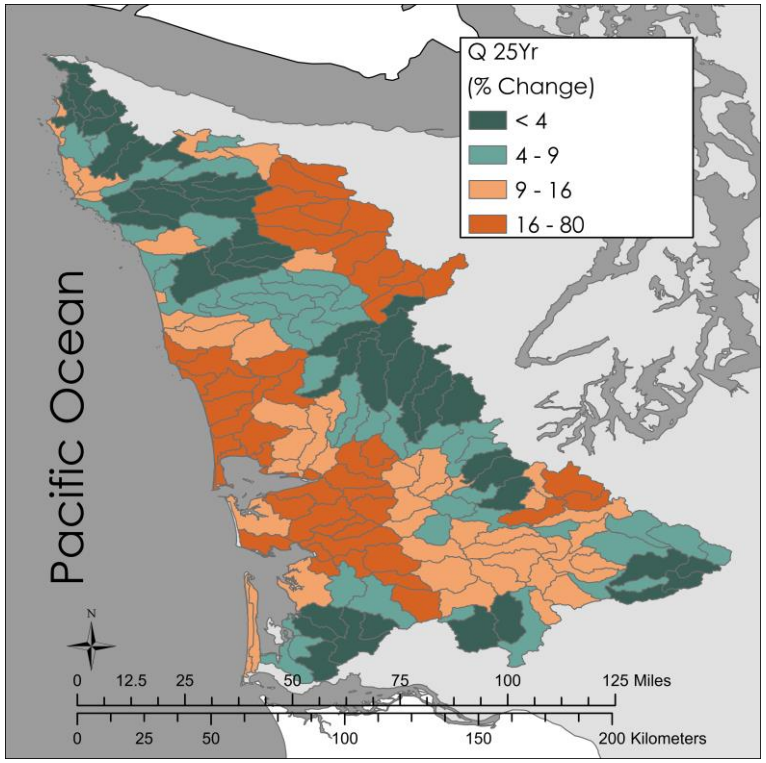
Percent regional coverage by land type



# Climate Resilience Index

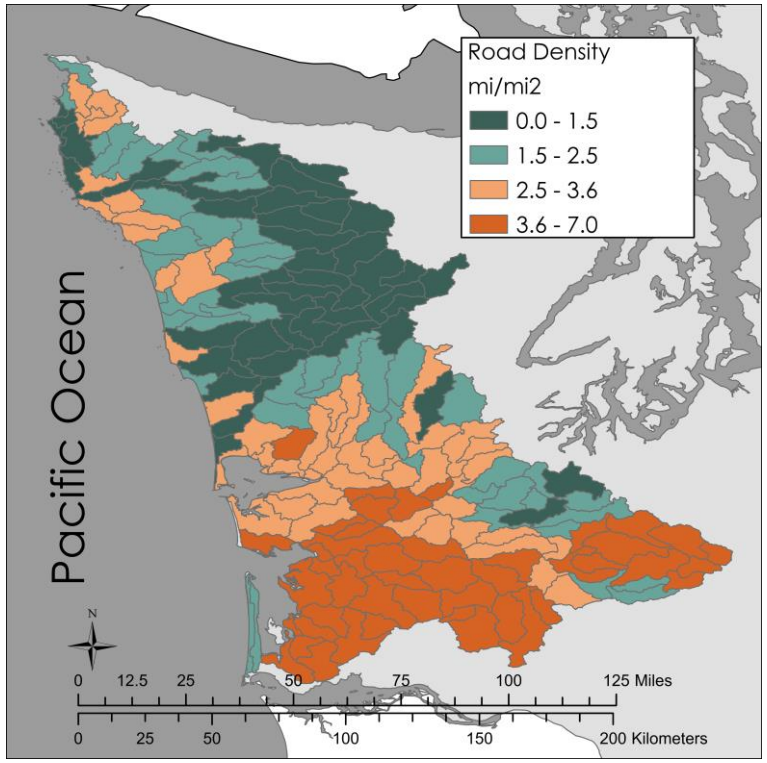
## Spatial Patterns Among Metrics (example)

### Climate Exposure



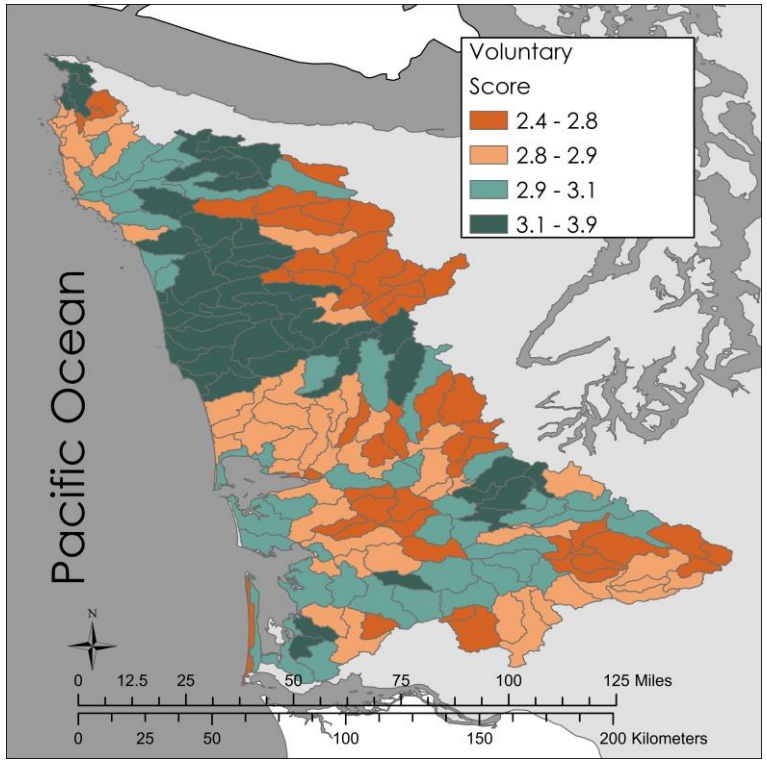

WINTER FLOODS

### Ecological Sensitivity



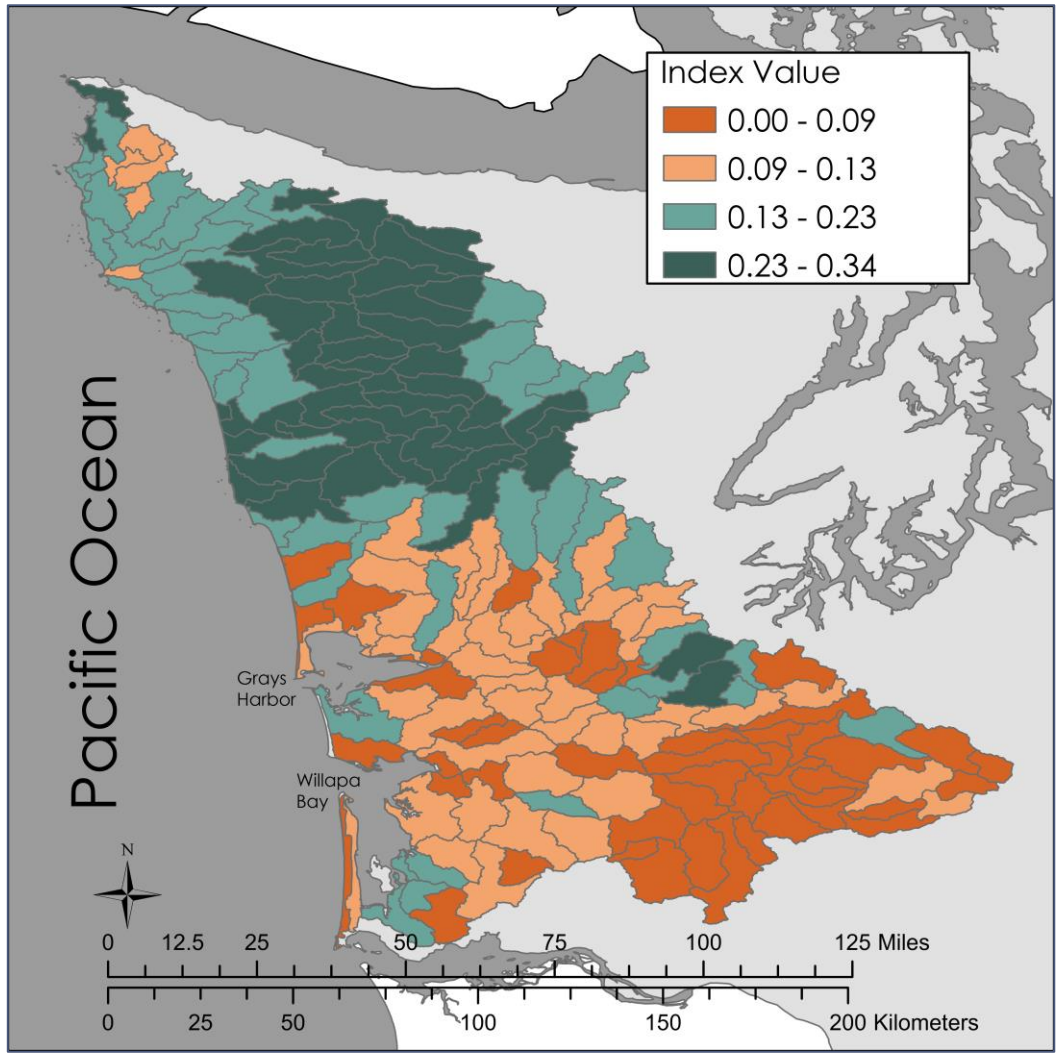

VALLEY-BOTTOM ROAD DENSITY

### Social Adaptability




VOLUNTARY ACTION RECEPTIVITY

# Climate Resilience Index for Salmon Habitat



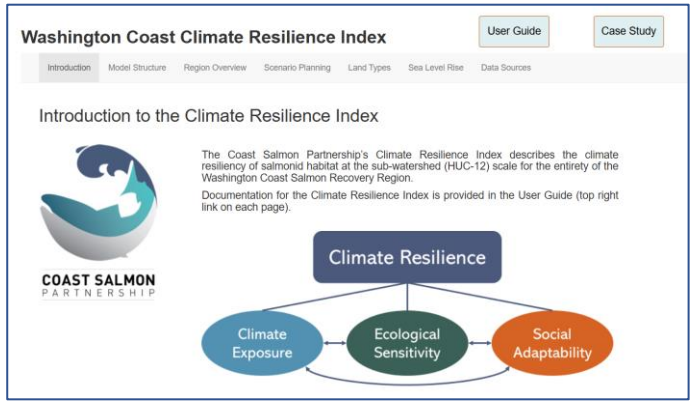

Overall index combines 22 metrics of exposure, sensitivity, and adaptability

- Describe spatial patterns in salmon habitat resilience
- Incorporate both ecological and social conditions
- Identify which actions are needed and where to improve resilience

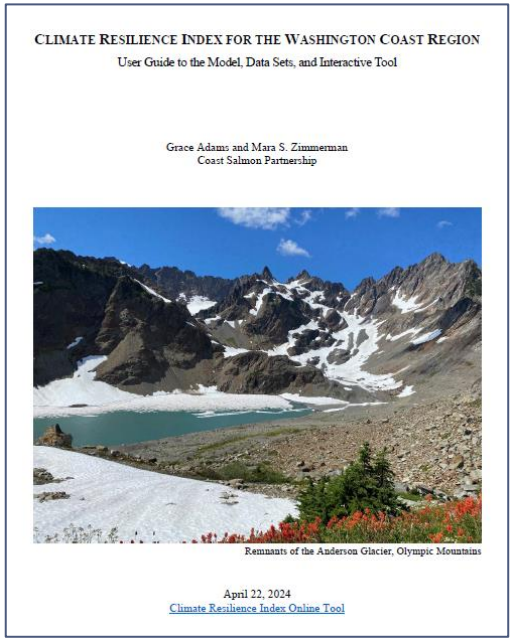
# Application

# Application
## Resources

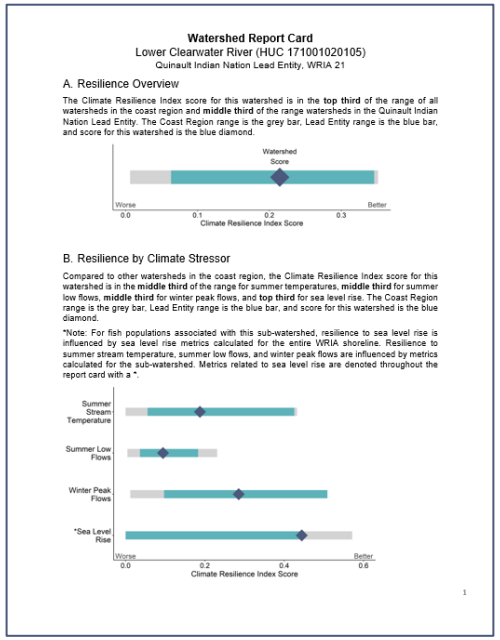
### Online Interactive Tool




### User Guide




### Watershed Report Cards



# Watershed Report Card

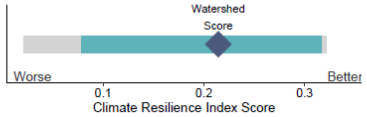
## Overview

Watershed Report Card
Lower Clearwater River (HUC 171001020105)
Quinault Indian Nation Lead Entity, WRIA 21

| Summer Coho | Fall Coho | Spring Chi-nook | Fall Chi-nook | Fall Chum | Sockeye | Summer Steel-head | Winter Steel-head | Bull Trout | Rainbow Trout | Cutthroat Trout |
|---|---|---|---|---|---|---|---|---|---|---|
| No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

**A. Resilience Overview**

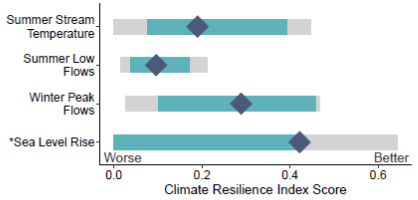
The Climate Resilience Index score for this watershed is in the *middle third* of the range for the region and *middle third* of the range for the Lead Entity. The Coast Region range is the grey bar, Lead Entity range is the blue bar, and score for this watershed is the blue diamond.




**B. Resilience by Climate Stressor**

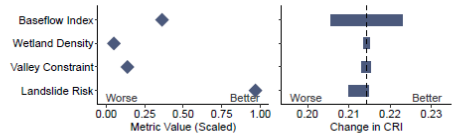
Compared to the region, the Climate Resilience Index score for this sub-watershed is in the *middle third* of the range for summer temperatures, *middle third* for summer low flows, *middle third* for winter peak flows, and *middle third* for sea level rise. The Coast Region range is the grey bar, Lead Entity range is the blue bar, and score for this watershed is the blue diamond.

*Note:* For fish populations from this sub-watershed, metrics associated with sea level rise are calculated for the WRIA shoreline whereas metrics for summer stream temperature, summer low flows, and winter peak flows are influenced by metrics calculated for the sub-watershed. Sea level rise metrics are denoted with an asterisk (*) throughout.

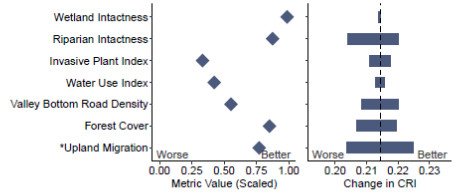



Watershed Report Card
Lower Clearwater River (HUC 171001020105)
Quinault Indian Nation Lead Entity, WRIA 21

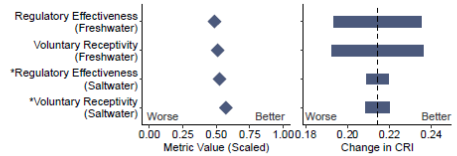
**Landscape Features (Sensitivity)**: The value of each metric represents natural limits of the watershed. To improve climate resilience of salmon habitat, actions should protect and/or restore the function of these landscape features.




**Landscape Characteristics (Sensitivity)**: Value of each metric represents human impacts on watershed function. To improve climate resilience of salmon habitat, actions should protect landscape characteristics in better condition and restore those in worse condition.




**Social Adaptability**: Value of each metric represents the human willingness to adapt behavior in a way that protects and/or restores watershed function. To improve climate resilience of salmon habitat, actions should focus on outreach and education, especially if adaptability is low.




Watershed Report Card
Lower Clearwater River (HUC 171001020105)
Quinault Indian Nation Lead Entity, WRIA 21

**D. Metric Values**

Metrics were scaled 0 (contribute to low resilience) to 1 (contribute to high resilience). All figures in this report card show the scaled value of each metric. The table below shows the scaled value and actual value of each metric. See *User Guide* for more information on metric definitions and scaling.

| Metric | Scaled Value | Actual Value | Unit |
|---|---|---|---|
| **Climate Exposure** | | | |
| August Stream Temp | 0.85 | 14.89 | Degrees C by 2080 |
| Low Flow (Jun-Aug) | 0.80 | -16.88 | % Change by 2080 |
| Low Flow (Sept) | 0.73 | -22.75 | % Change by 2080 |
| Low Flow (Minimum) | 0.81 | -15.99 | % Change by 2080 |
| Bankfull Flood (Q1.5 Yr) | 1.00 | 0.00 | % Change by 2080 |
| Peak Flood (Q25 Yr) | 0.96 | 3.41 | % Change by 2080 |
| Anadromous Miles | 1.00 | 7.87 | Miles |
| **Landscape Features** | | | |
| Base Flow Index | 0.36 | 49.13 | N/A |
| Wetland Density | 0.05 | 1.50 | % |
| Valley Constraint | 0.14 | 7.95 | % Depositional Reaches |
| Landslide Risk | 0.97 | 0.70 | % |
| **Landscape Conditions** | | | |
| Wetland Intactness | 0.99 | 99.23 | % |
| Riparian Intactness | 0.87 | 89.83 | % |
| Invasive Plant Index | 0.33 | 9.00 | N/A |
| Water Use Index | 0.42 | 42.28 | % |
| Valley Bottom Road Density | 0.55 | 3.11 | Mile/Sq. Mile |
| Forest Cover | 0.85 | 84.51 | % |
| Upland Migration | 0.77 | 73.63 | % |
| **Social Adaptability** | | | |
| Regulatory Effectiveness (Freshwater) | 0.49 | 3.22 | N/A |
| Voluntary Receptivity (Freshwater) | 0.51 | 3.27 | N/A |
| Regulatory Effectiveness (Saltwater) | 0.52 | 3.30 | N/A |
| Voluntary Receptivity (Saltwater) | 0.57 | 3.40 | N/A |

Watershed Report Card
Lower Clearwater River (HUC 171001020105)
Quinault Indian Nation Lead Entity, WRIA 21

**E. Land Types**

Land Type information can be used to interpret scores representing regulatory effectiveness and receptivity to voluntary action. The table below shows the percent of each land type in this sub-watershed. See *User Guide* for a description of land type categories.

| Land Type | Percent |
|---|---|
| Commercial | 0.01 |
| Conservation Forests | 14.91 |
| Industrial | 0.44 |
| Olympic National Park | 0.07 |
| Private Forestland | 28.28 |
| Rural Residential | 0.76 |
| State Upland Forest | 53.14 |
| Tribal Lands | 0.12 |
| Undeveloped | 0.85 |
| WDFW Wildlife Areas | 0.02 |

Climate resilience score and climate stressors

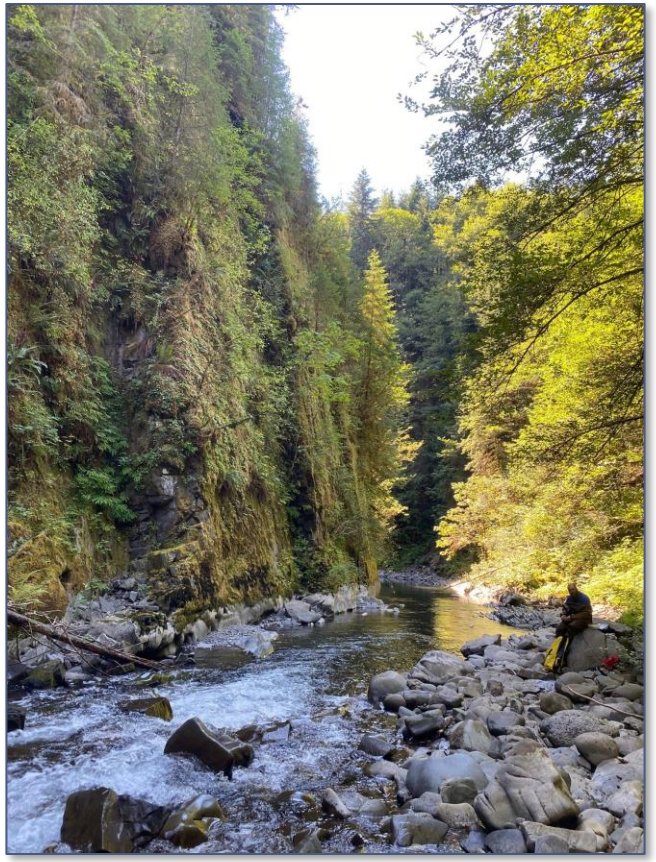
What is influencing resilience? How to improve resilience?

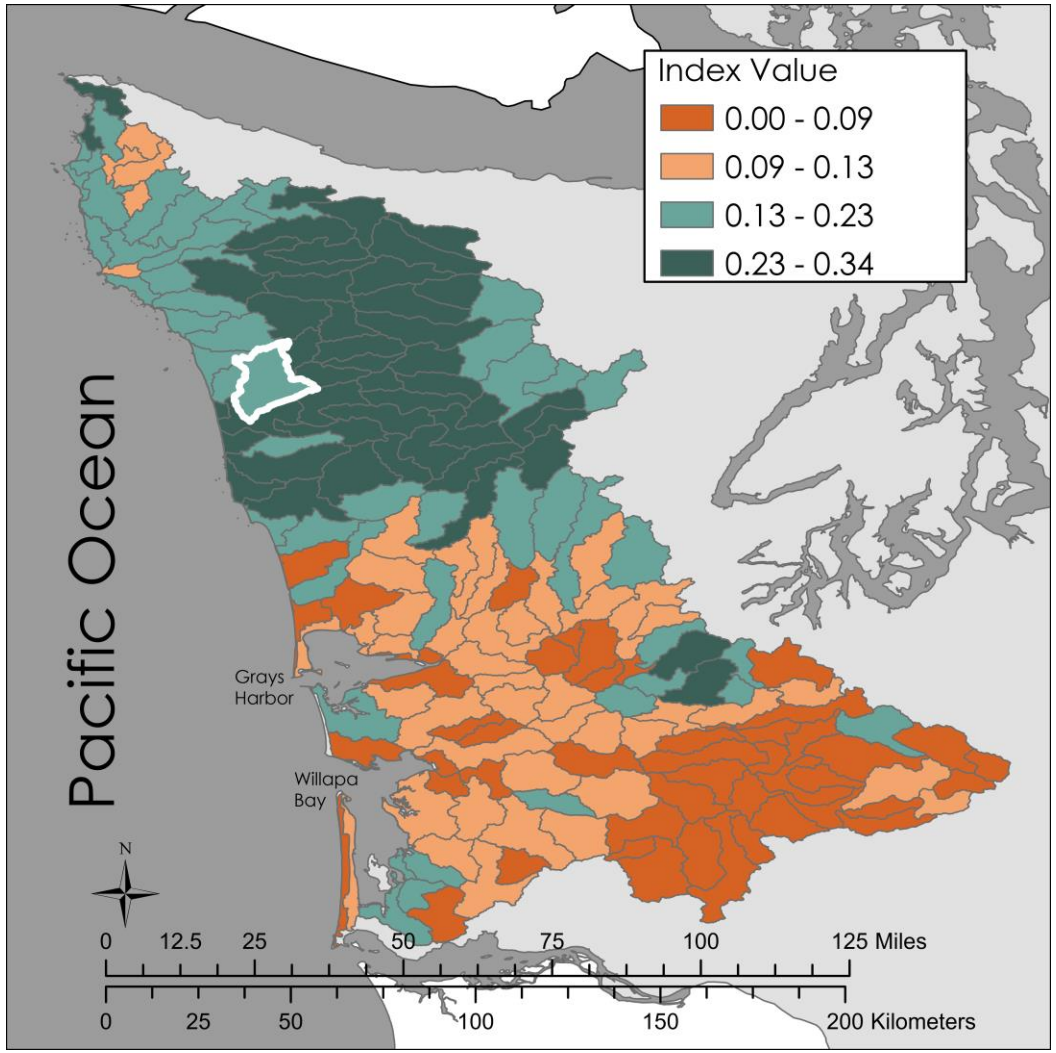
Metric Values

Land Types

# Case Study

## Lower Clearwater River

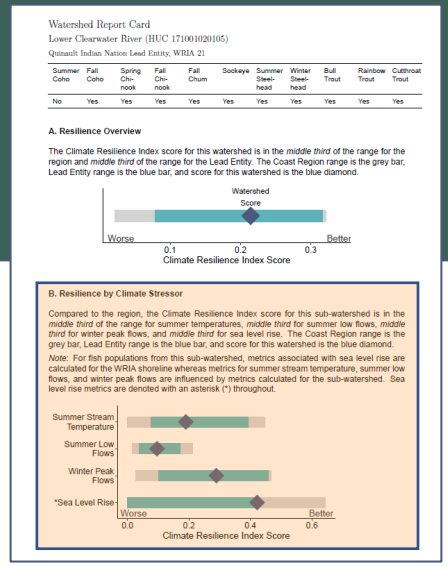




# Case Study

## Lower Clearwater River

Climate resilience score and climate stressors



Watershed Report Card

Lower Clearwater River (HUC 171001020105)

Quinault Indian Nation Lead Entity, WRIA 21

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**A. Resilience Overview**

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**B. Resilience by Climate Stressor**

Compared to the region, the Climate Resilience Index score for this sub-watershed is in the *middle third* of the range for summer temperatures, *middle third* for summer low flows, *middle third* for winter peak flows, and *middle third* for sea level rise. The Coast Region range is the grey bar, Lead Entity range is the blue bar, and score for this watershed is the blue diamond.

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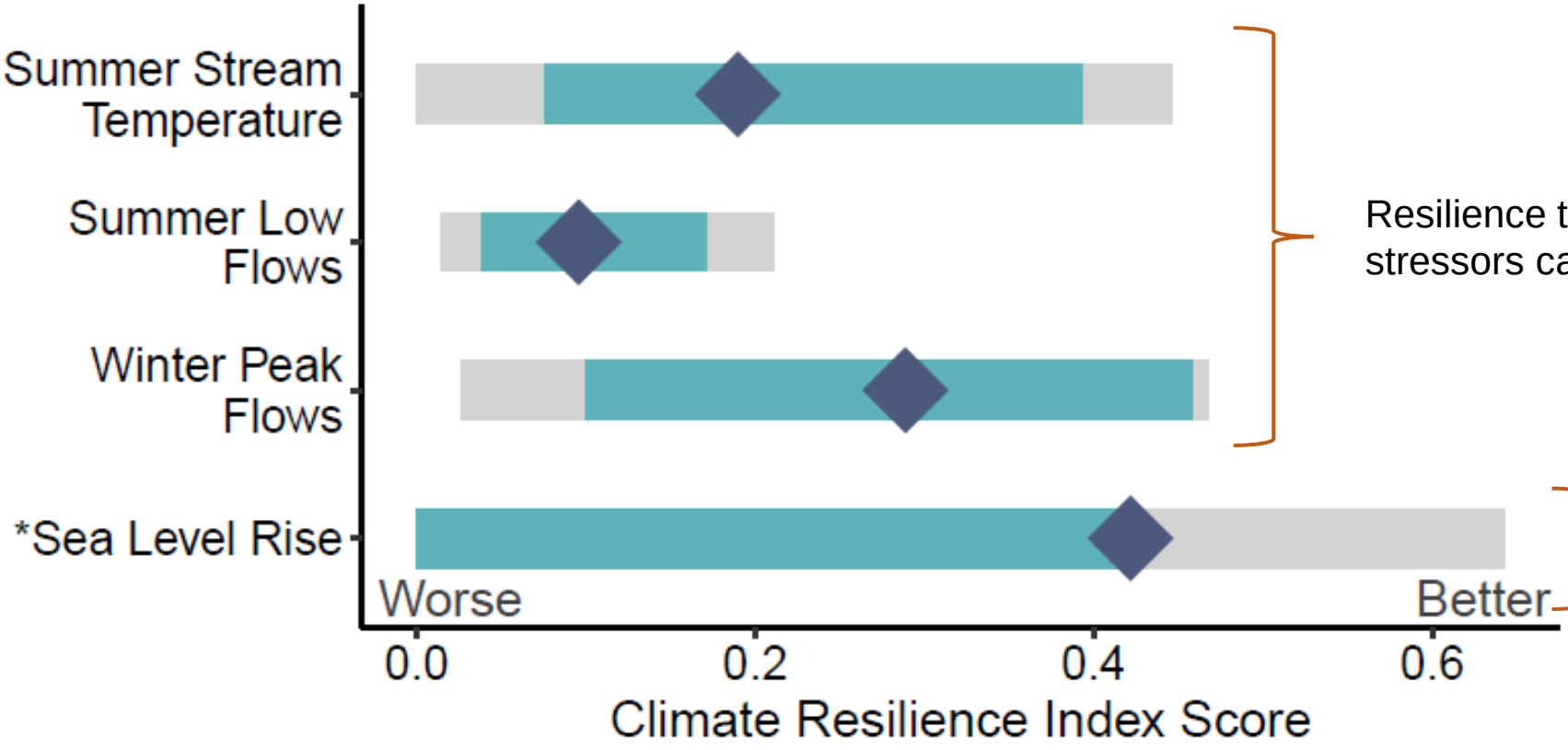



Resilience to these stressors can be improved

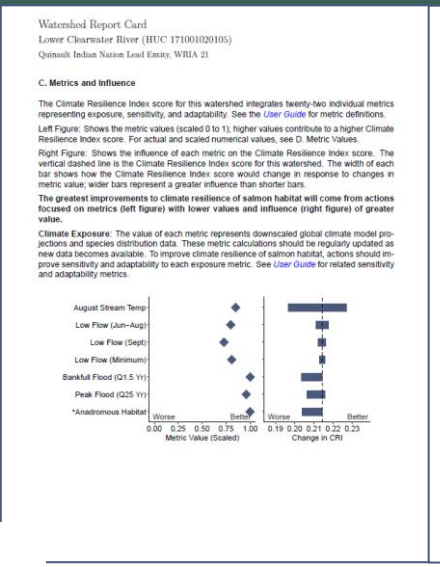
External factor that affects resilience. No estuary habitat in this watershed.

# Case Study

## Lower Clearwater River

What is influencing resilience?

How to improve resilience?


Watershed Report Card
Lower Clearwater River (HUC 171001020105)
Quinault Indian Nation Lead Entity, WRIA 21

C. Metrics and Influence

The Climate Resilience Index score for this watershed integrates twenty-two individual metrics representing exposure, sensitivity, and adaptability. See the User Guide for metric definitions.

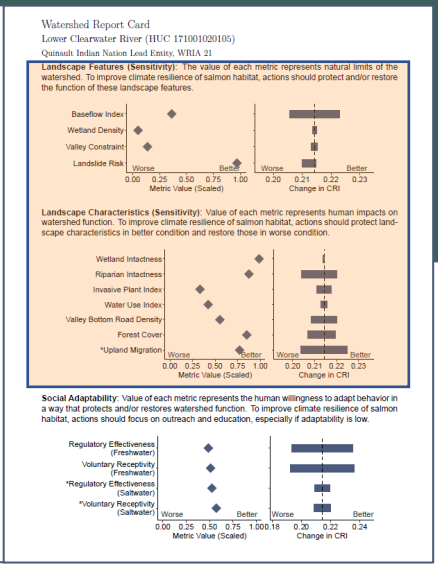
Left Figure: Shows the metric values (scaled 0 to 1); higher values contribute to a higher Climate Resilience Index score. For actual and scaled numerical values, see D. Metric Values.

Right Figure: Shows the influence of each metric on the Climate Resilience Index score. The vertical dashed line is the Climate Resilience Index score for this watershed. The width of each bar shows how the Climate Resilience Index score would change in response to changes in metric value; wider bars represent a greater influence than shorter bars.

**The greatest improvements to climate resilience of salmon habitat will come from actions focused on metrics (left figure) with lower values and influence (right figure) of greater value.**

**Climate Exposure**: The value of each metric represents downscaled global climate model projections and species distribution data. These metric calculations should be regularly updated as new data becomes available. To improve climate resilience of salmon habitat, actions should improve sensitivity and adaptability to each exposure metric. See User Guide for related sensitivity and adaptability metrics.

August Stream Temp
Low Flow (Jun–Aug)
Low Flow (Sept)
Low Flow (Minimum)
Bankfull Flood (Q1.5 Yr)
Peak Flood (Q25 Yr)
*Anadromous Habitat
Worse
Better
0.00 0.25 0.50 0.75 1.00
Metric Value (Scaled)
0.19 0.20 0.21 0.22 0.23
Change in CRI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Lower Clearwater River (HUC 171001020105)
Quinault Indian Nation Lead Entity, WRIA 21

**Landscape Features (Sensitivity)**: The value of each metric represents natural limits of the watershed. To improve climate resilience of salmon habitat, actions should protect and/or restore the function of these landscape features.

Baseflow Index
Wetland Density
Valley Constraint
Landslide Risk
Worse
Better
0.00 0.25 0.50 0.75 1.00
Metric Value (Scaled)
0.20 0.21 0.22 0.23
Change in CRI

**Landscape Characteristics (Sensitivity)**: Value of each metric represents human impacts on watershed function. To improve climate resilience of salmon habitat, actions should protect landscape characteristics in better condition and restore those in worse condition.

Wetland Intactness
Riparian Intactness
Invasive Plant Index
Water Use Index
Valley Bottom Road Density
Forest Cover
*Upland Migration
Worse
Better
0.00 0.25 0.50 0.75 1.00
Metric Value (Scaled)
0.20 0.21 0.22 0.23
Change in CRI

**Social Adaptability**: Value of each metric represents the human willingness to adapt behavior in a way that protects and/or restores watershed function. To improve climate resilience of salmon habitat, actions should focus on outreach and education, especially if adaptability is low.

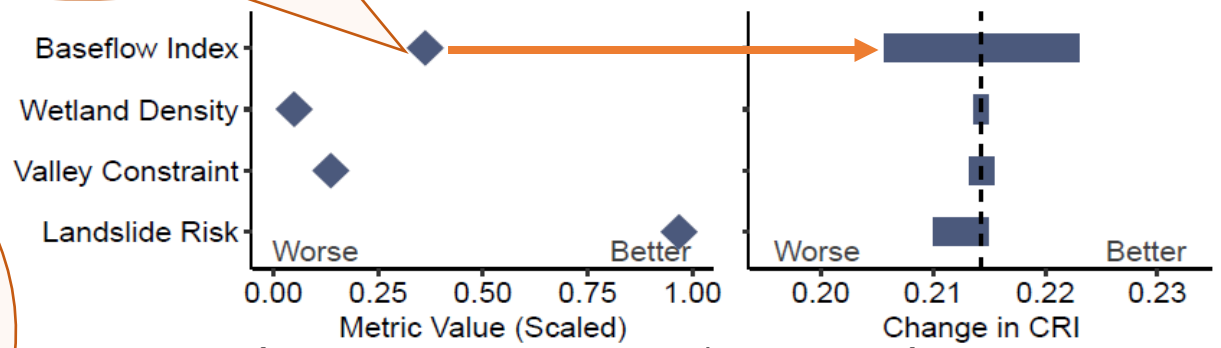
Regulatory Effectiveness (Freshwater)
Voluntary Receptivity (Freshwater)
*Regulatory Effectiveness (Saltwater)
*Voluntary Receptivity (Saltwater)
Worse
Better
0.00 0.25 0.50 0.75 1.00
Metric Value (Scaled)
0.18 0.20 0.22 0.24
Change in CRI

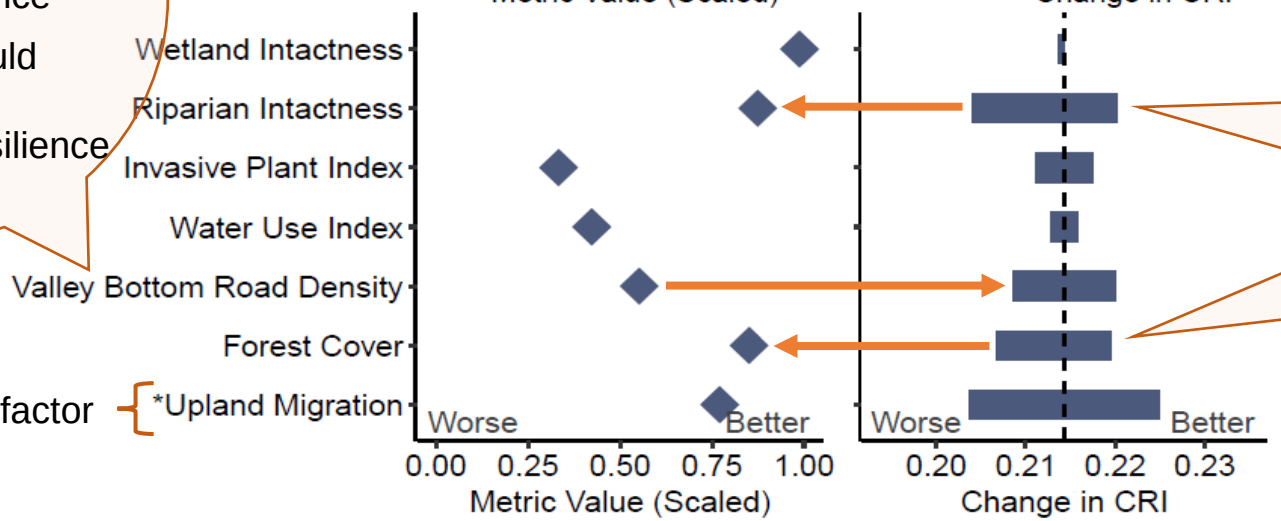
**Baseflow Index**

- Moderate condition + high influence
- Naturally limited

**Valley-Bottom Road Density**

- Moderate condition + high influence
- Changes could increase or decrease resilience




**Riparian Intactness and Forest Cover**

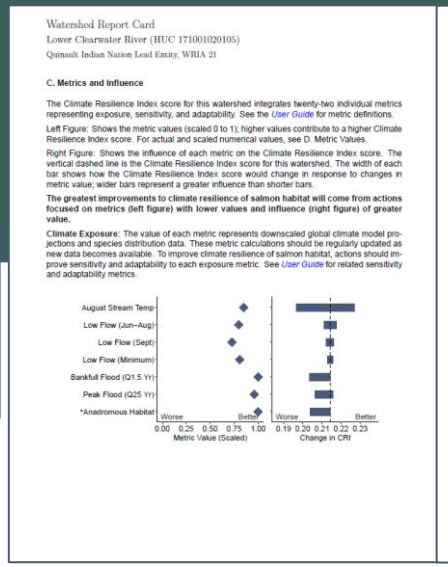
- Good condition + high influence
- Changes could increase or decrease resilience

# Case Study

## Lower Clearwater River

What is influencing resilience?

How to improve resilience?


Watershed Report Card
Lower Clearwater River (HUC 171001020105)
Quinault Indian Nation Lead Entity, WRIA 21

C. Metrics and Influence

The Climate Resilience Index score for this watershed integrates twenty-two individual metrics representing exposure, sensitivity, and adaptability. See the User Guide for metric definitions.

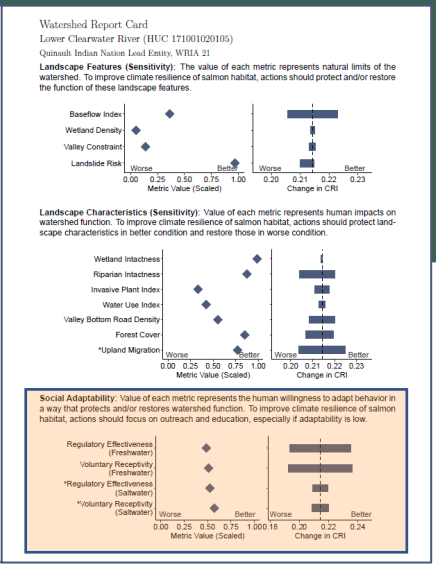
Left Figure: Shows the metric values (scaled 0 to 1); higher values contribute to a higher Climate Resilience Index score. For actual and scaled numerical values, see D. Metric Values.

Right Figure: Shows the influence of each metric on the Climate Resilience Index score. The vertical dashed line is the Climate Resilience Index score for this watershed. The width of each bar shows how the Climate Resilience Index score would change in response to changes in metric value; wider bars represent a greater influence than shorter bars.

**The greatest improvements to climate resilience of salmon habitat will come from actions focused on metrics (left figure) with lower values and influence (right figure) of greater value.**

**Climate Exposure**: The value of each metric represents downscaled global climate model projections and species distribution data. These metric calculations should be regularly updated as new data becomes available. To improve climate resilience of salmon habitat, actions should improve sensitivity and adaptability to each exposure metric. See User Guide for related sensitivity and adaptability metrics.

August Stream Temp
Low Flow (Jun–Aug)
Low Flow (Sept)
Low Flow (Minimum)
Bankfull Flood (Q1.5 Yr)
Peak Flood (Q25 Yr)
*Anadromous Habitat
Worse
Better
0.00 0.25 0.50 0.75 1.00
Metric Value (Scaled)
0.19 0.20 0.21 0.22 0.23
Change in CRI


Watershed Report Card
Lower Clearwater River (HUC 171001020105)
Quinault Indian Nation Lead Entity, WRIA 21

**Landscape Features (Sensitivity)**: The value of each metric represents natural limits of the watershed. To improve climate resilience of salmon habitat, actions should protect and/or restore the function of these landscape features.

Baseflow Index
Wetland Density
Valley Constraint
Landslide Risk
Worse
Better
0.00 0.25 0.50 0.75 1.00
Metric Value (Scaled)
0.20 0.21 0.22 0.23
Change in CRI

**Landscape Characteristics (Sensitivity)**: Value of each metric represents human impacts on watershed function. To improve climate resilience of salmon habitat, actions should protect landscape characteristics in better condition and restore those in worse condition.

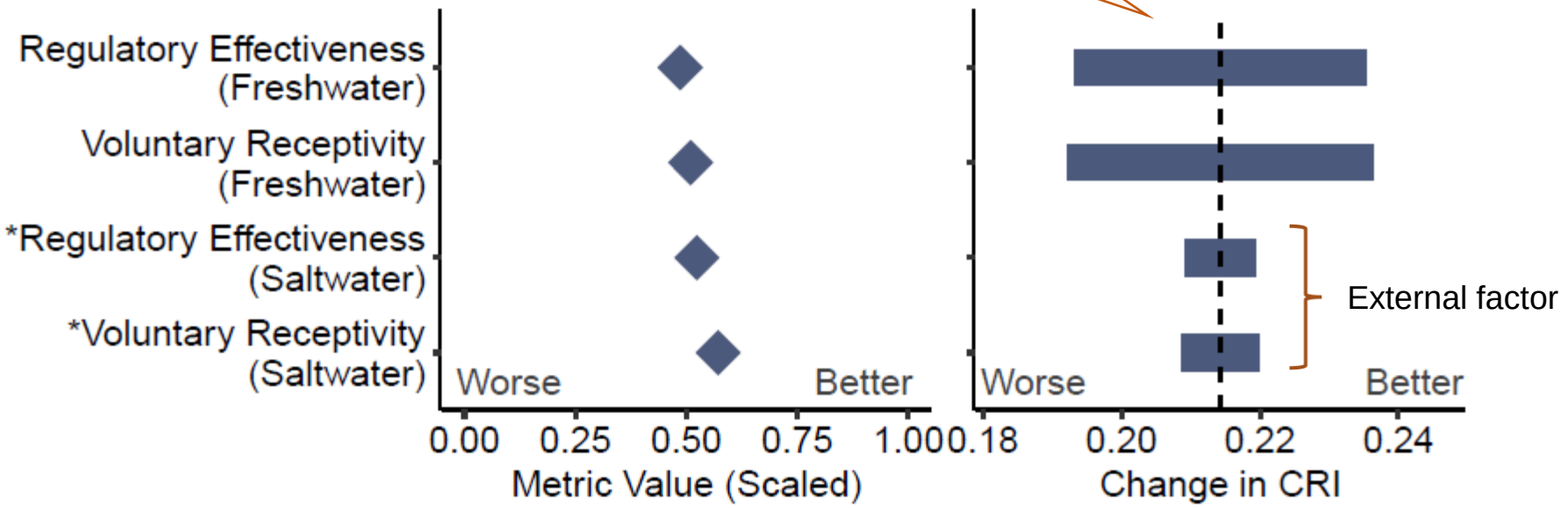
Wetland Intactness
Riparian Intactness
Invasive Plant Index
Water Use Index
Valley Bottom Road Density
Forest Cover
*Upland Migration
Worse
Better
0.00 0.25 0.50 0.75 1.00
Metric Value (Scaled)
0.20 0.21 0.22 0.23
Change in CRI

**Social Adaptability**: Value of each metric represents the human willingness to adapt behavior in a way that protects and/or restores watershed function. To improve climate resilience of salmon habitat, actions should focus on outreach and education, especially if adaptability is low.

Regulatory Effectiveness (Freshwater)
Voluntary Receptivity (Freshwater)
*Regulatory Effectiveness (Saltwater)
*Voluntary Receptivity (Saltwater)
Worse
Better
0.00 0.25 0.50 0.75 1.00 0.18
Metric Value (Scaled)
0.20 0.22 0.24
Change in CRI

Freshwater Regulatory Effectiveness and Voluntary Receptivity

- Moderate condition + high influence
- Resilience may increase or decrease if adaptability changes



# Case Study

## Lower Clearwater River

Interpretation:

By considering ecological sensitivity and social adaptability together, priority actions for the Lower Clearwater River are:

1. Maintain riparian intactness and promote maturation of riparian forests (maintain metric value, improve quality not captured by metric)
2. Maintain intactness of upland forest where practical (maintain metric value)
3. Decrease valley-bottom road density where practical (improve metric value)
4. Increase collaborations with forest managers to advance priorities 1-3

# Coordination, Collaboration, and Next Steps

# Next Steps

**CRI is a tool designed to be refined as new data becomes available!**

Gaps in Existing CRI Data:

- Coast-wide spatial footprint of sea level rise
- Wetland data (e.g., cryptic wetlands)
- Climate projections are continually updated

Impacts Not Yet Included:

- Wildfire
- Ocean conditions
  - Ocean acidification
  - Harmful algal blooms
- Invasive species interactions (e.g., green crab, smallmouth bass)

# Next Steps

1. Value added: climate resilience lens causes us to think about restoration actions AND land use together
2. These tools can be used to:
    a. develop and evaluate habitat projects
    b. prioritize and coordinate outreach strategies
    c. refine watershed-scale restoration strategies
    d. identify species-specific vulnerabilities

# Thank you!


Photo: November 2023 Workshop

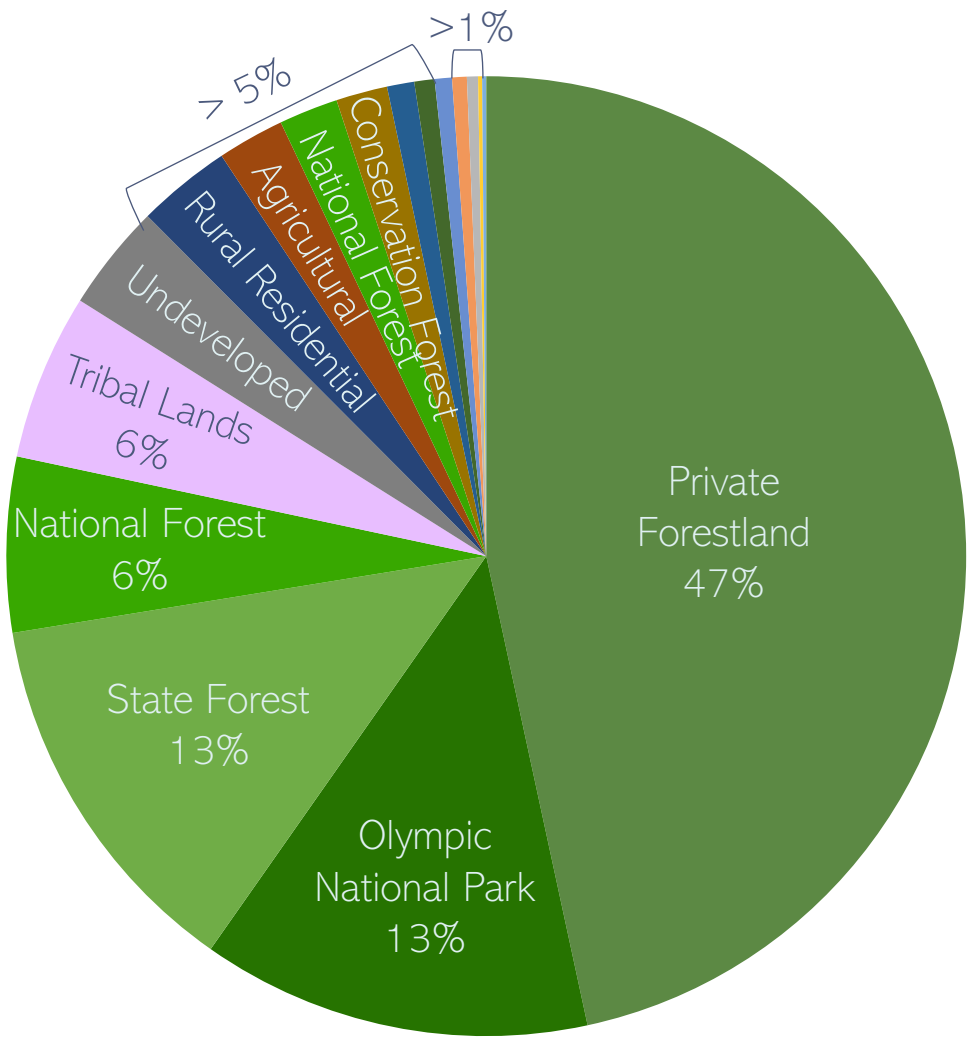
# Additional Slides

# Species Informed Climate Resilience Index

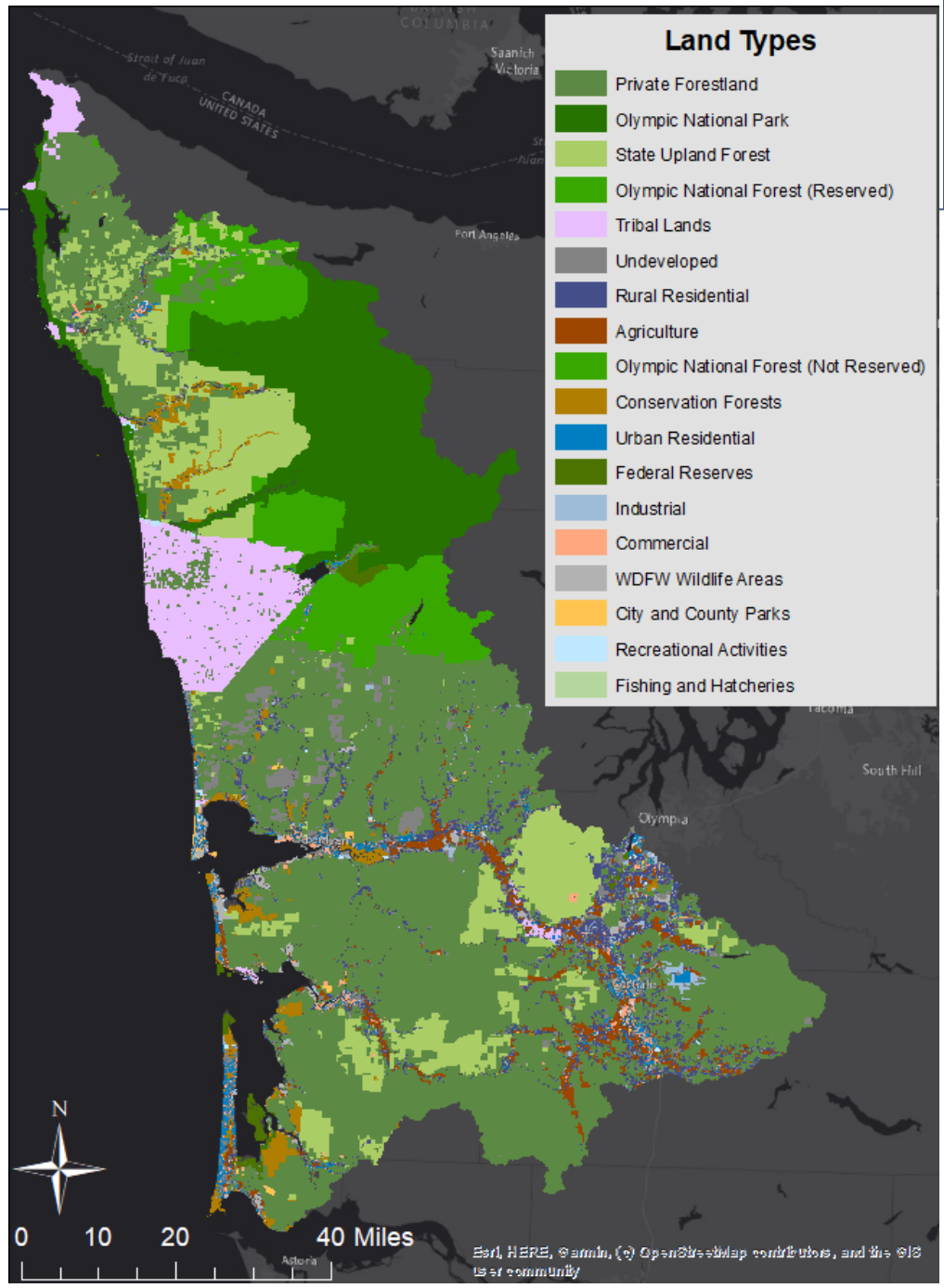
$$CRI = a*CRI_{SST} + b*CRI_{SLF} + c*CRI_{WiPF} + d*CRI_{SLR}$$

| Species/Run | a | b | c | d |
|---|---|---|---|---|
| Summer Coho | 0.3 | 0.5 | 0.1 | 0.1 |
| Coho | 0.3 | 0.3 | 0.3 | 0.1 |
| Spring/Summer Chinook | 0.5 | 0.1 | 0.2 | 0.2 |
| Fall Chinook | 0.2 | 0.3 | 0.4 | 0.3 |
| Chum | 0 | 0 | 0.7 | 0.3 |
| Sockeye | 0.6 | 0.2 | 0.2 | 0 |
| Summer Steelhead | 0.5 | 0.4 | 0.1 | 0 |
| Winter Steelhead | 0.4 | 0.4 | 0.2 | 0 |
| Bull Trout | 0.7 | 0.2 | 0.05 | 0.05 |
| Cutthroat | 0.2 | 0.5 | 0.2 | 0.1 |

# Social Adaptability – Land Types




- Private Forestland
- Olympic National Park
- State Upland Forest
- Olympic National Forest - Reserved
- Tribal
- Undeveloped
- Residential - Rural
- Agricultural
- Olympic National Forest - Not Reserved
- Conservation Forests
- Residential - Urban
- Federal Reserves
- Industrial
- Commercial
- WDFW Wildlife Areas
- City and County Parks
- Recreational Activities
- Hatcheries



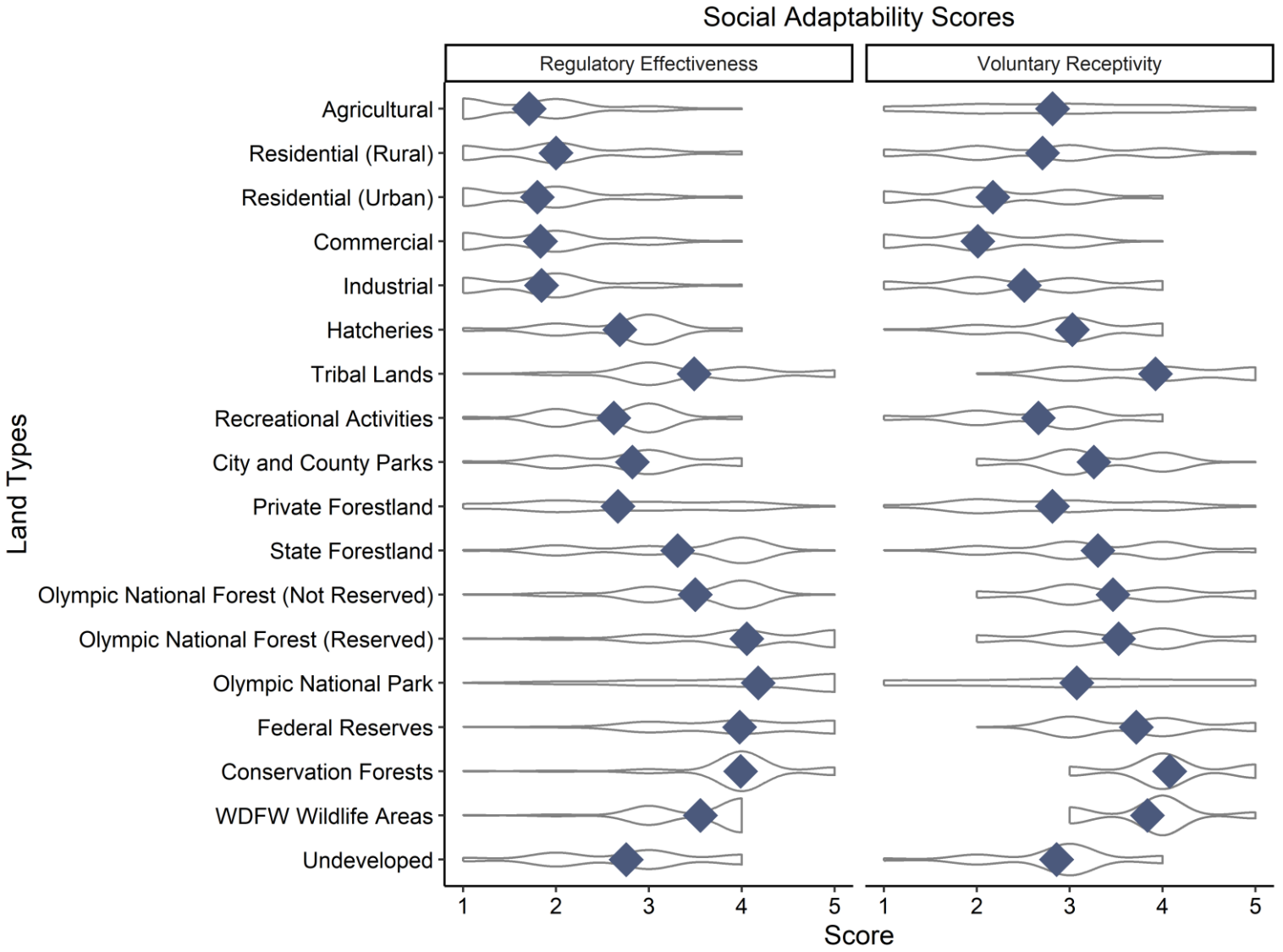
# Social Adaptability – Scoring Process

## Regulatory Effectiveness

Are regulatory protections effective on this land type?

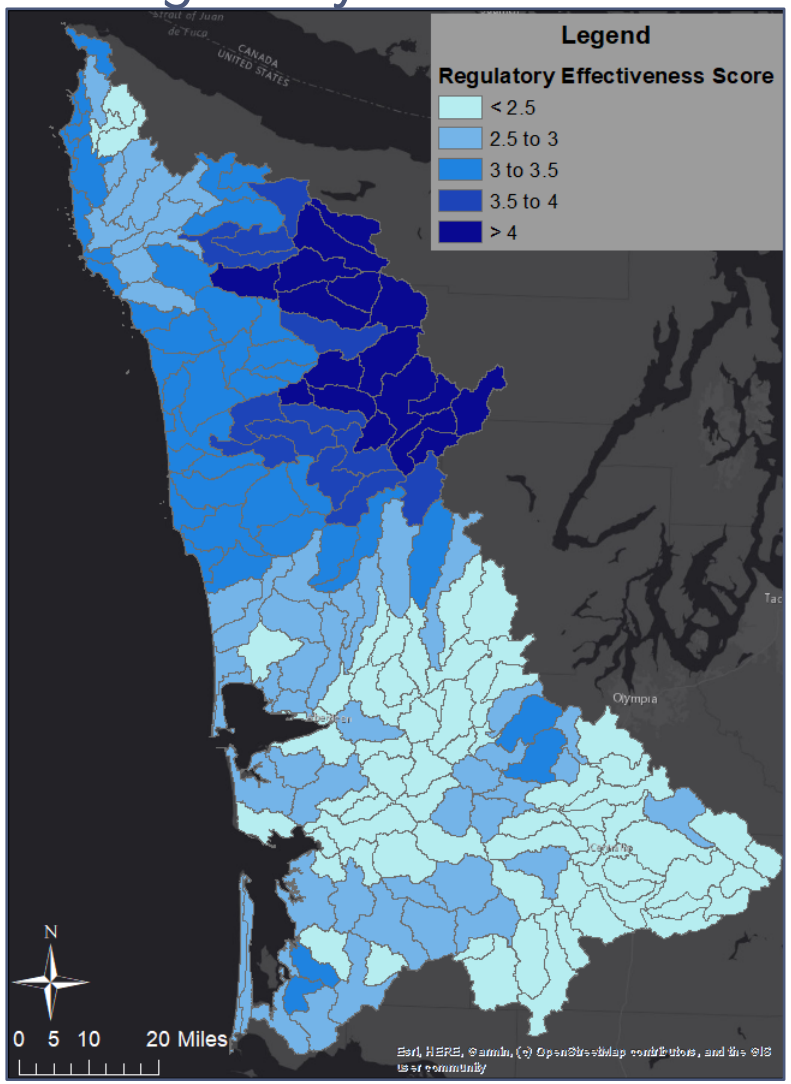
## Voluntary Receptivity

Are these land types receptive to voluntary protection/restoration?

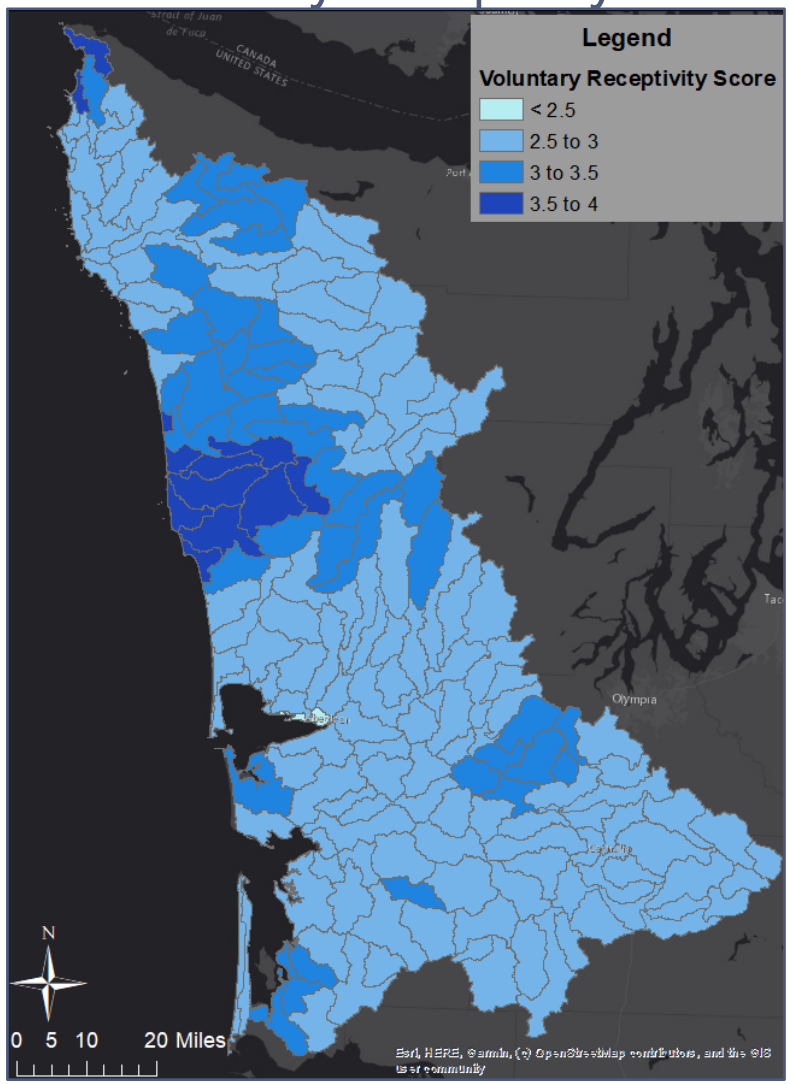


# Social Adaptability – Results

## Regulatory Effectiveness




## Voluntary Receptivity

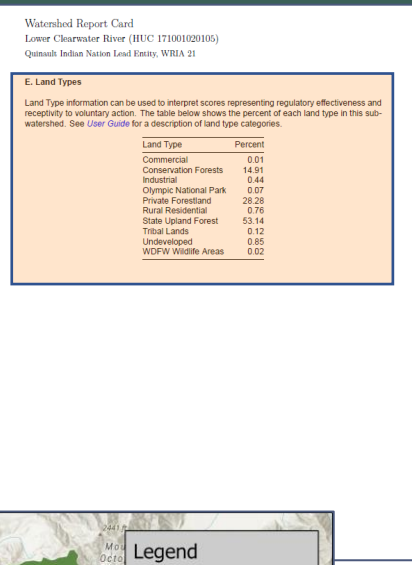


# Case Study

## Lower Clearwater River

| Land Type | Percent |
|---|---|
| Commercial | 0.01 |
| Conservation Forests | 14.91 |
| Industrial | 0.44 |
| Olympic National Park | 0.07 |
| Private Forestland | 28.28 |
| Rural Residential | 0.76 |
| State Upland Forest | 53.14 |
| Tribal Lands | 0.12 |
| Undeveloped | 0.85 |
| WDFW Wildlife Areas | 0.02 |

Land Types


Watershed Report Card
Lower Clearwater River (HUC 171001020105)
Quinault Indian Nation Lead Entity, WRIA 21

E. Land Types

Land Type information can be used to interpret scores representing regulatory effectiveness and receptivity to voluntary action. The table below shows the percent of each land type in this sub-watershed. See *User Guide* for a description of land type categories.

| Land Type | Percent |
|---|---|
| Commercial | 0.01 |
| Conservation Forests | 14.91 |
| Industrial | 0.44 |
| Olympic National Park | 0.07 |
| Private Forestland | 28.28 |
| Rural Residential | 0.76 |
| State Upland Forest | 53.14 |
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