Landscape setting filters projected climate change impacts to growth rates of stream-resident juvenile salmon in the Kenai River watershed

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USGS science for a changing world

Alaska Cooperative Fish & Wildlife Research Unit

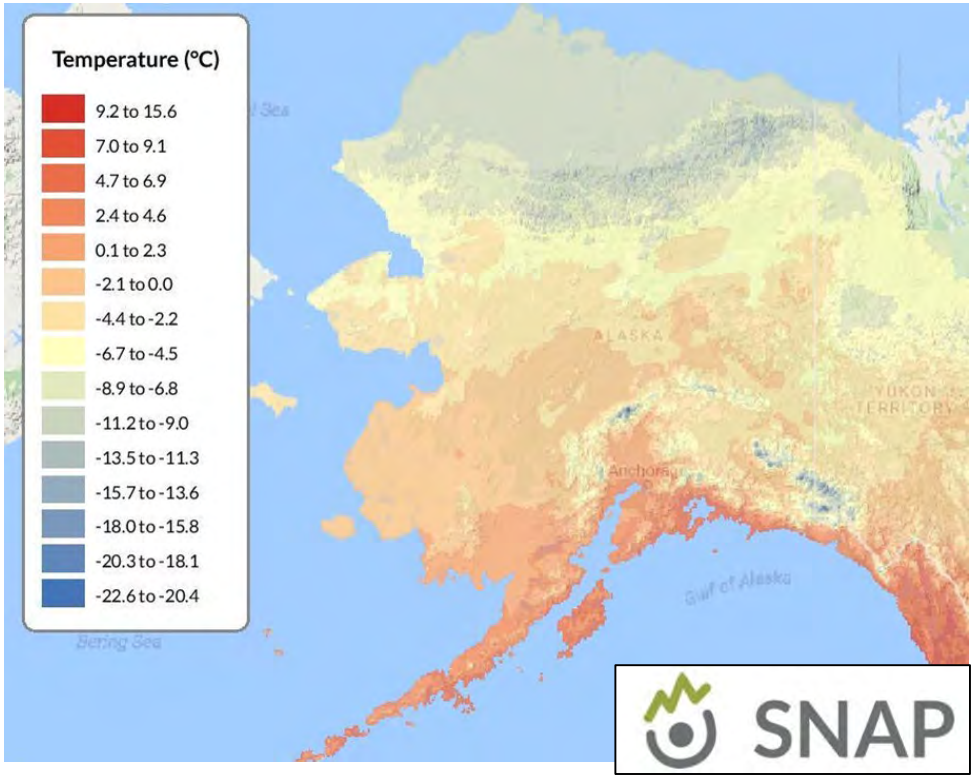
UAF University of Alaska Fairbanks

CFOS

Alaska EPSCoR

High latitudes are predicted to get warmer…

Current 10-Year Average Air Temperatures



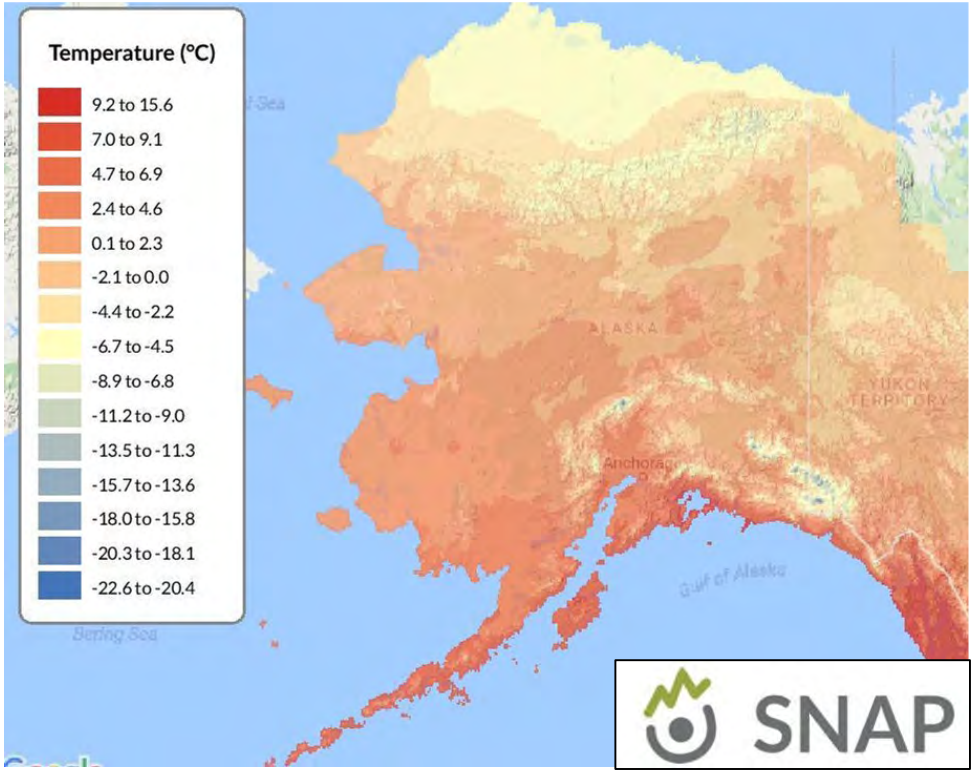
Today…

2010 - 2019

snap.uaf.edu (A1B Scenario)

High latitudes are predicted to get warmer…

Projected 10-Year Average Air Temperatures



…Future

2090 - 2099

snap.uaf.edu (A1B Scenario)

Climate change affects habitats differently based on landscape setting

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Think of salmon landscapes as heterogeneous "filters" of climate.

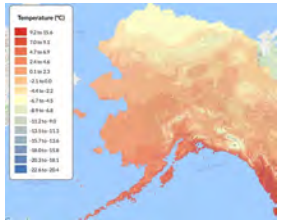
Climate change affects habitats differently based on landscape setting

Think of salmon landscapes as heterogeneous "filters" of climate.

Local impact from climate change is influenced by geomorphic, hydrologic, and ecological characteristics.

How does landscape “filter” the effects of climate change on salmon habitat?

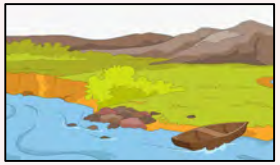
Climate Signal



“Filter”

Lowland

Montane



Glacial

Main Stem

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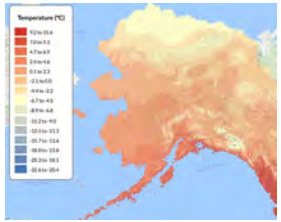

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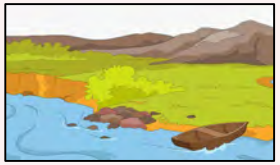

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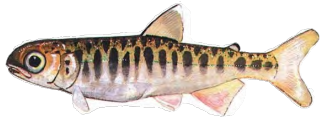
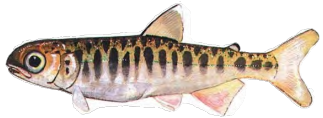
Main Stem

Biological Effect





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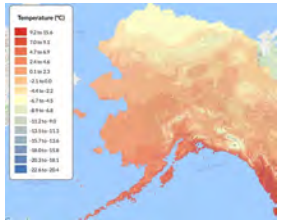

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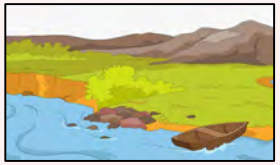

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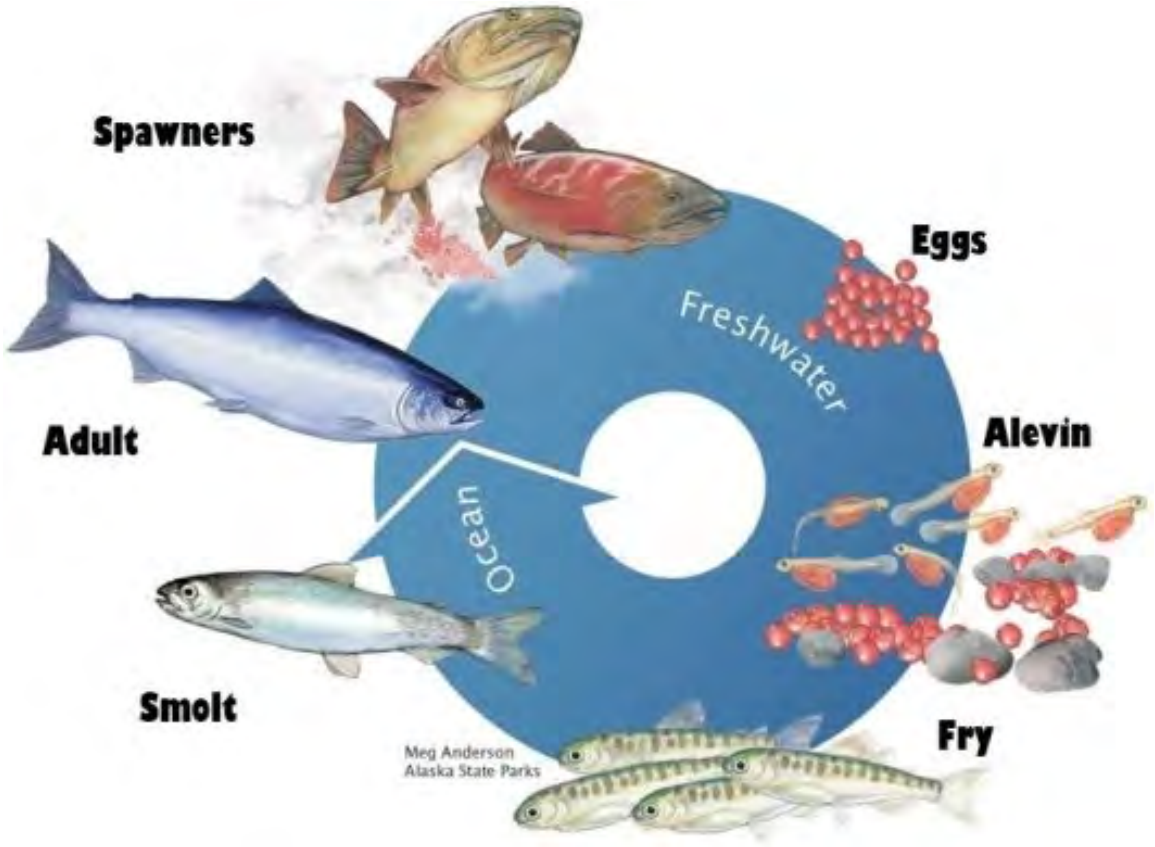
Biological Effect

Typical Life Cycle of Pacific Salmon



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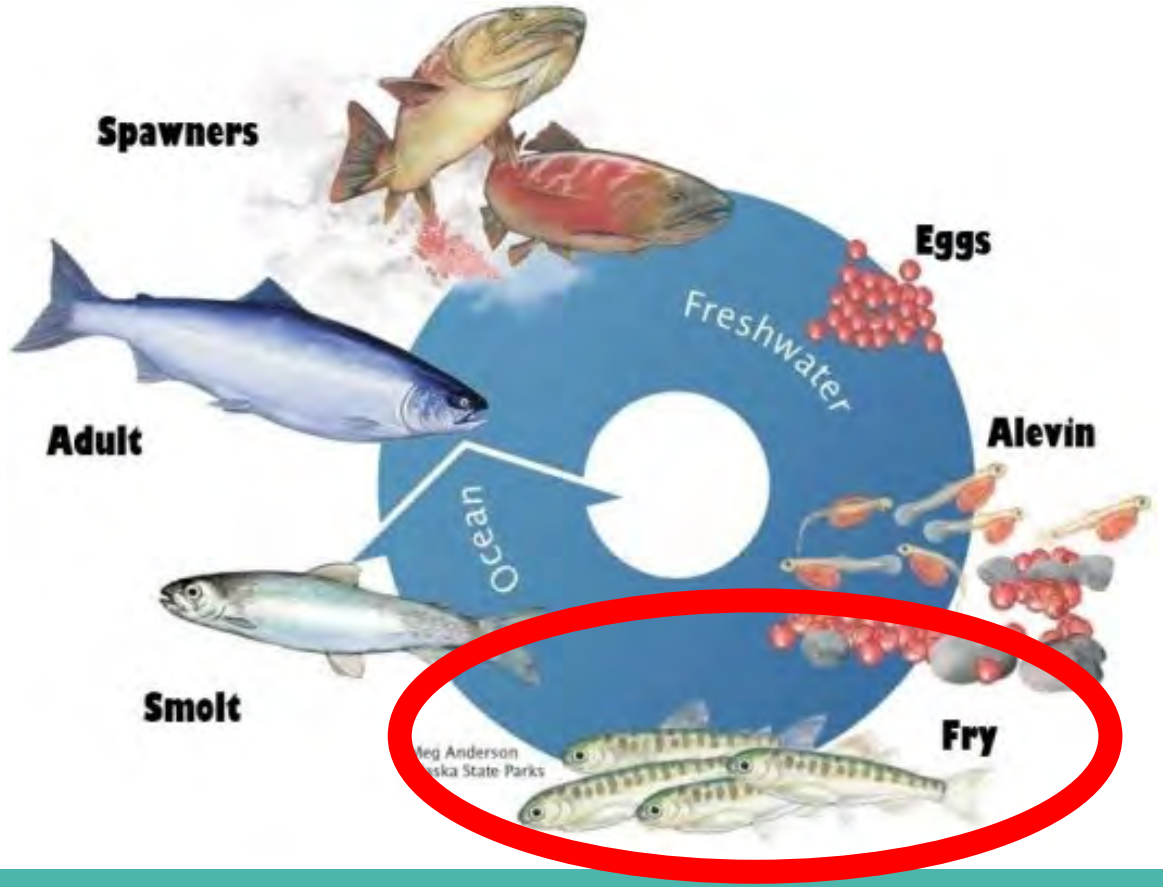
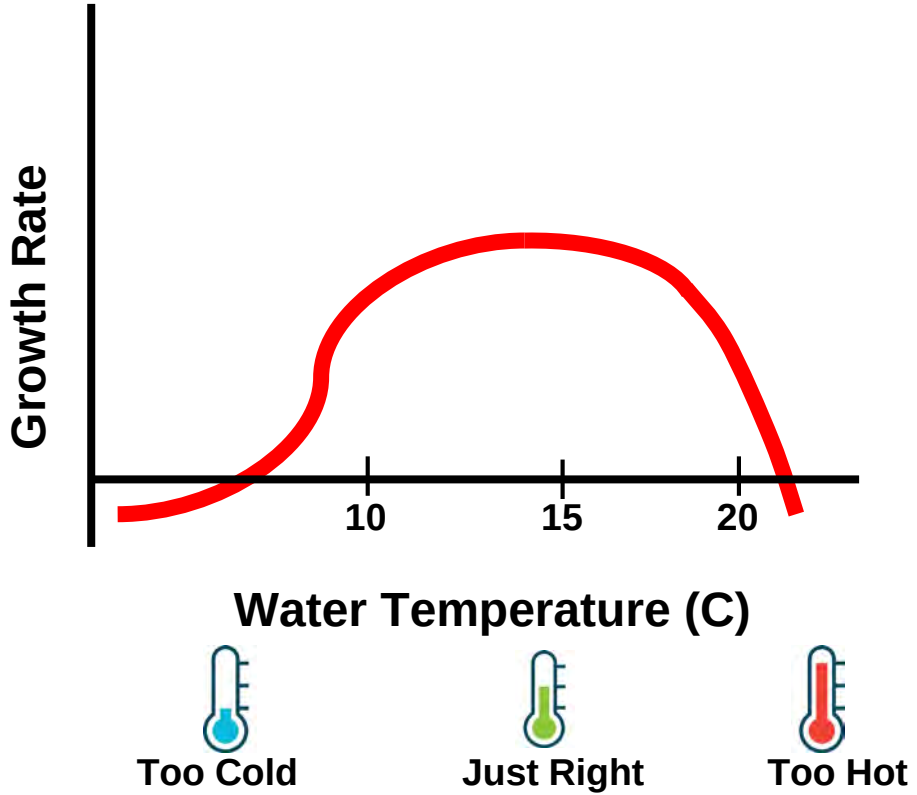


“Fry” also known as “Parr”

How will future changes in thermal regime affect juvenile salmon growth rates?

Water Temperature Influences Growth Rates



Water Temperature Influences Growth Rates

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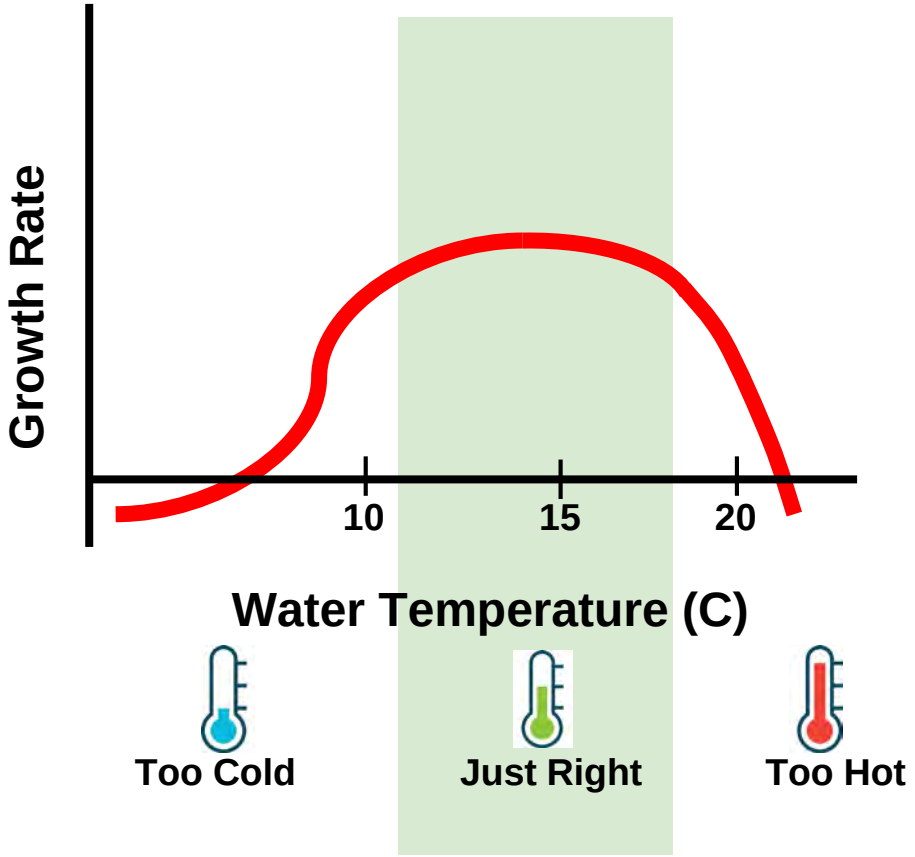

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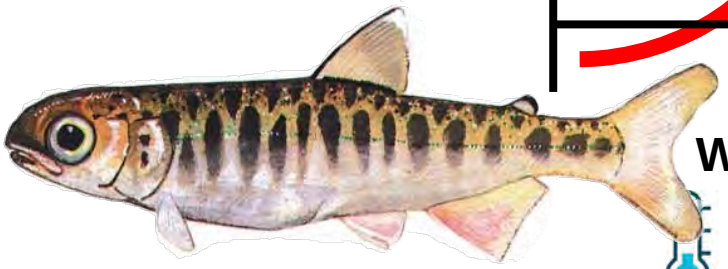

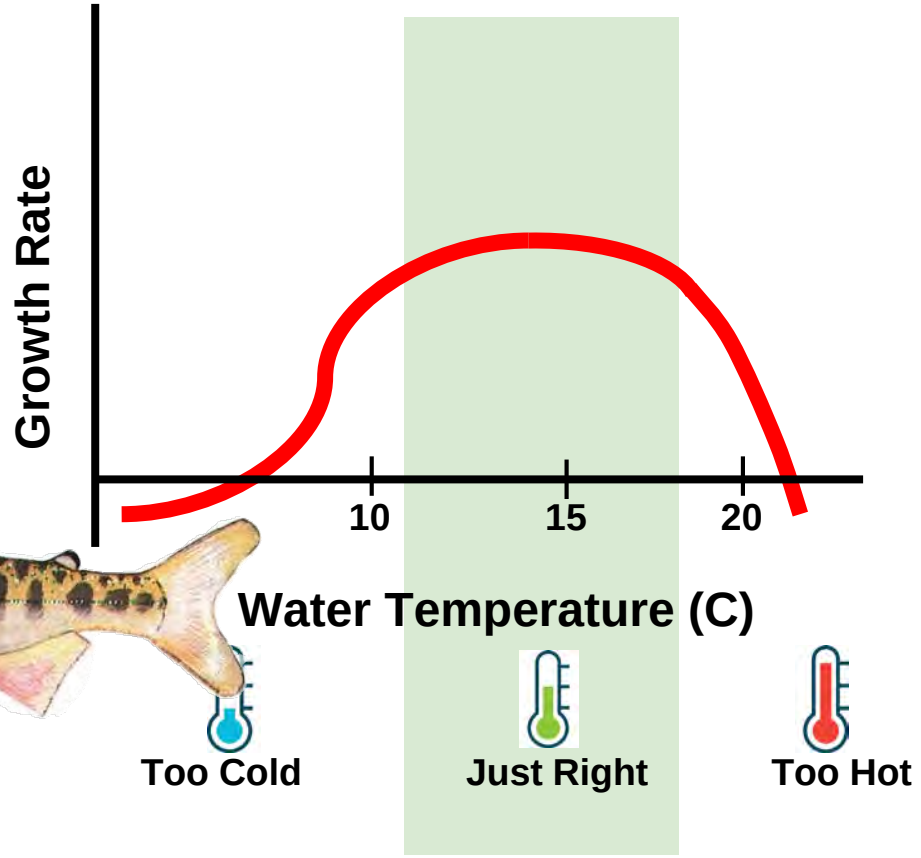

Water Temperature Influences Growth Rates

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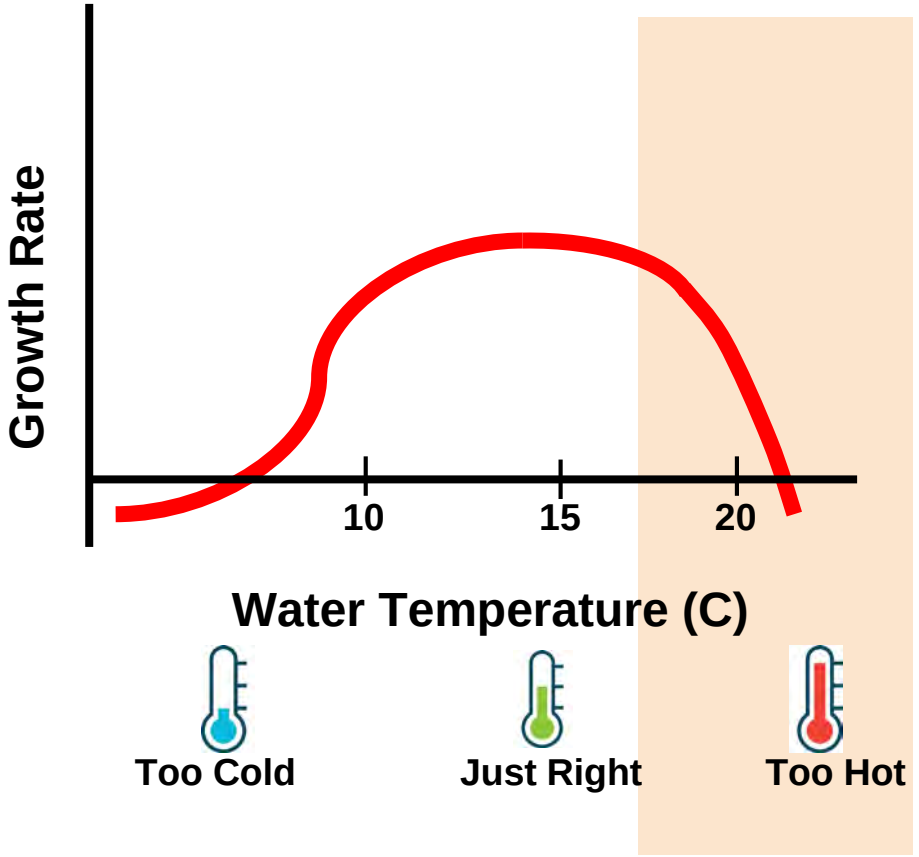

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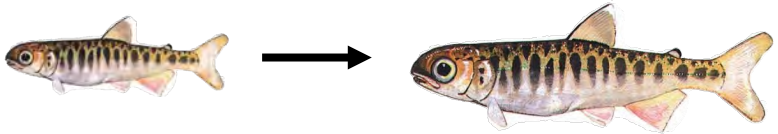
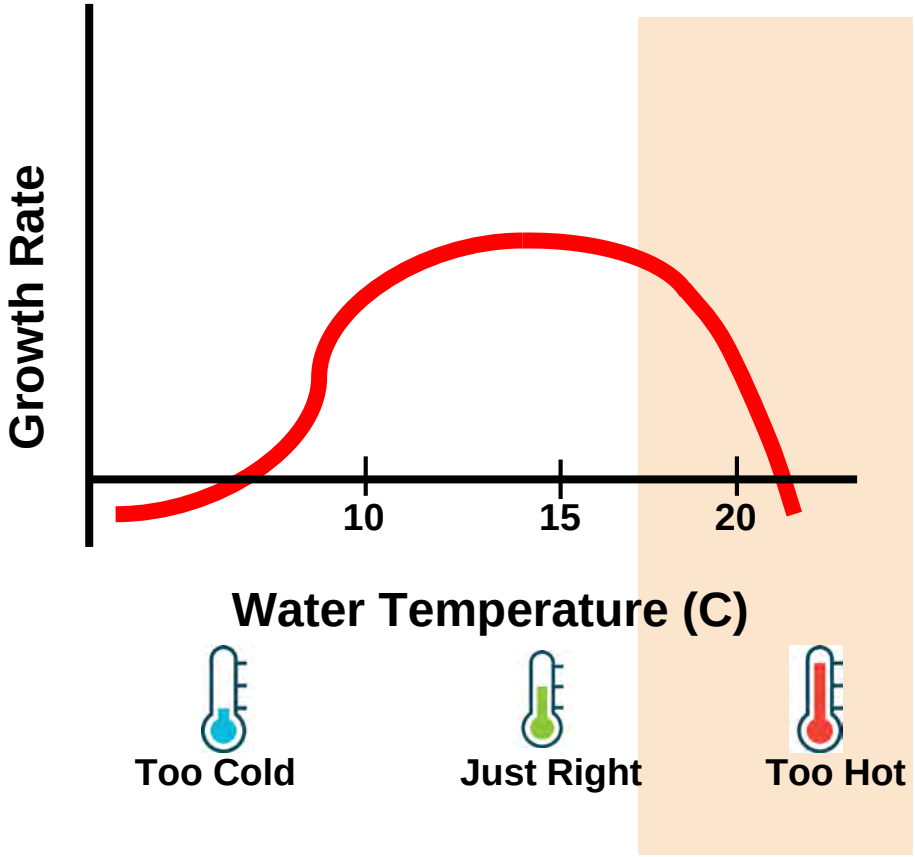
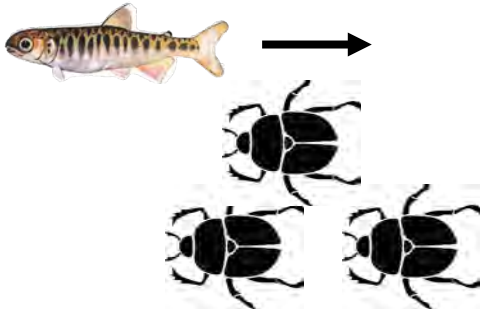
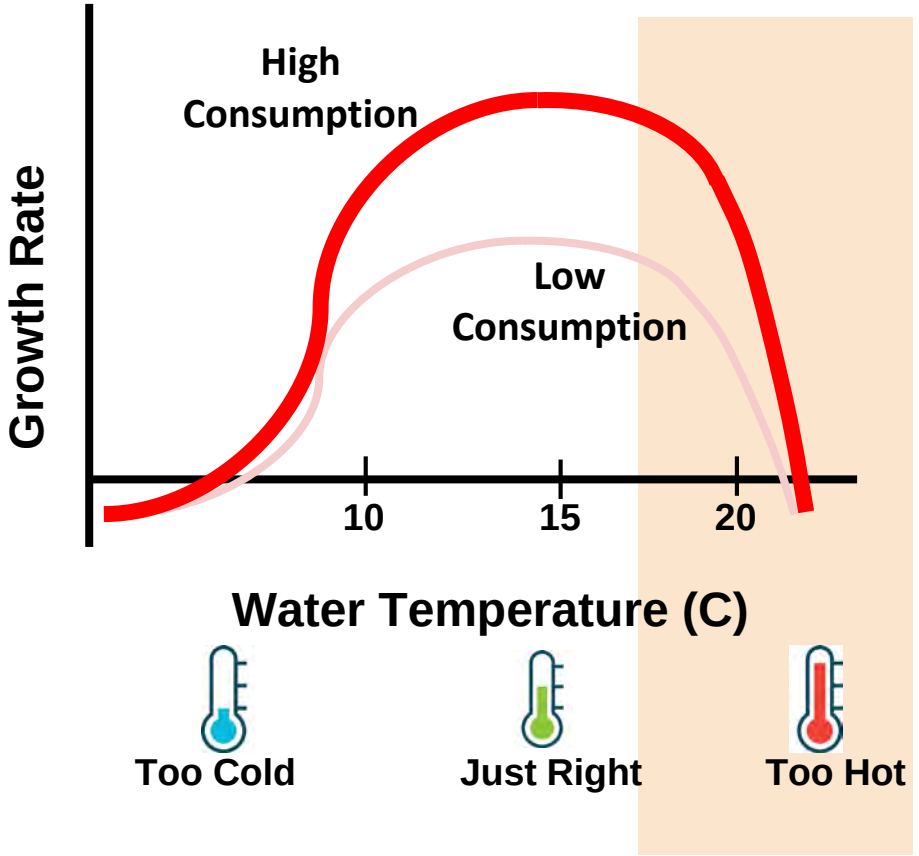




Water Temperature And Food Influences Growth Rates

Future…?





Water Temperature And Food Influences Growth Rates

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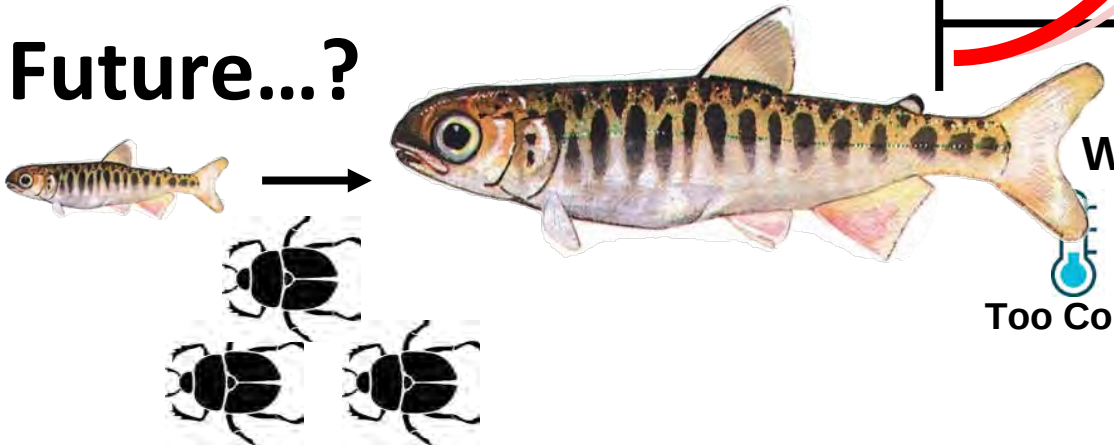

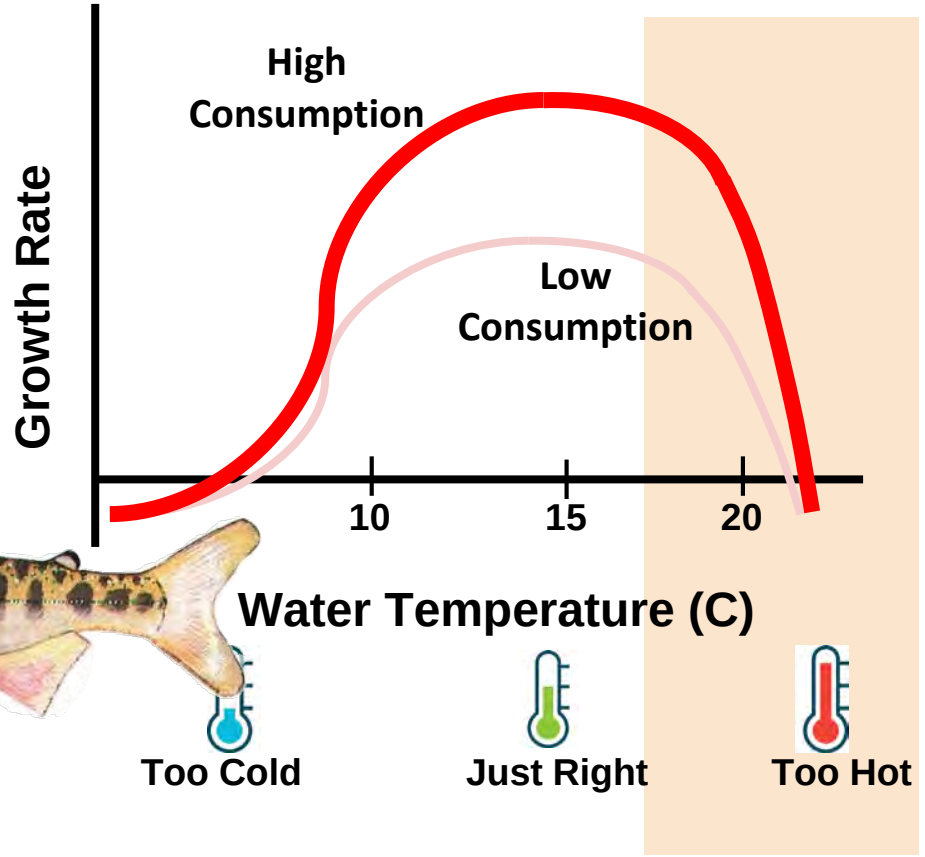

Objectives

Characterize how juvenile Chinook and Coho growth rates respond to projected rising air temperatures across diverse ecoregions

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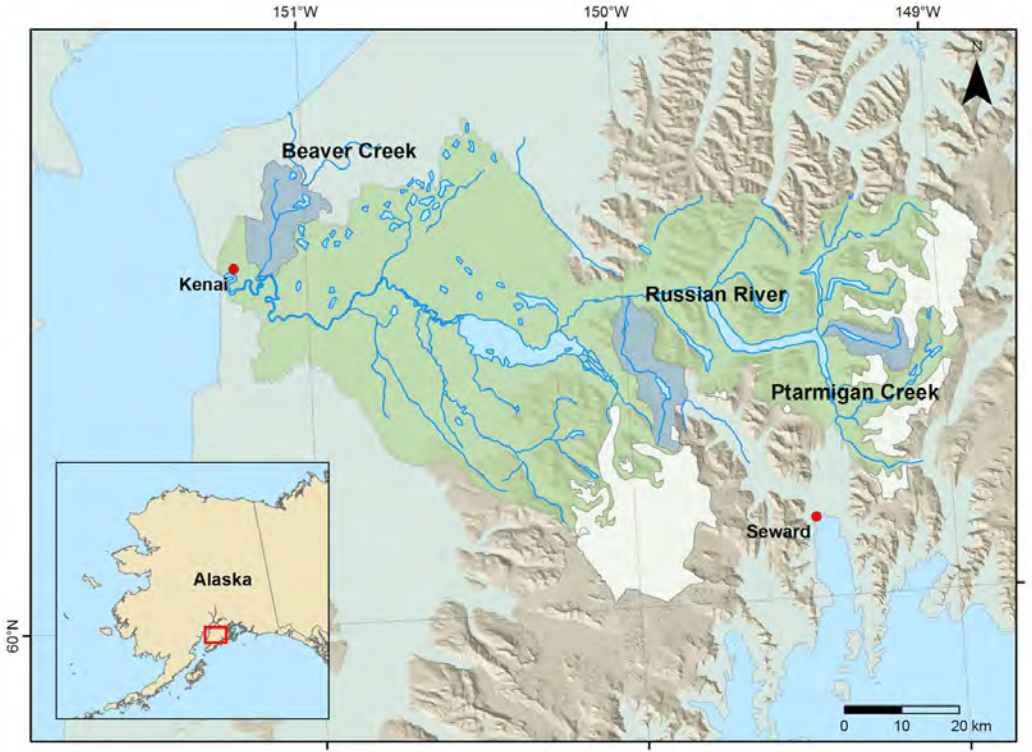
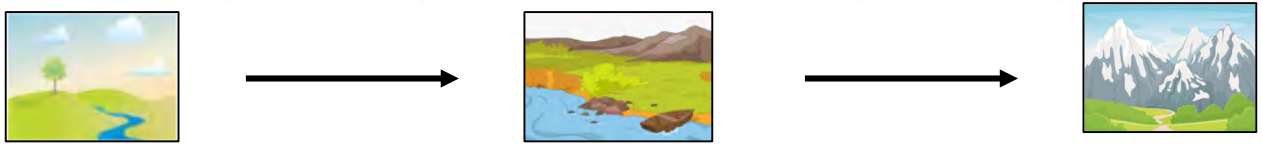
Characterize how juvenile Chinook and Coho growth rates respond to projected rising air temperatures across diverse ecoregions

1. **Measurements:** Identify air-water sensitivity relationships, diet, and growth patterns in study watersheds
2. **Simulations:** model fish growth under projected climate and diet scenarios

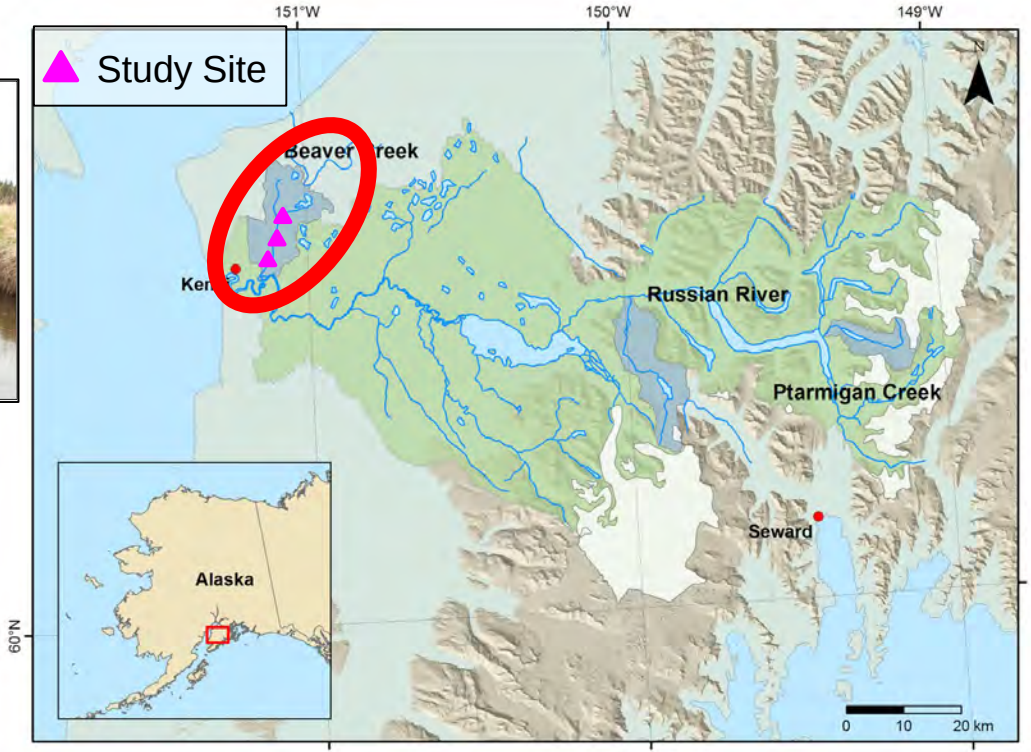
Kenai River Watershed



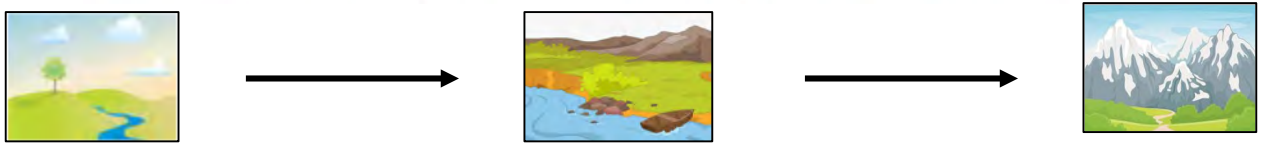


Kenai River Study Areas

Beaver Creek (Lowland)

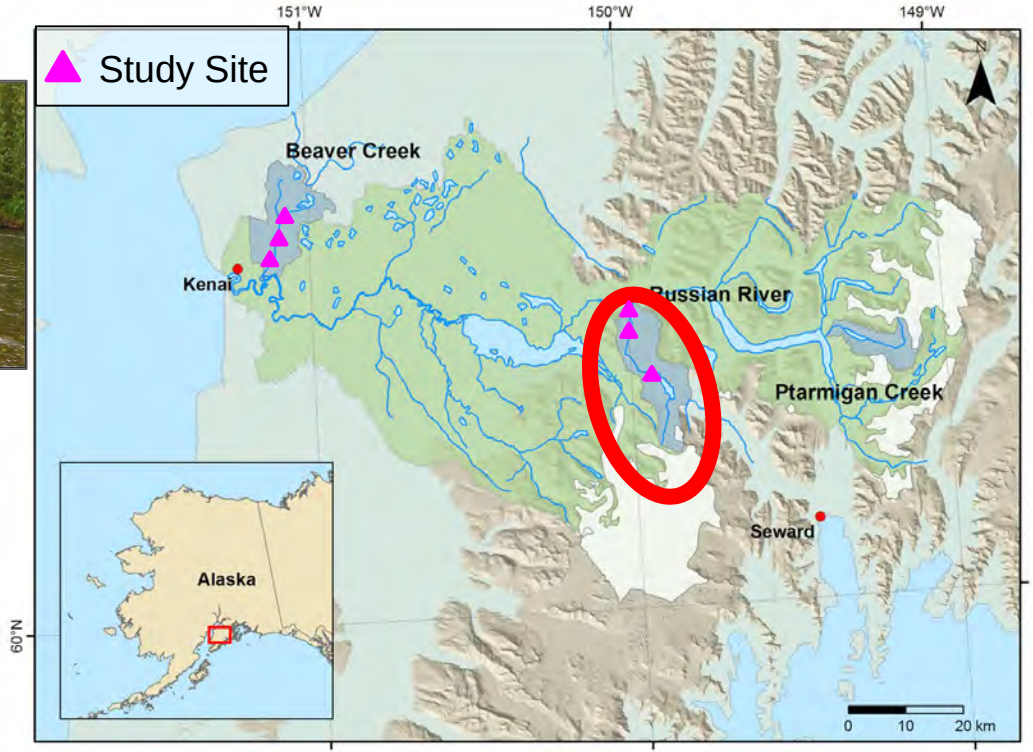


- **2% Average Gradient**
- **0% Glacial Coverage**

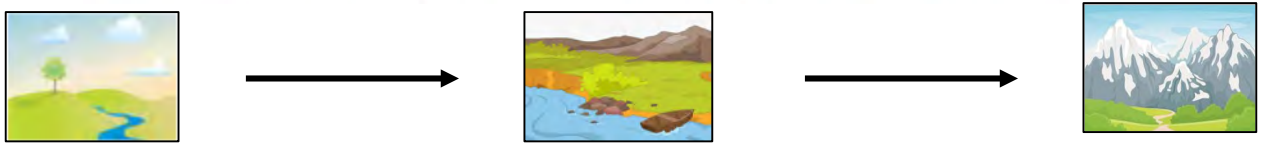


Kenai River Study Areas

Russian River (Montane)

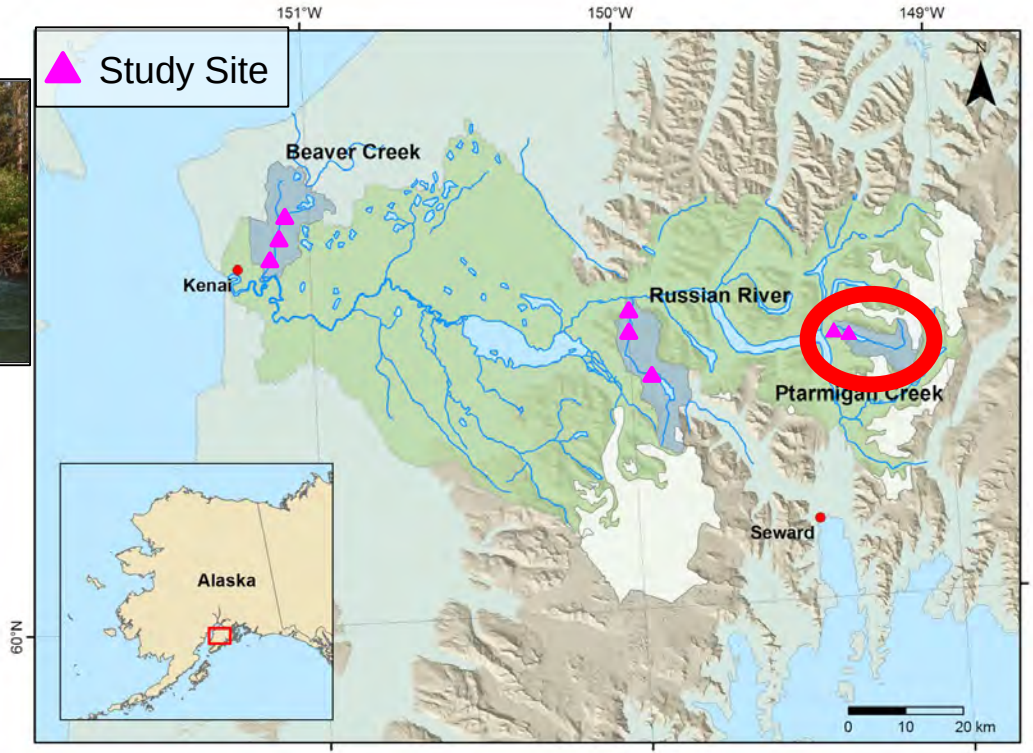


- **9% Average Gradient**
- **<1% Glacial Coverage**

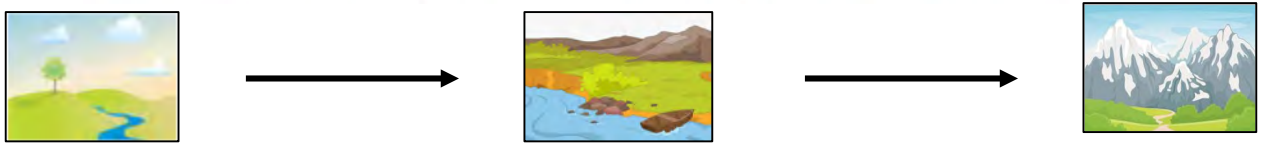


Kenai River Study Areas

Ptarmigan Creek (Glacial)

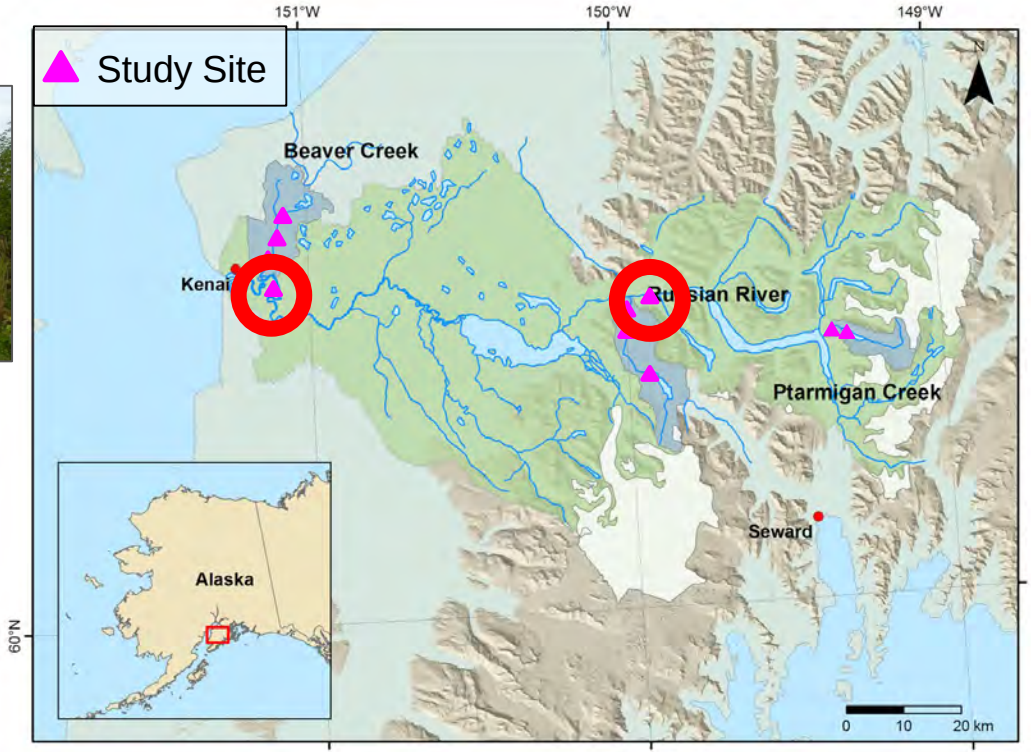


- **14% Average Gradient**
- **7% Glacial Coverage**

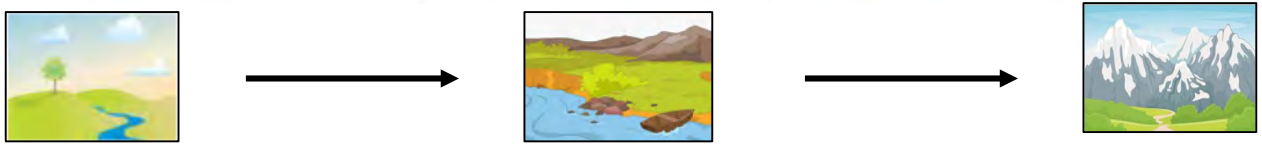


Kenai River Study Areas

Kenai Mainstem Site



- **23% Average Gradient**
- **14% Glacial Coverage**



Fish Growth Modeling Process

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Inputs

- Water Temp (Projected)
- Initial Fish Mass (Observed)
- Diet (Observed)

Bioenergetics Model

Output

- Projected Fish Mass

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Model Inputs: Projected Water Temperatures

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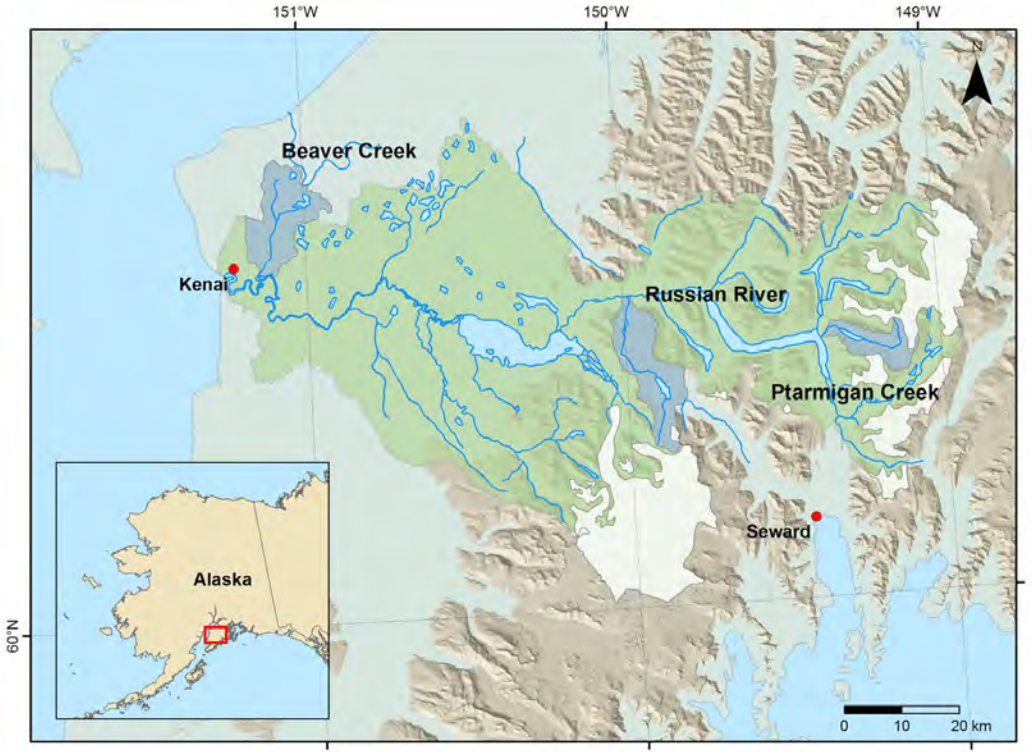
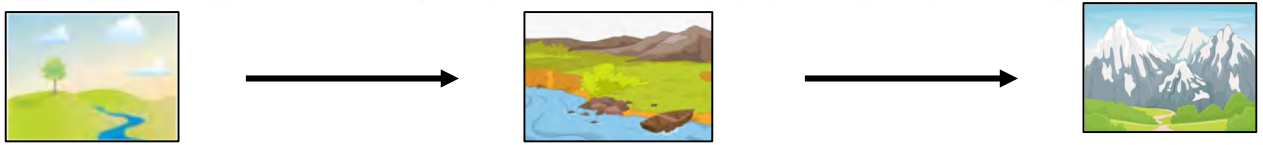
Percent Increase

- < 5%
- 5% - 10%
- > 10%



- 2060 - 2069 mean May - Sept water temps relative to 2010 -2019



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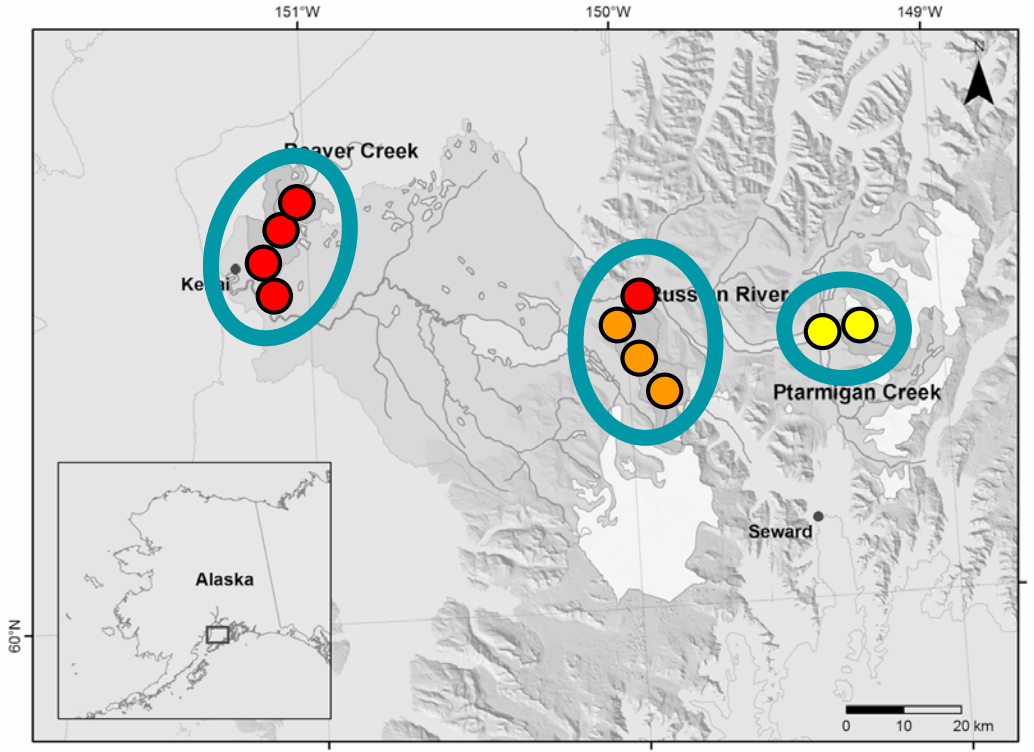

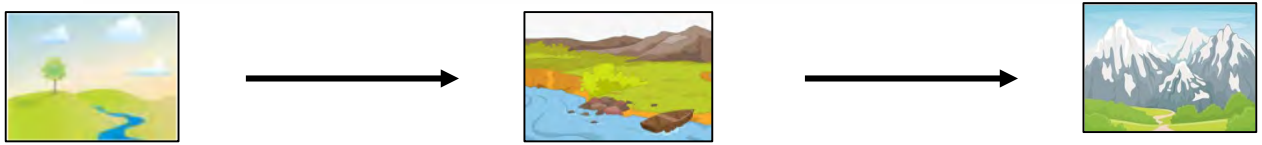

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Fish Growth Modeling Process

Inputs

- Water Temp (Projected)
- **Initial Fish Mass (Observed)**
- Diet (Observed)

Bioenergetics Model

Output

- Projected Fish Mass

Growth and Diet: Field Methods 2015-2016

- Monthly site visits

  May - Sept
  - Weight and Length
  - Diet
  - Scales

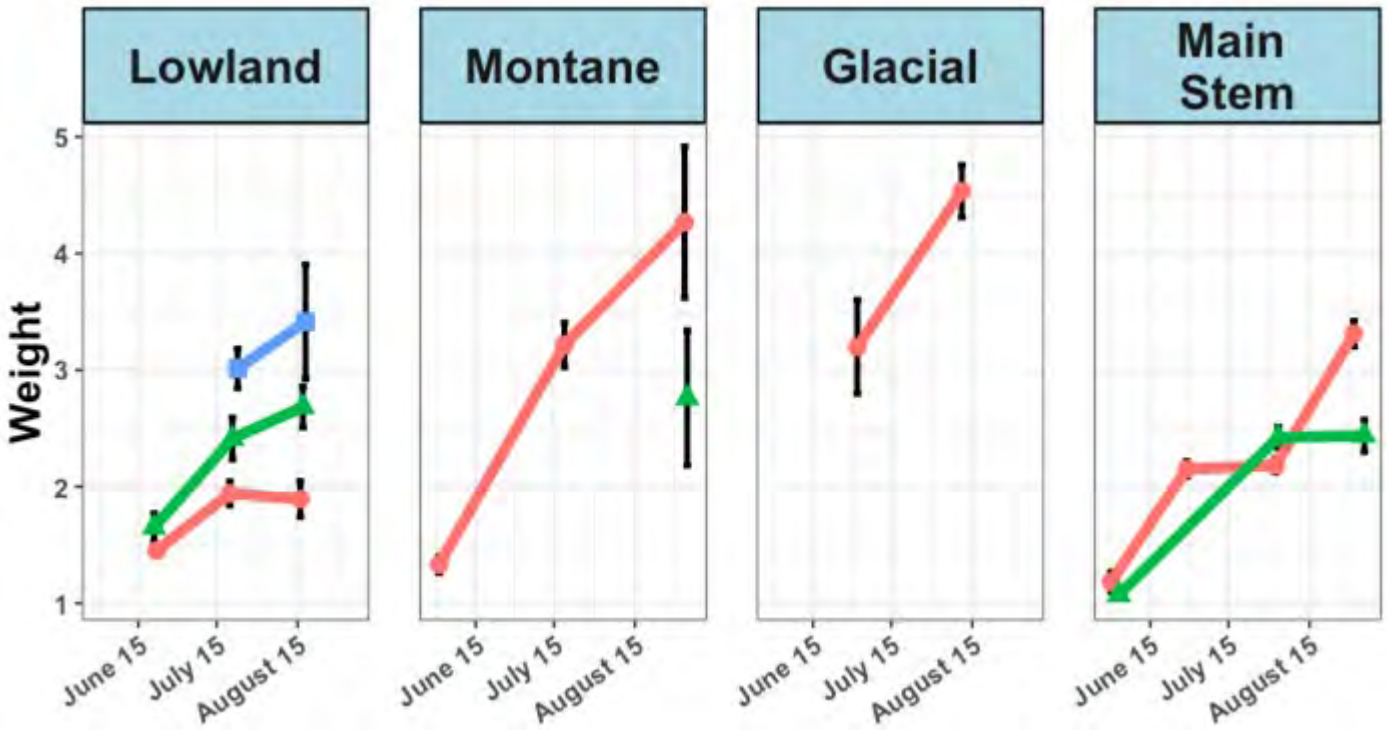
Minnow trap

Gastric lavage sample collection

Example diet item, stonefly (Order: Plecoptera)

Model Input: Fish Growth

Example: Chinook Weights 2016



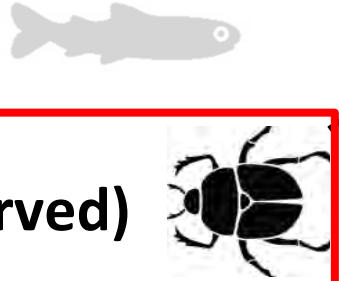
Hydrologic Segment

- Upper
- Middle
- Lower

Fish Growth Modeling Process

Inputs

- Water Temp (Projected)
- Initial Fish Mass (Observed)
- **Diet (Observed)**



Bioenergetics Model

Output

- Projected Fish Mass

Model Inputs: Diets

Smaller *Overall Caloric Contribution* **Larger**

Other Fish Eggs

Terrestrial Invertebrates, Aquatic Origin

Aquatic Invertebrates, Aquatic Origin

Terrestrial Invertebrates, Terrestrial Origin

Salmon Eggs

Model Inputs: Diets

Smaller *Overall Caloric Contribution* **Larger**

Riparian & Marine Subsidies = Major Calorie Source

Other Fish Eggs

Terrestrial Invertebrates, Aquatic Origin

Aquatic Invertebrates, Aquatic Origin

Terrestrial Invertebrates, Terrestrial Origin

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Fish Growth Modeling Process

Inputs

- Water Temp (Projected)
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Bioenergetics Model

Output

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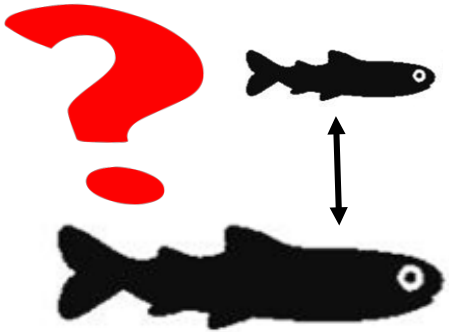


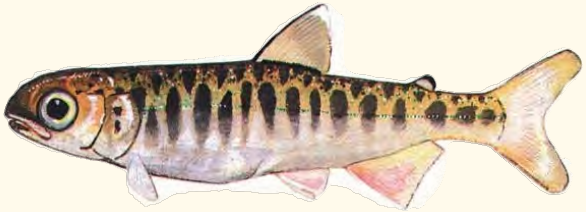
Results

Results

For most future scenarios, size at the end of the summer was smaller

Size at end of summer

Today

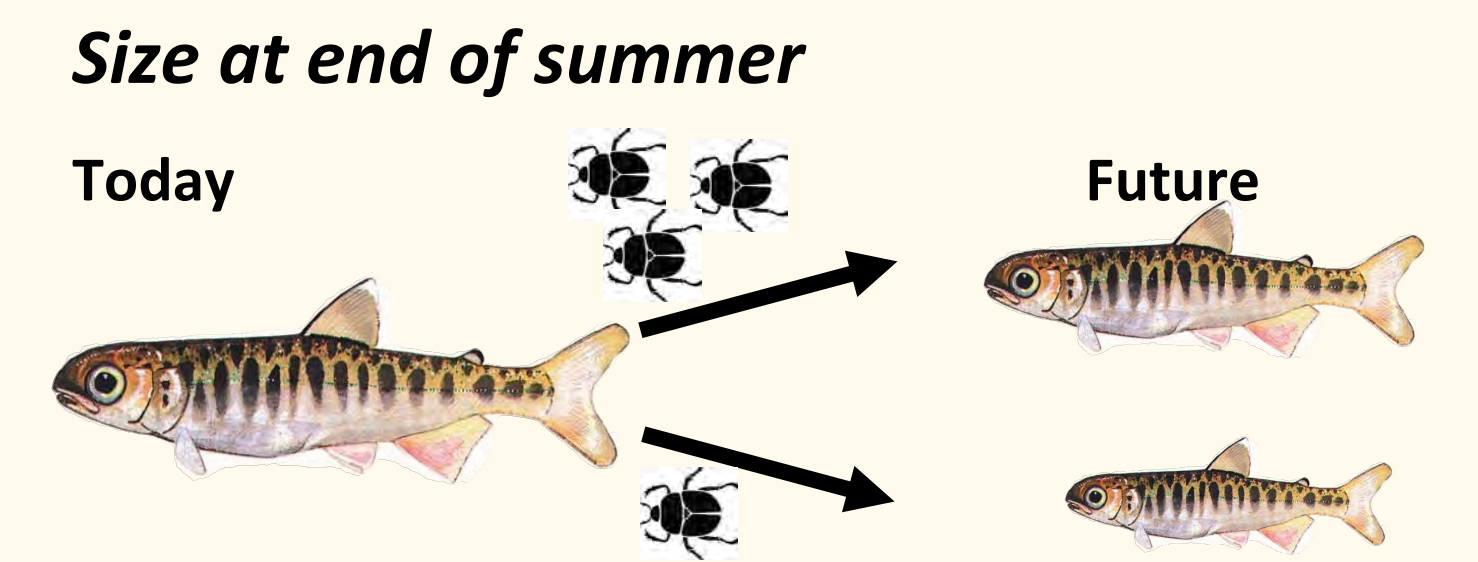


Future

Results

For most future scenarios, size at the end of the summer was smaller

High consumption rates lowered magnitude of change



Growth Scenarios (Results)

Simulated change in size at end of summer ranged from -19.9% to +3.8%

How does landscape “filter” the effects of climate change on salmon habitat ?

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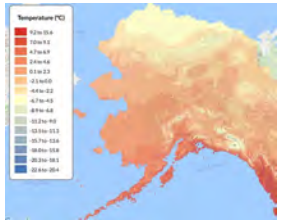

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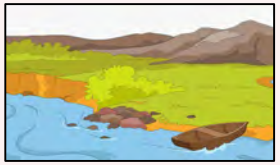
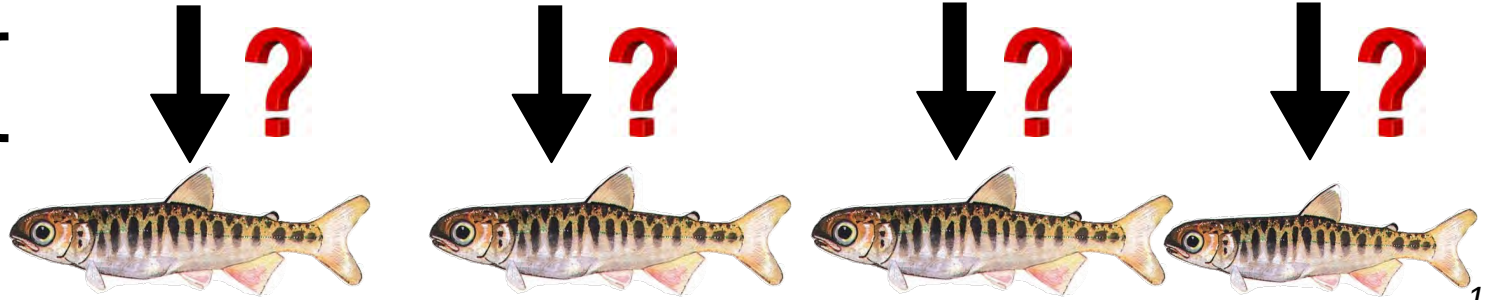


Glacial

Main Stem

Growth Rate



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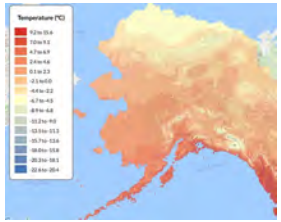

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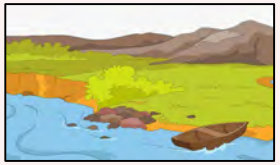

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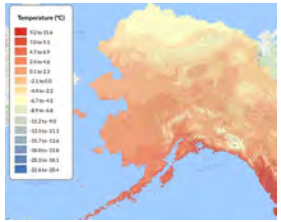
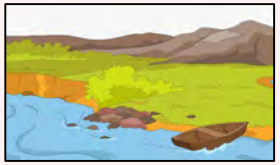


“Filter”

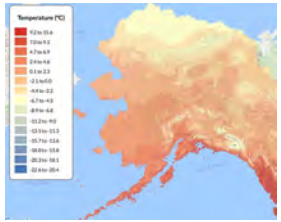
Lowland	Montane	Glacial	Main Stem
			

Growth Rate

Lowland	Montane	Glacial	Main Stem
+0% to -13%	+1% to -20%	+0% to -5%	+4% to -8%

How does landscape “filter” the effects of climate change on salmon habitat ?

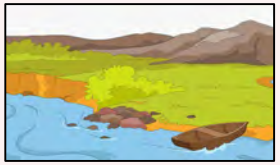
Climate Signal



“Filter”

Lowland

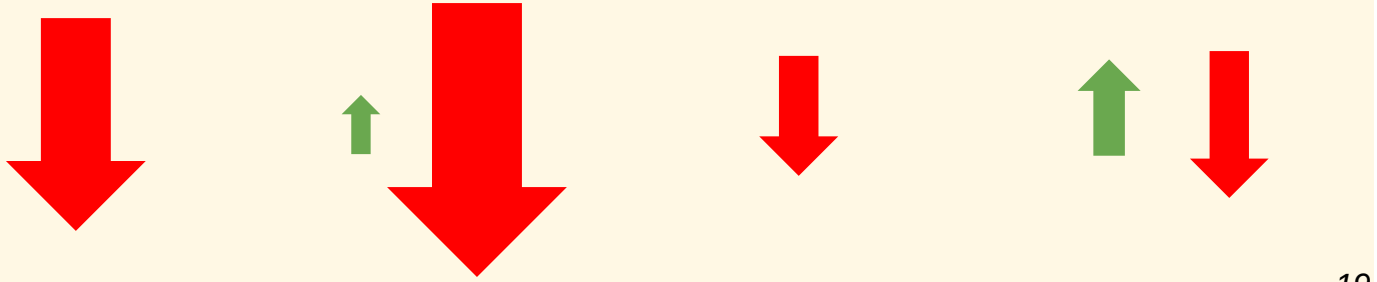
Montane



Glacial

Main Stem

Growth Rate



Discussion

- Response of juvenile Chinook and Coho growth rate to future warming thermal regime varied by
  - Sub-population (unique Age/Species/Site)
  - Diet scenario
  - Climate scenario

Discussion

- Lowland and Montane fish populations saw greatest magnitude of change in growth rates
  - Smaller magnitude of change when food consumption was higher

Ecological and Management Implications

Ecological and Management Implications

- Terrestrial and marine subsidies are important food sources for juvenile Chinook and Coho
  - **Fish can usually still grow at high rates outside of optimum temperatures if food consumption remains high**

Ecological and Management Implications

- **Diverse portfolio of habitats = Diverse responses to climate change**
  - **Uncertainty of physiological response to climate change highlights the value of maintaining a diverse habitat portfolio**

Thanks!

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- UAF Department of Biology and Wildlife

Advisory Committee

- Dr. Mark Wipfli (Co-Advisor)
- Dr. Daniel Rinella (Co-Advisor)
- Dr. Jeff Falke
- Dr. Erik Schoen

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- Kenai Peninsula College

USGS science for a changing world

Alaska Cooperative Fish & Wildlife Research Unit

UAF UNIVERSITY OF ALASKA FAIRBANKS

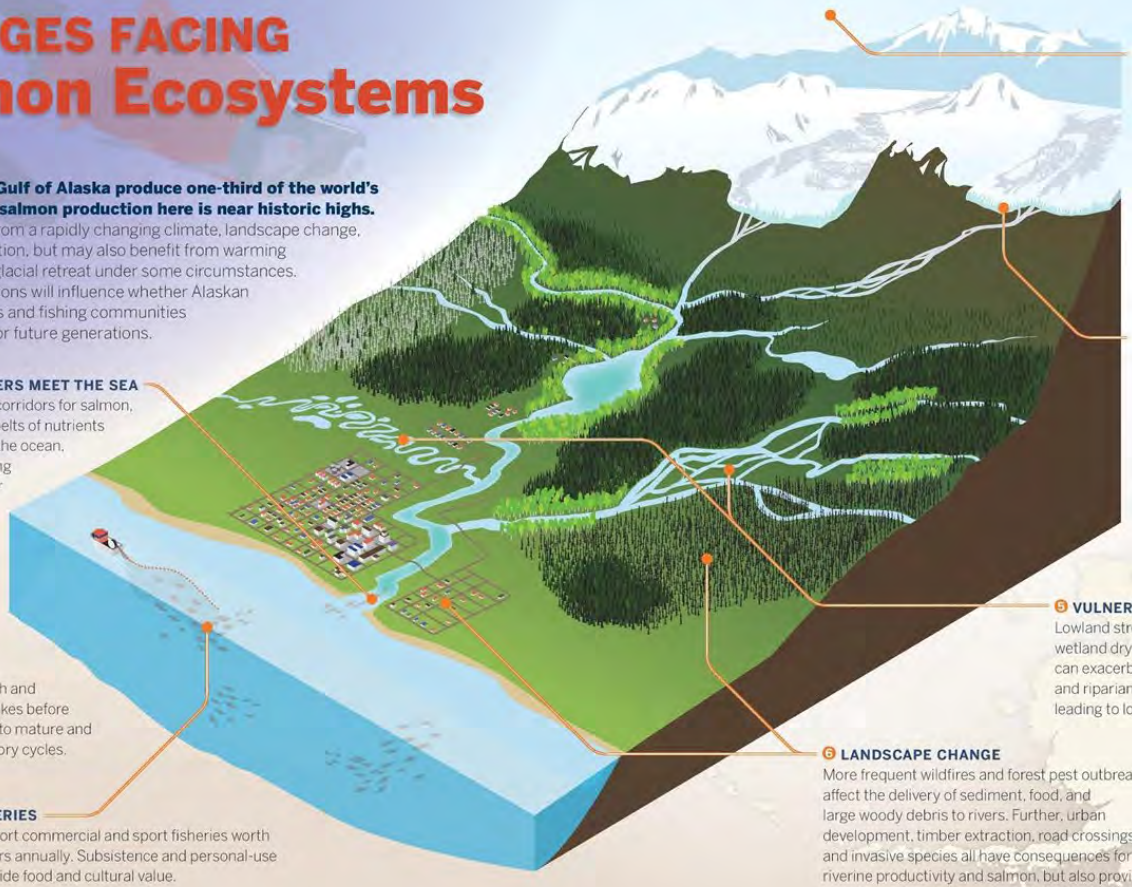
CFOS

Alaska EPSCoR

<End Presentation>

CHANGES FACING
Salmon Ecosystems

Rivers along the Gulf of Alaska produce one-third of the world's wild salmon, and salmon production here is near historic highs. Salmon face risks from a rapidly changing climate, landscape change, and ocean acidification, but may also benefit from warming temperatures and glacial retreat under some circumstances. Management decisions will influence whether Alaskan salmon ecosystems and fishing communities continue to thrive for future generations.



1 WHERE THE RIVERS MEET THE SEA

Rivers are migration corridors for salmon, serving as conveyor belts of nutrients and energy between the ocean, rivers, and surrounding forests. Each summer millions of adult salmon migrate from the ocean to rivers to spawn, and their eggs overwinter in the streambed. During spring, juvenile Chinook, Coho, and Sockeye salmon hatch and rear in streams and lakes before swimming out to sea to mature and continue their migratory cycles.

2 VALUABLE FISHERIES

Alaskan salmon support commercial and sport fisheries worth over a billion US dollars annually. Subsistence and personal-use salmon fisheries provide food and cultural value.

3 CHANGING CLIMATE, CHANGING STREAMFLOWS

Warmer and drier summers cause wetland drying, reducing streamflows for spawning salmon. Warmer and wetter autumns and winters are expected to increase flood frequency, which can be deadly to incubating salmon eggs. Glacial meltwater and lakes buffer some salmon populations from these risks.

4 MELTING GLACIERS

Moderate inputs of water, nutrients, and sediments from melting glaciers enhance aquatic productivity and benefit young salmon, while too much or too little input may reduce productivity. In some cases, glacial retreat may also uncover new stream reaches, which could increase salmon numbers.

5 VULNERABLE LOWLAND STREAMS

Lowland streams are especially sensitive to wetland drying and loss. Human activities can exacerbate these effects on streams and riparian areas that are not protected, leading to loss of salmon habitat.

6 LANDSCAPE CHANGE

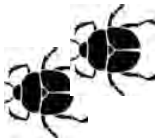
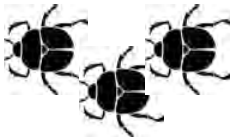
More frequent wildfires and forest pest outbreaks affect the delivery of sediment, food, and large woody debris to rivers. Further, urban development, timber extraction, road crossings, and invasive species all have consequences for riverine productivity and salmon, but also provide opportunities for enhancing riverine ecosystems through local management.

GULF OF ALASKA

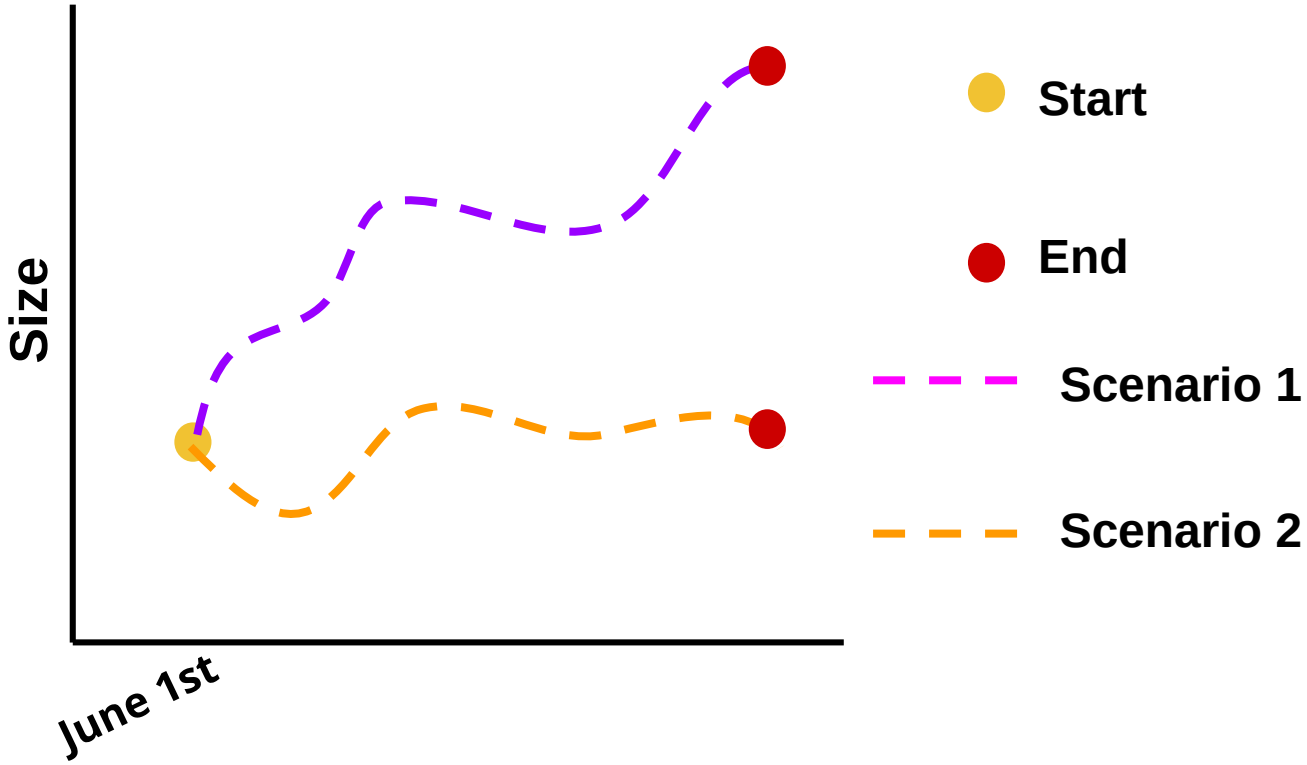
NSF Alaska EPSCoR · USGS science for a changing world · UAF University of Alaska Fairbanks · UAA University of Alaska Anchorage · University of Alaska Southeast

This illustration appears in Schoen et al. in the October 2017 edition of Fisheries magazine. The full article can be found at http://dx.doi.org/10.1080/03632415.2017.1374251 or by scanning the QR code with your mobile device. Support from Alaska EPSCoR NSF award #OIA-1208927 and the state of Alaska. The University of Alaska is an AA/EO employer and educational institution and prohibits illegal discrimination against any individual. Learn more at www.alaska.edu/nondiscrimination.

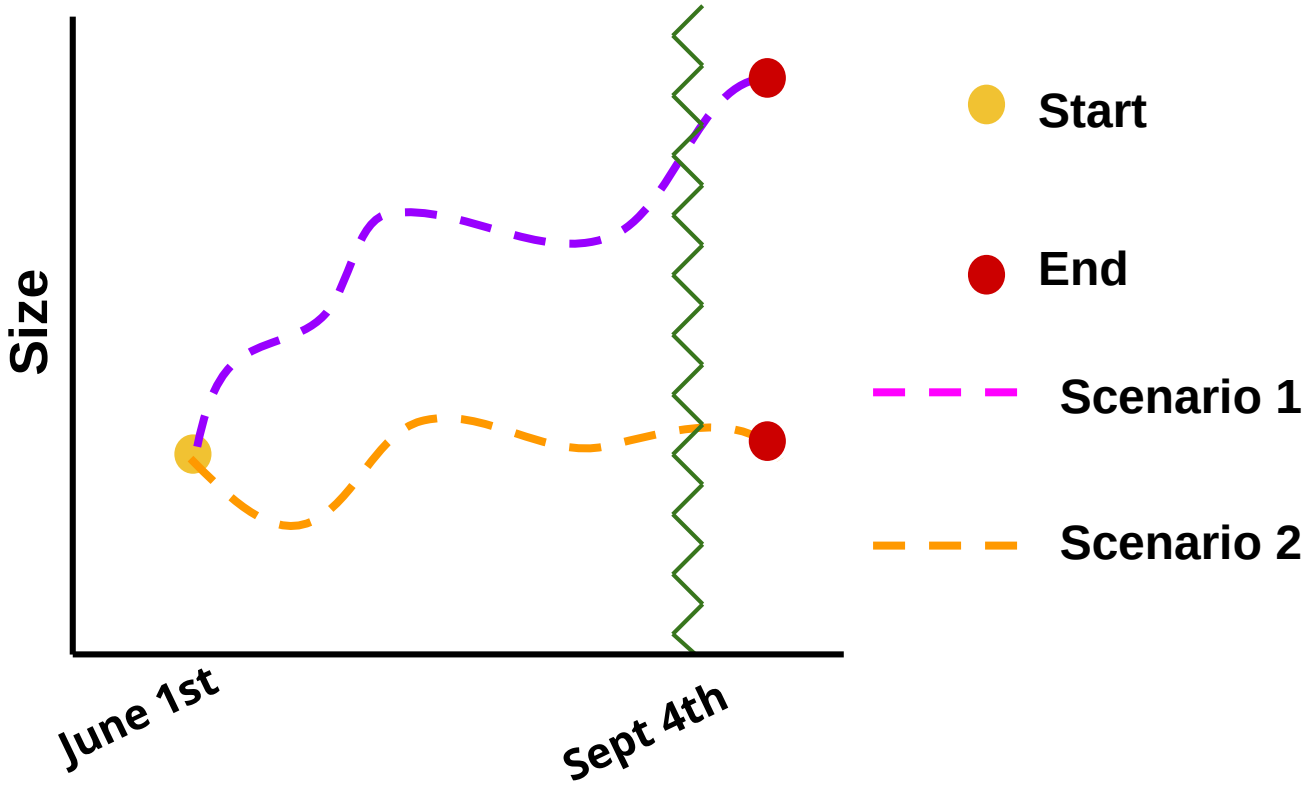
Scenarios Modeled

Population	Food Consumption	Climate	Time Period
Age 0 Chinook	"Low" (-20% Observed Diet) 	Mid-Range (A1B)	2010-2019
Age 0 Coho	"Average" (Mean Observed Diet) 	Rapid Increase (A2)	2030-2039
Age 1 Coho	"Feast" (+20% Observed Diet) 		2060-2069

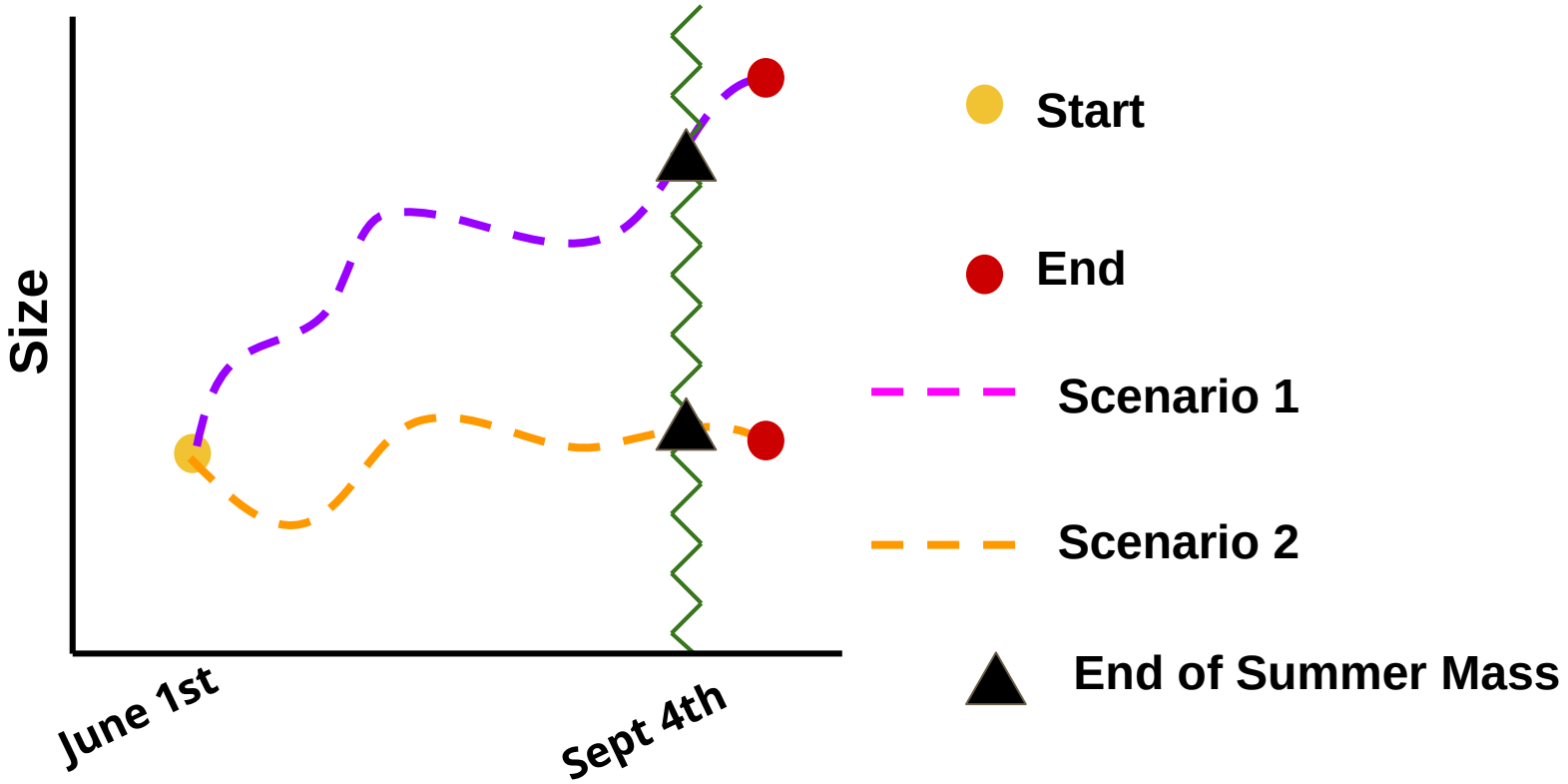
Response Metric: Size at end of Summer



Response Metric: Size at end of Summer

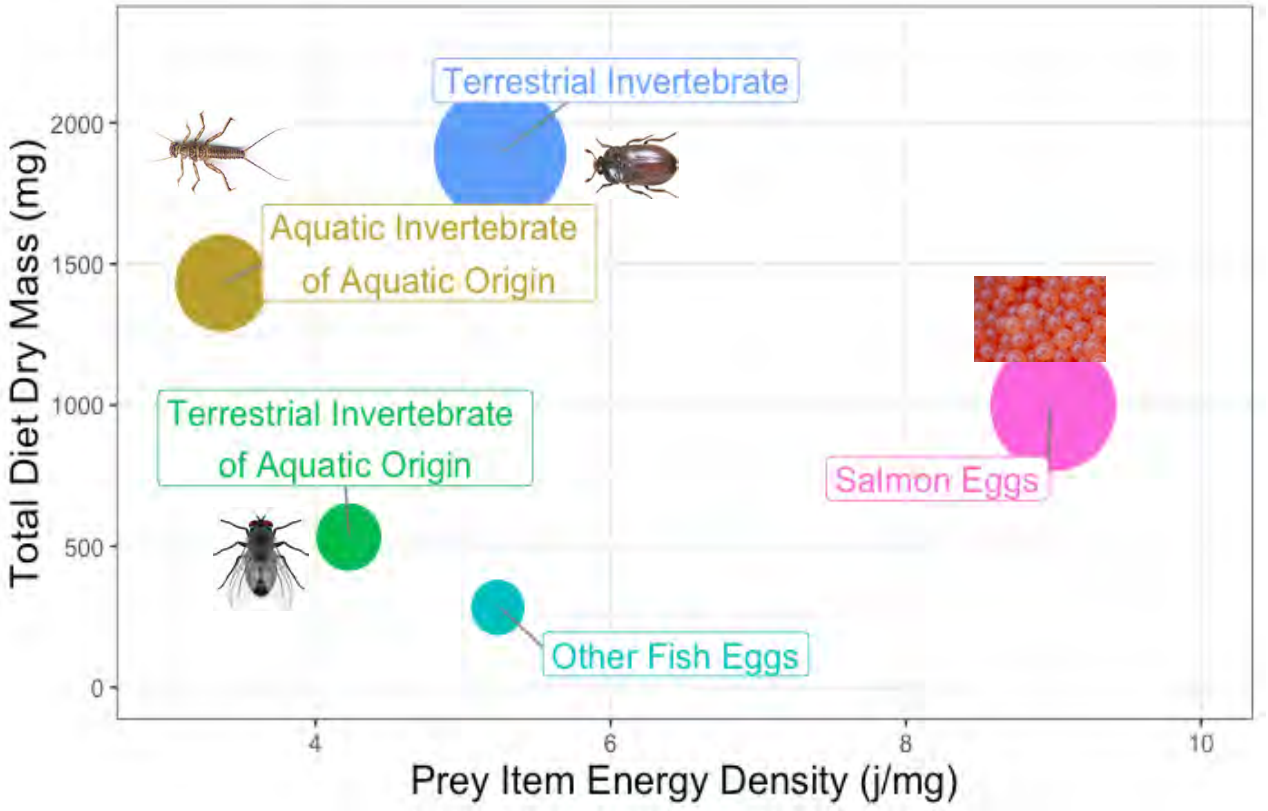


Response Metric: Size at end of Summer



Results: Diets

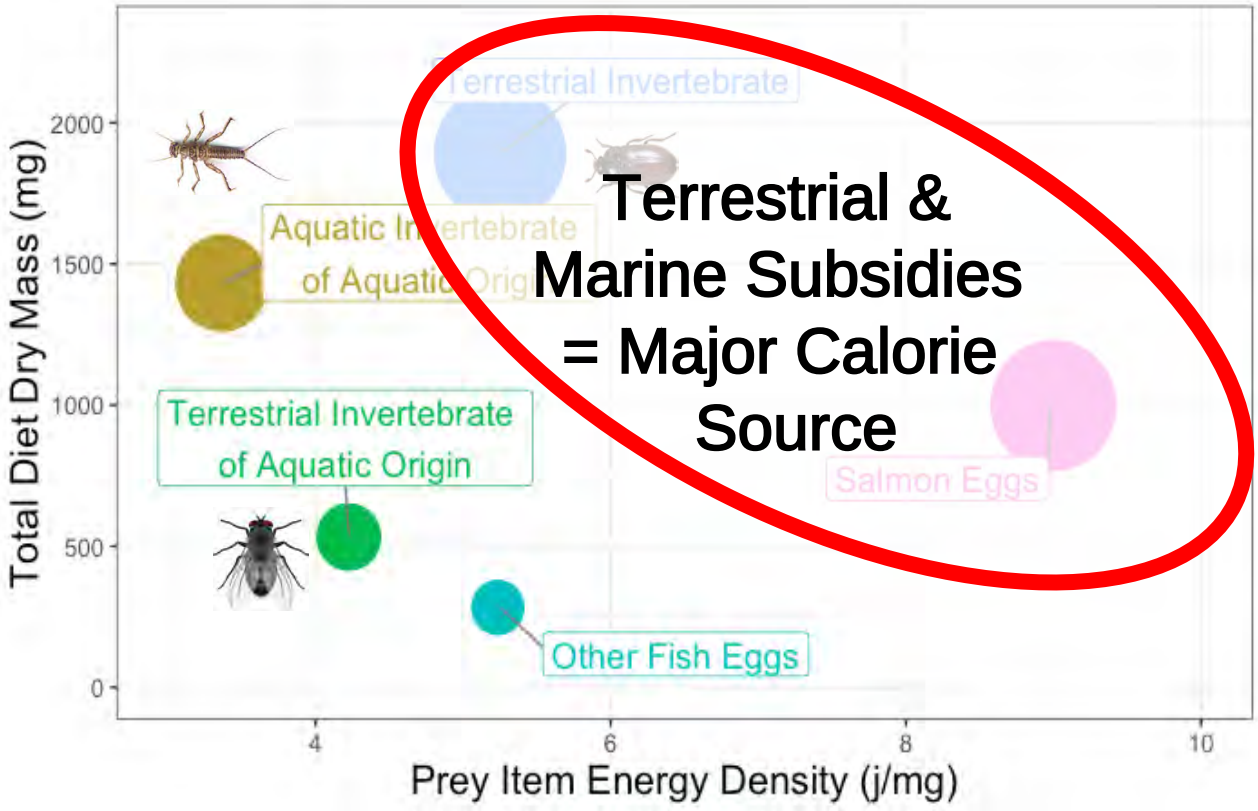
Identifying diet contents from ~800 fish



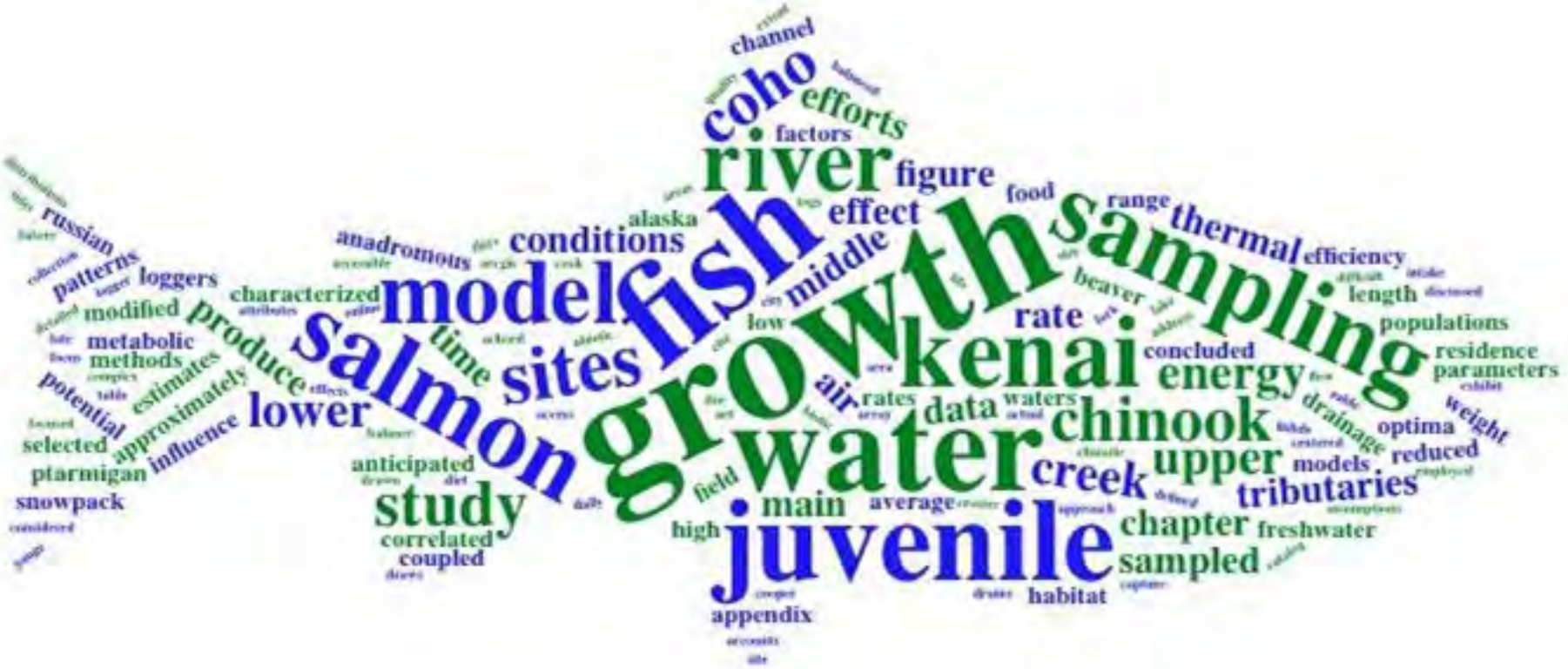
- Point size = Proportion of overall calories 2015-2016

Results: Diets

Identifying diet contents from ~800 fish



- Point size = Proportion of overall calories 2015-2016
- **Take Home: Terrestrial & Marine subsidies make up majority of overall caloric intake!**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sampled
habitat
appendix