Using Genetics to Inform Climate Adaptation Science

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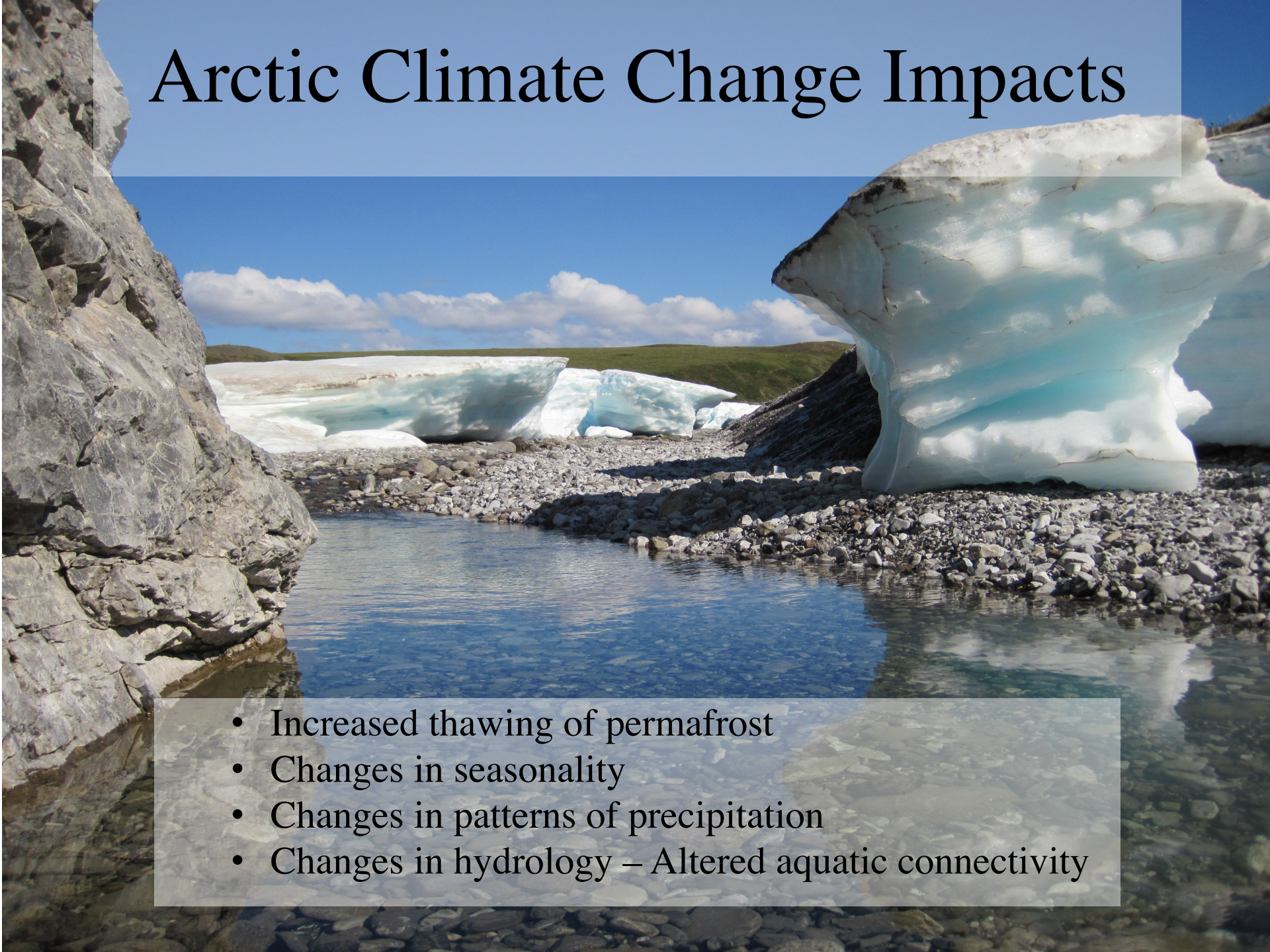
Woods Hole Research Center
ranked world's #1 climate change think tank

University of Connecticut

Genetic Tools for Management

1. Neutral Markers - Population Structure
2. Local Adaptation – CG Experiments
3. Signatures of Selection – Genomics
4. eDNA and aDNA - Species Detection

Arctic Climate Change Impacts



- Increased thawing of permafrost
- Changes in seasonality
- Changes in patterns of precipitation
- Changes in hydrology – Altered aquatic connectivity


Extensive Dry Zone
Lower Kuparuk
Increased Drying
Shifting Balance
PPT vs ET

How might climate change influence population persistence over time?

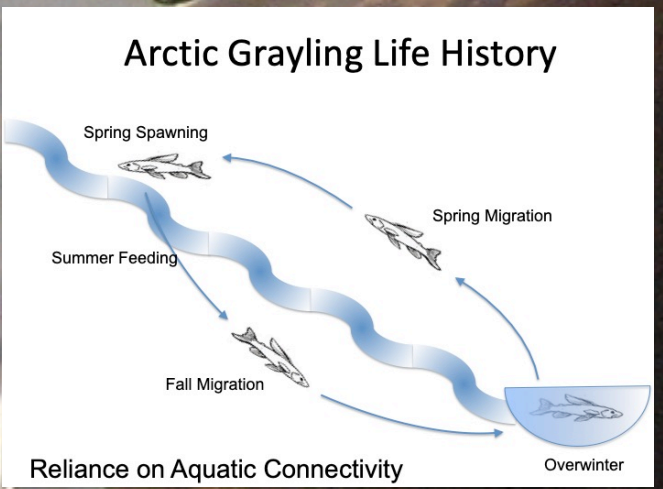


Photo: H. E. Golden

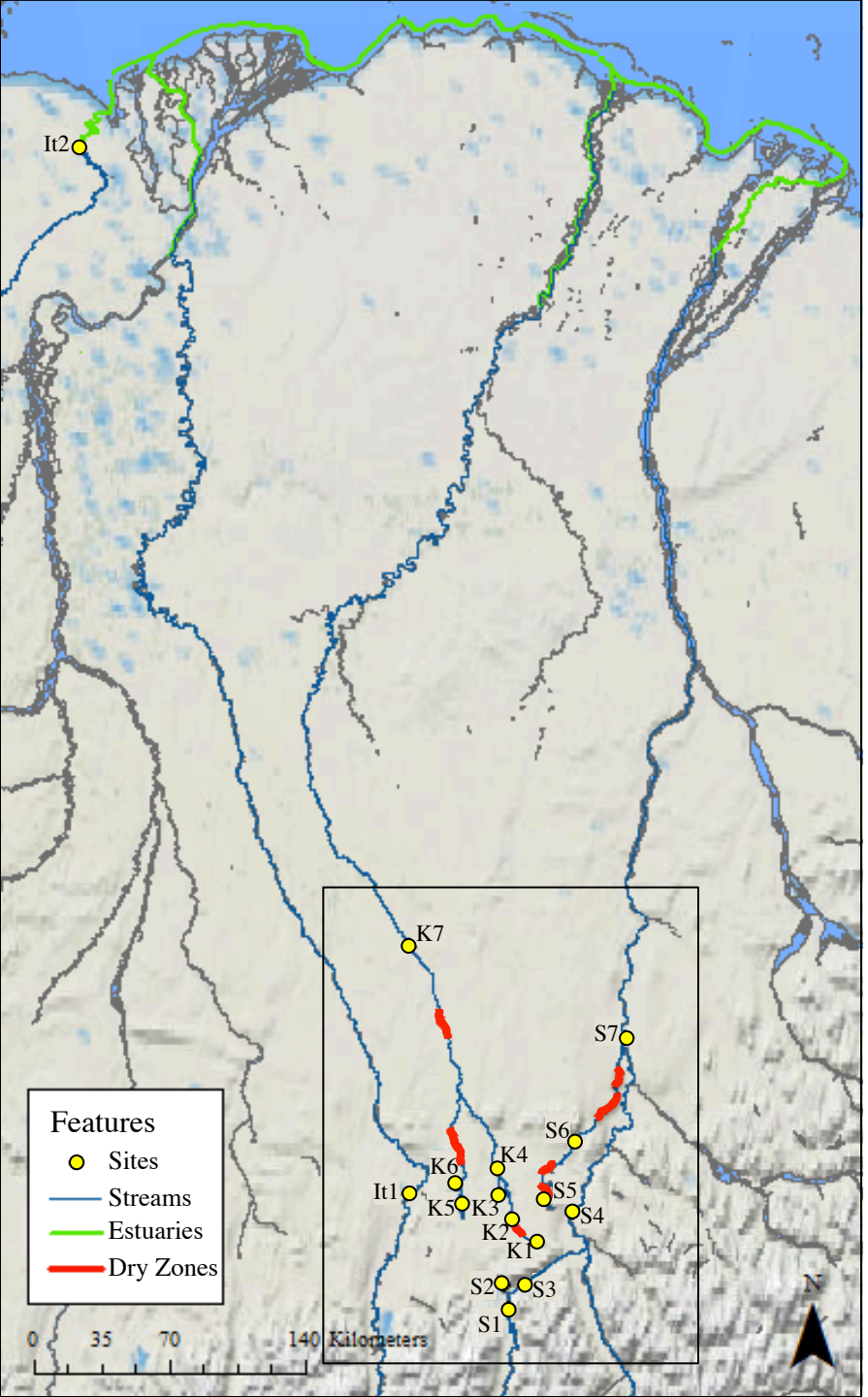
Neutral Markers

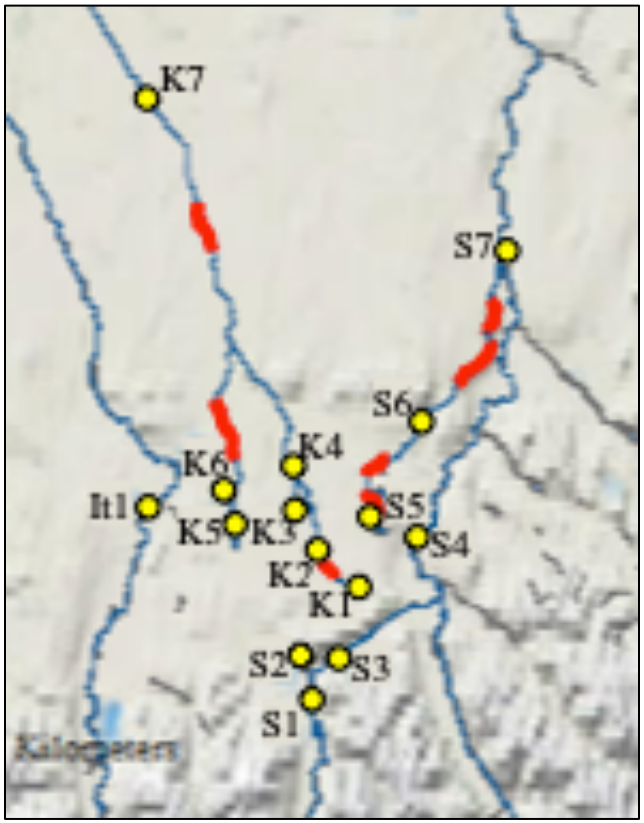
Microsatellites or SNPs

1. Number of populations
2. Gene flow – connectivity
3. Effective population size
4. Factors influencing structure

Population Structure and Environmental Factors

Watersheds (It, K, S)
Distance (km)
Estuaries (km)
Dry Zones (km)

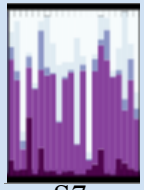


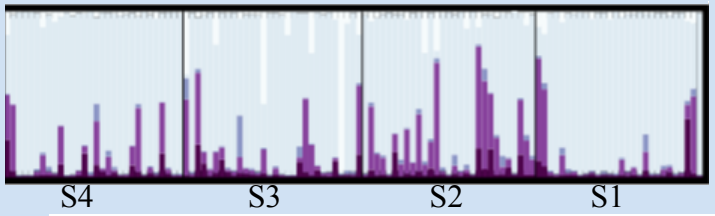


Population Structure

Genetic Clusters

Sagavanirktok





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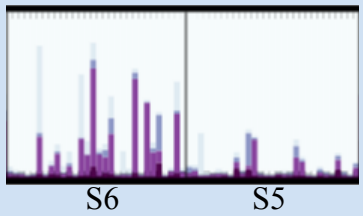

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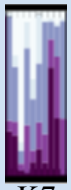
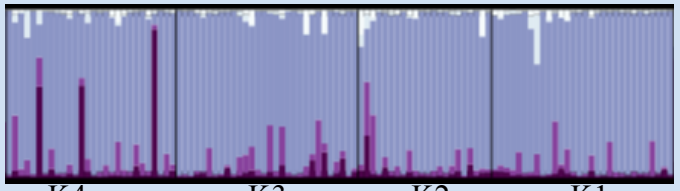
Kuparuk





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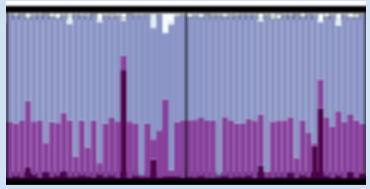

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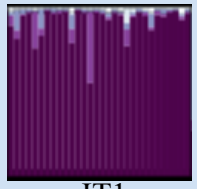
Itkillik



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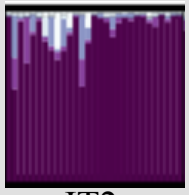


Coast

Downstream Toward Coast

Headwaters

Env. Factors

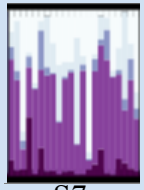
Dry Zones
0
1
2+

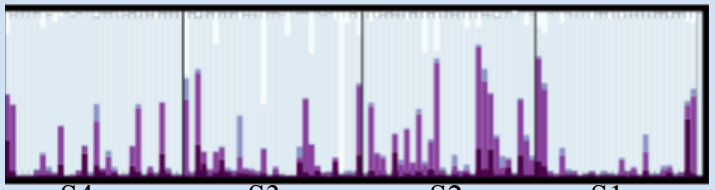
MEM-RDA & Hier AMOVA
70% Distance
18% Dry Zones
↑Drying → ↑Isolation

Watersheds (It, K, S)
Distance (km)
Estuaries (km)
Dry Zones (km)

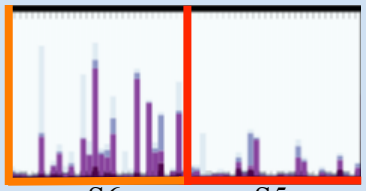
Genetic Clusters

Sagavanirktok


S7

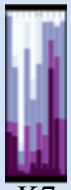

S4 S3 S2 S1

5


S6 S5

4

Kuparuk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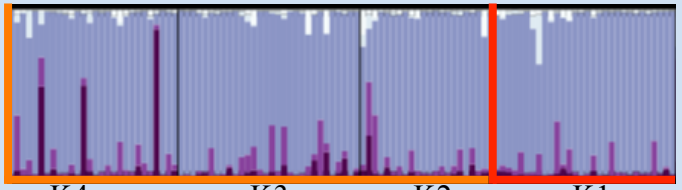
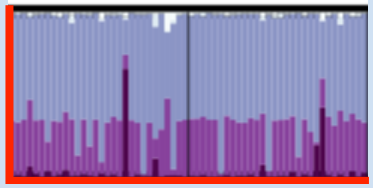
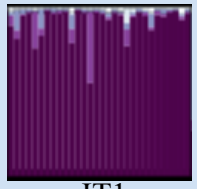

K4 K3 K2 K1

3

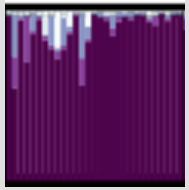

K6 K5

2

Itkillik


IT1

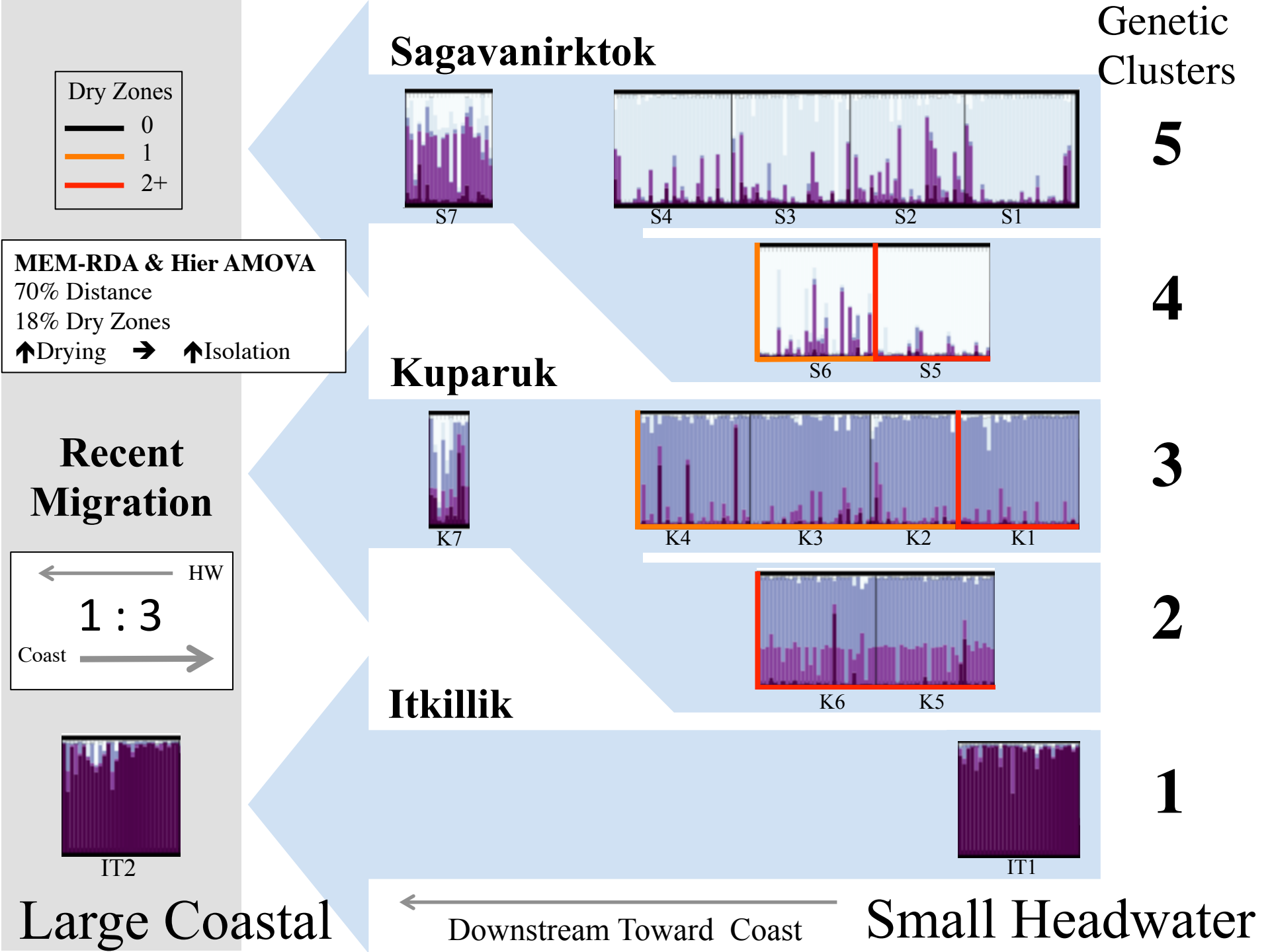
1


IT2

Coast

Downstream Toward Coast

Headwaters


Genetic Clusters
Dry Zones
0
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70% Distance
18% Dry Zones
Drying
Isolation
Sagavanirktok
S7
S4
S3
S2
S1
5
S6
S5
4
Kuparuk
K7
K4
K3
K2
K1
3
K6
K5
2
Itkillik
IT1
1
Recent Migration
HW
1 : 3
Coast
IT2
Large Coastal
Downstream Toward Coast
Small Headwater

Neutral Markers Inform Climate Adaptation

Microsatellites or SNPs

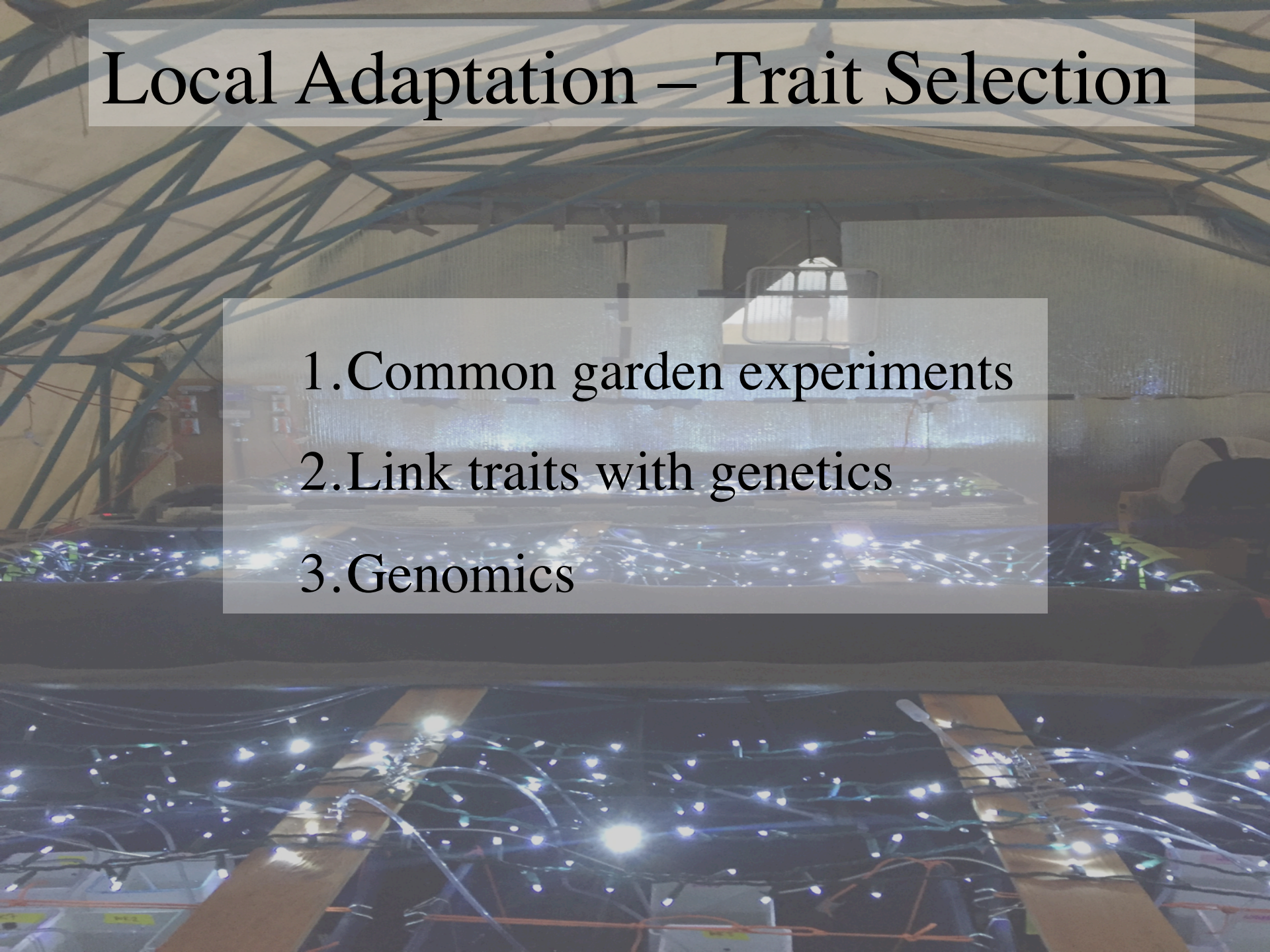
1. Small Isolated Pops = Higher Extinction Risk

   Low Genetic Diversity

   Stochastic Events (b and d rates)

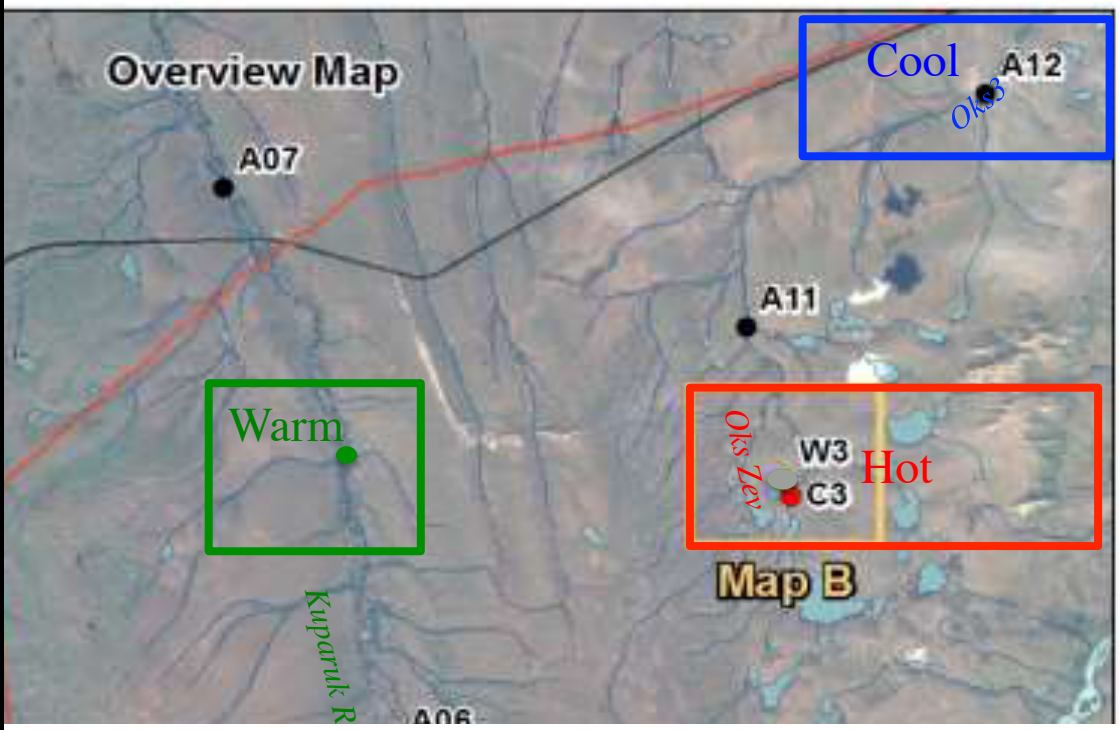
2. Understanding Factors associated w Genetic Variation Allows for Potential Mitigation

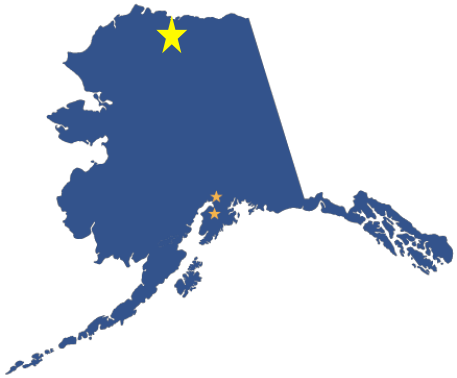
Local Adaptation – Trait Selection



1. Common garden experiments
2. Link traits with genetics
3. Genomics

Arctic Grayling Common Garden Experiment





Three Populations

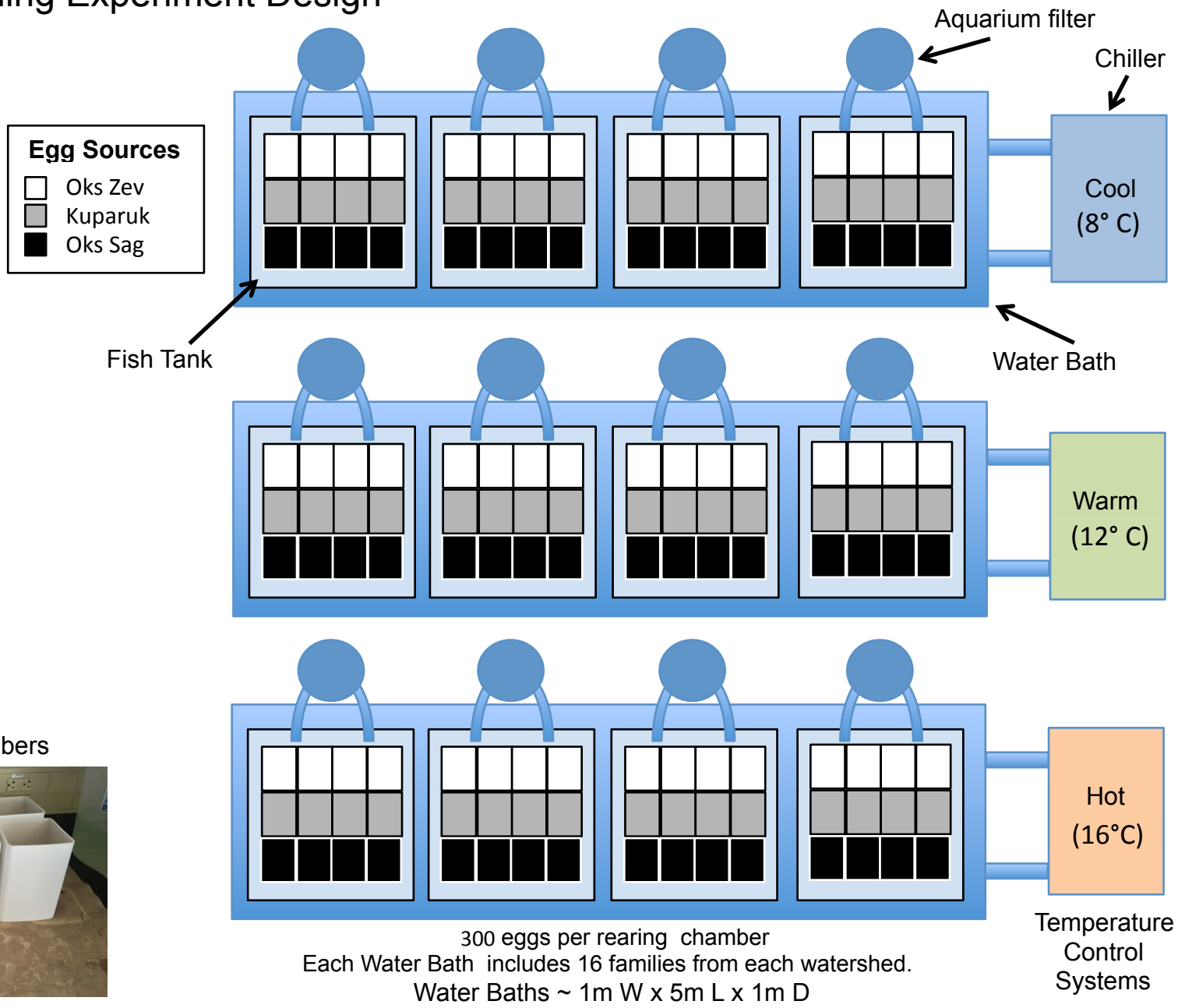
Oks Zev: Hot ~ 12 degrees

Kuparuk: Warm ~ 8 degrees

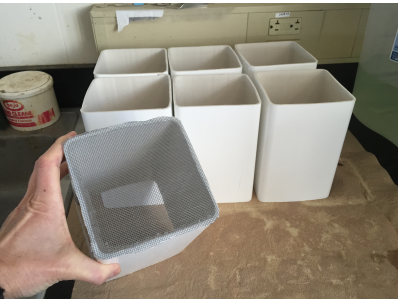
Oks Sag: Cool ~ 5 degrees

$$\text{Phenotype} = G + E + (G \times E)$$

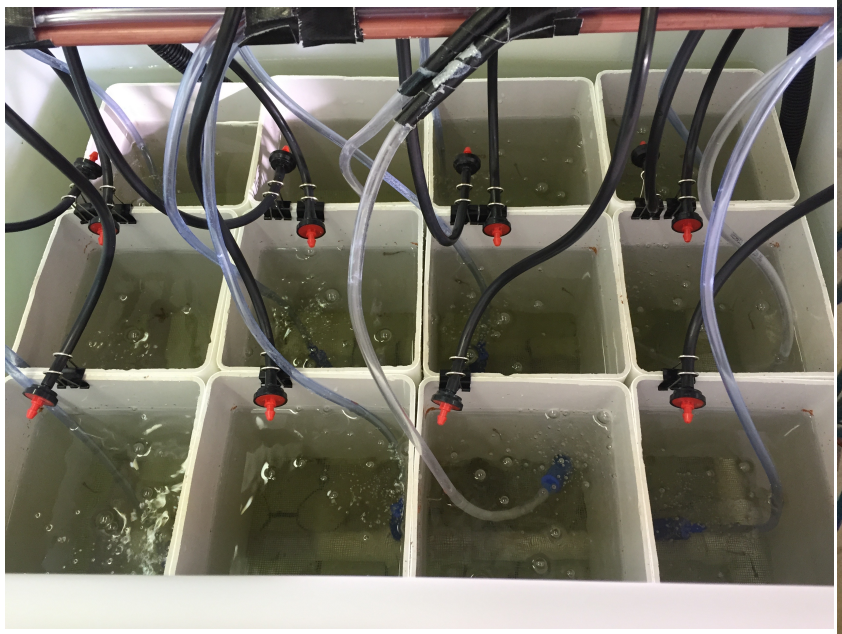
Arctic Grayling Experiment Design



Rearing Chambers



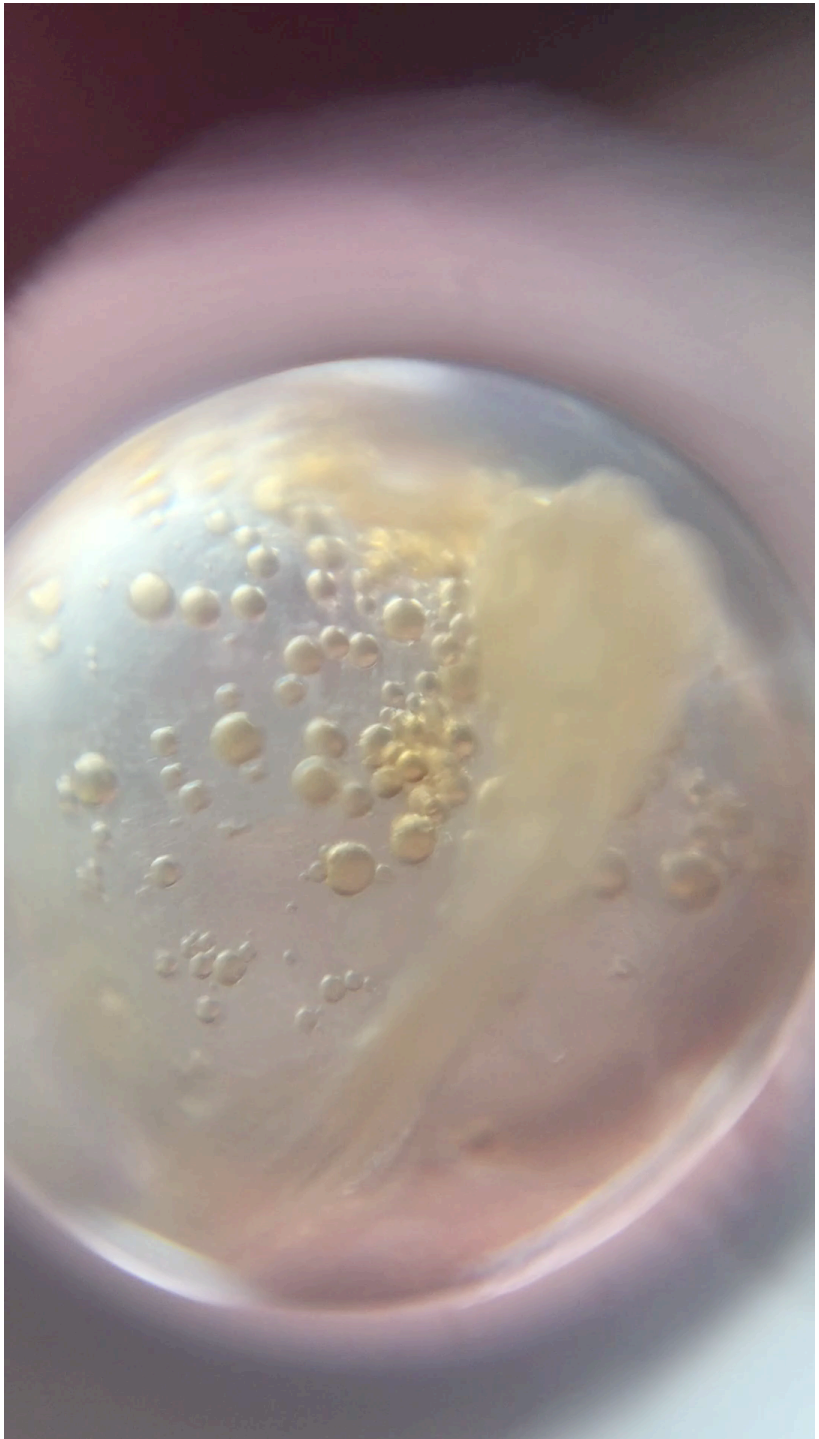
300 eggs per rearing chamber
Each Water Bath includes 16 families from each watershed.
Water Baths ~ 1m W x 5m L x 1m D



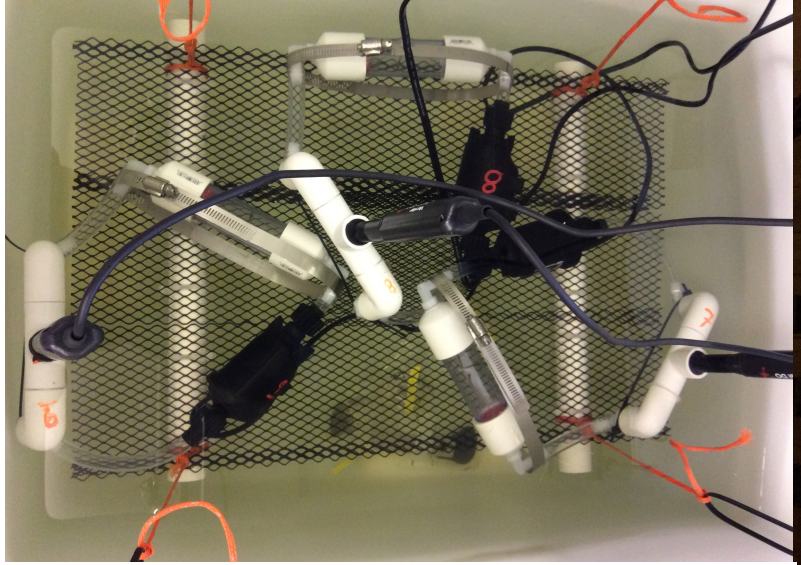
Traits
Survival
Growth
Yolk sack volume
Length at hatching
Length at swim-up

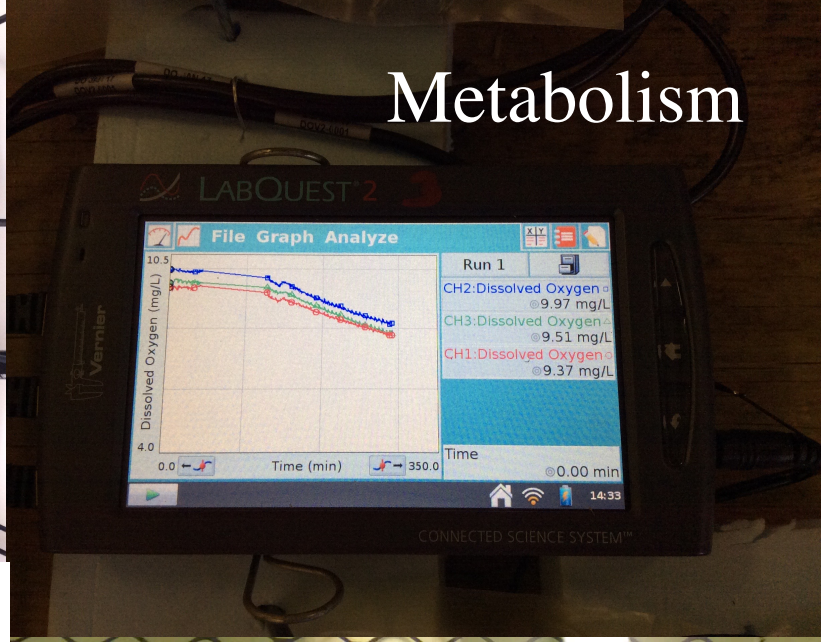
Metabolism
Temperature Preference
Rheotaxis – Directionality Preference

Developing Embryo

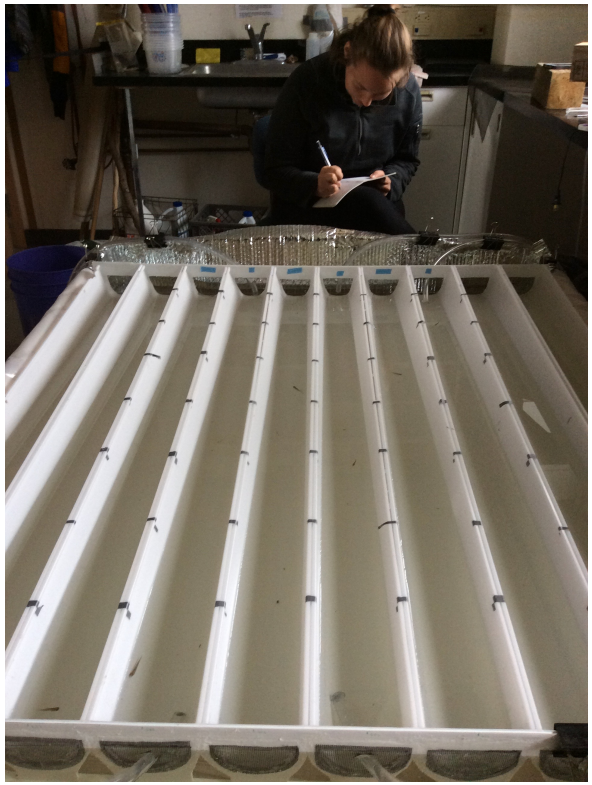


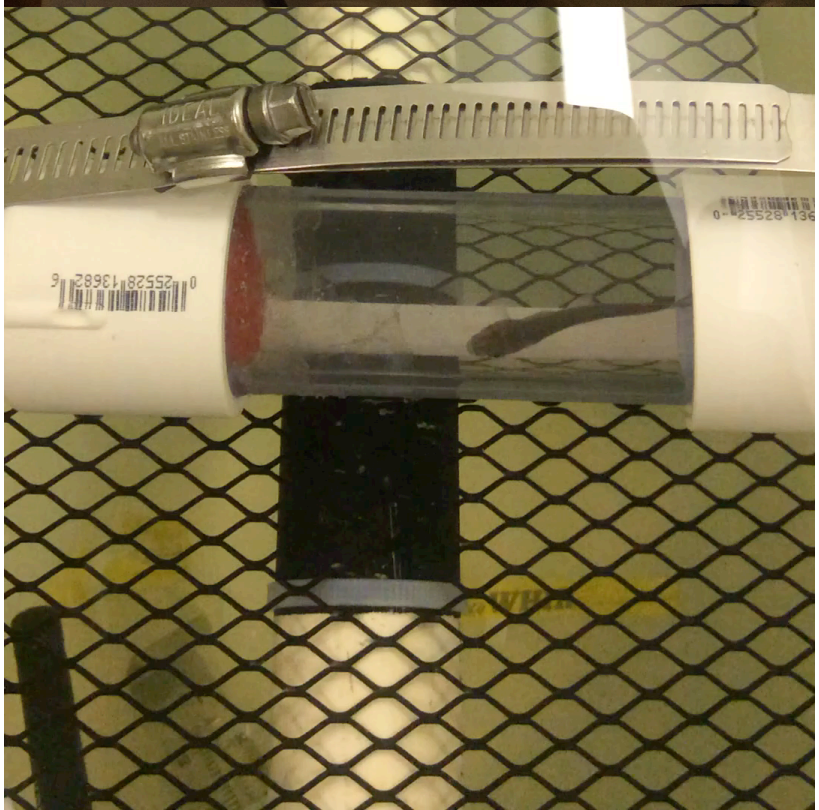
Trait Measurements



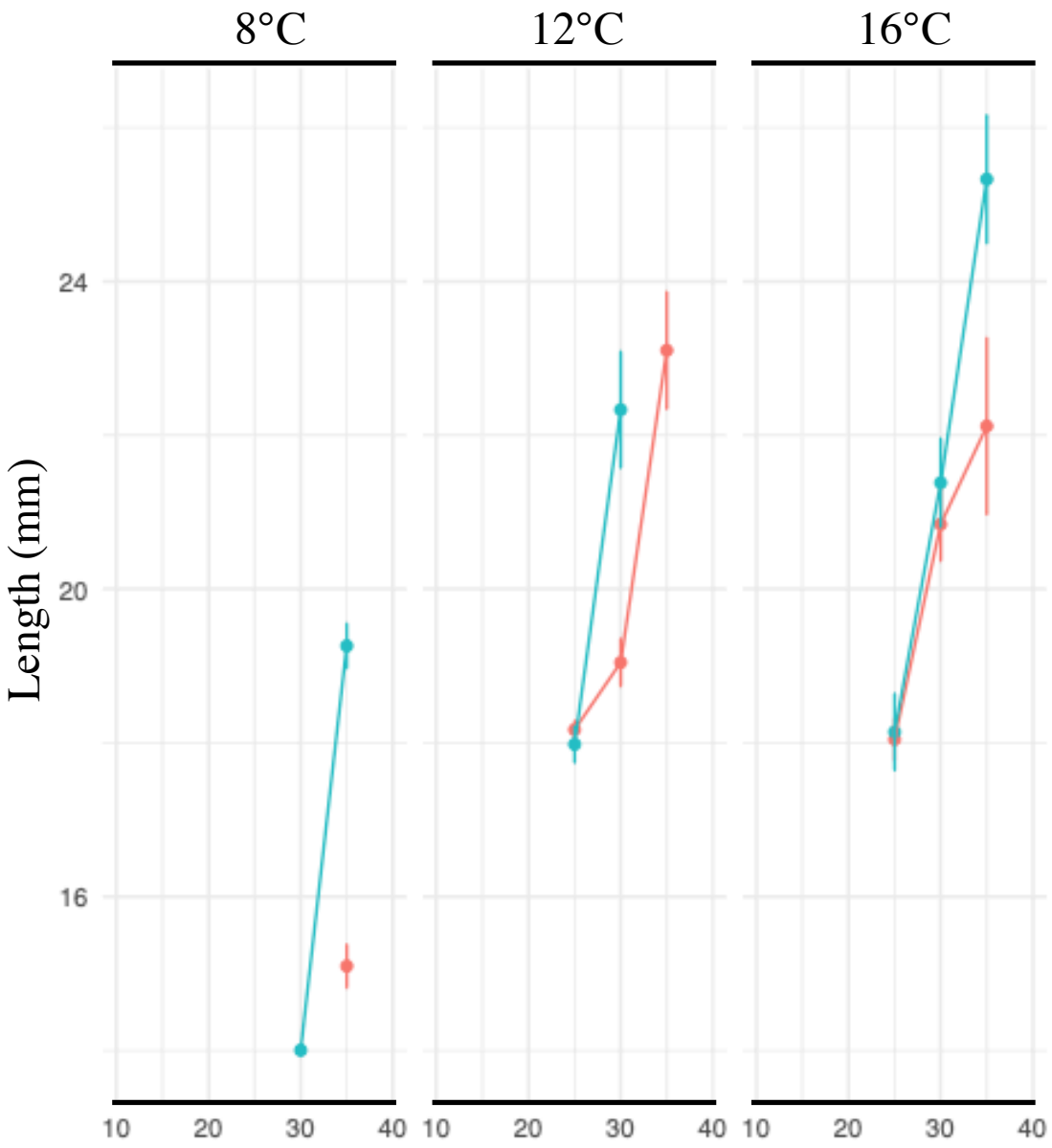


Direction & Temperature Preference





Common Garden Experiments



Preliminary Results

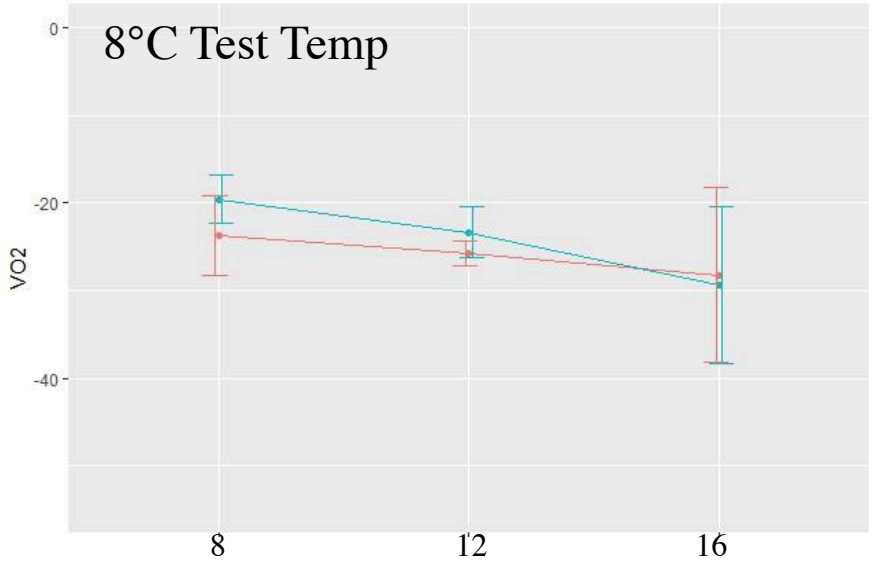
Location

Kuparuk (warm river)

Oksrukuyik (cool river)

Countergradient Variation in Growth

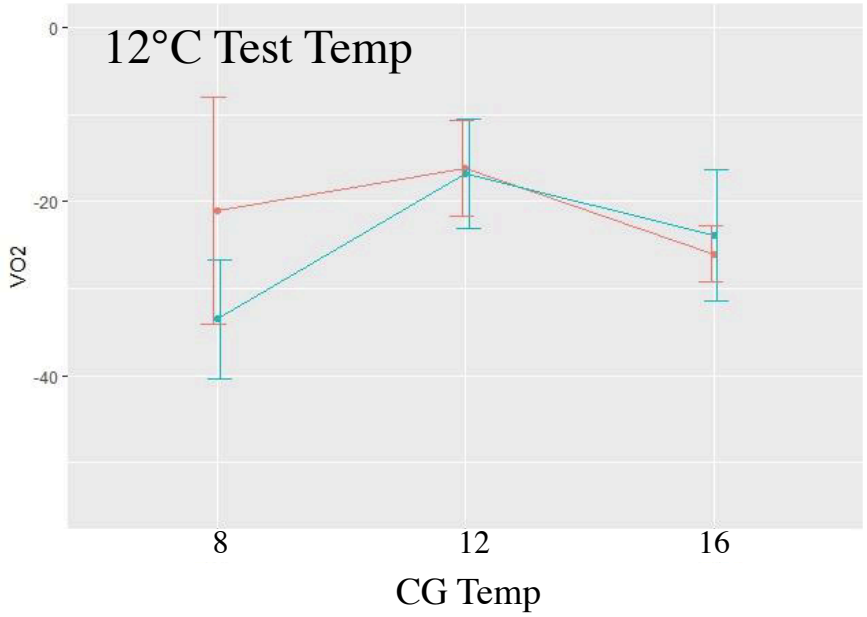
Common Garden Experiments - Respiration

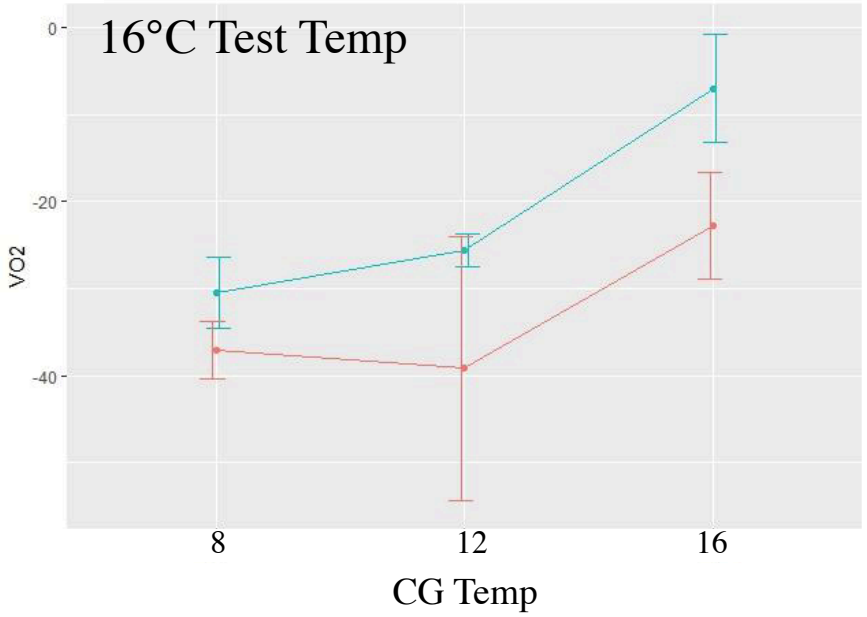


Fish Reared at 8, 12, and 16 degrees (CG temp), then tested at 8, 12, and 16 degrees (Test Temp).

Location
Kup (warm river)
Oks3 (cool river)

Local Adaptation to River Temp

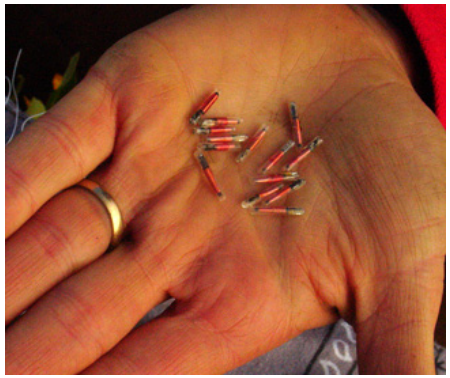




Traits that Occur at Maturation?

Trait Variation for Migration Distance

PIT-Tags and Antennas



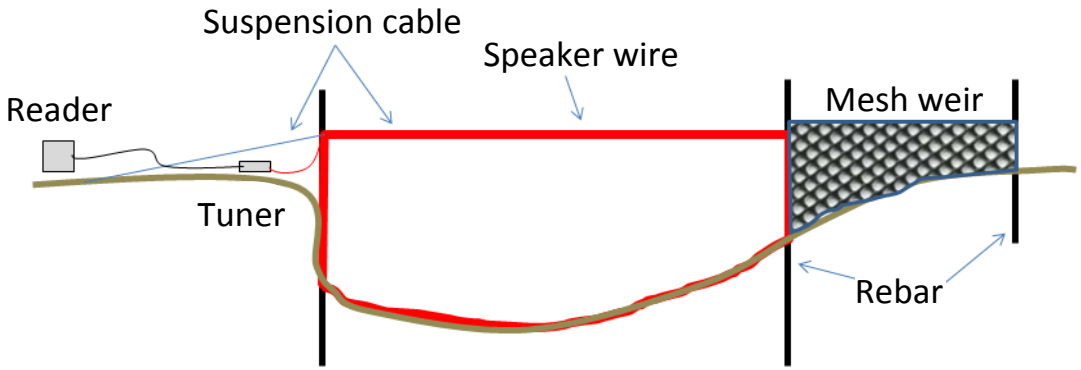
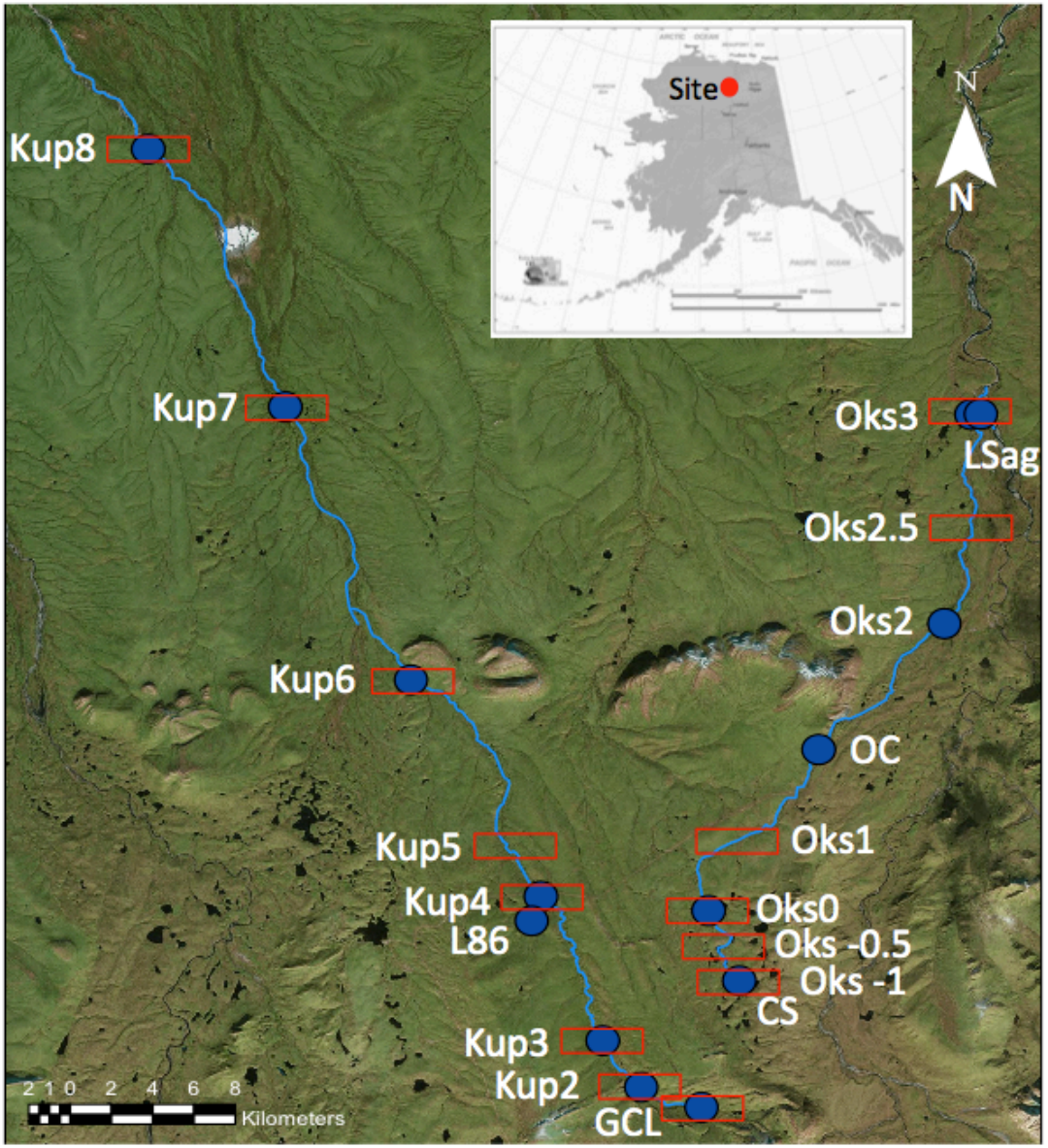


photo by C. MacKenzie

PIT Antenna and Genetic Sampling Locations



DNA from Adults and YOY

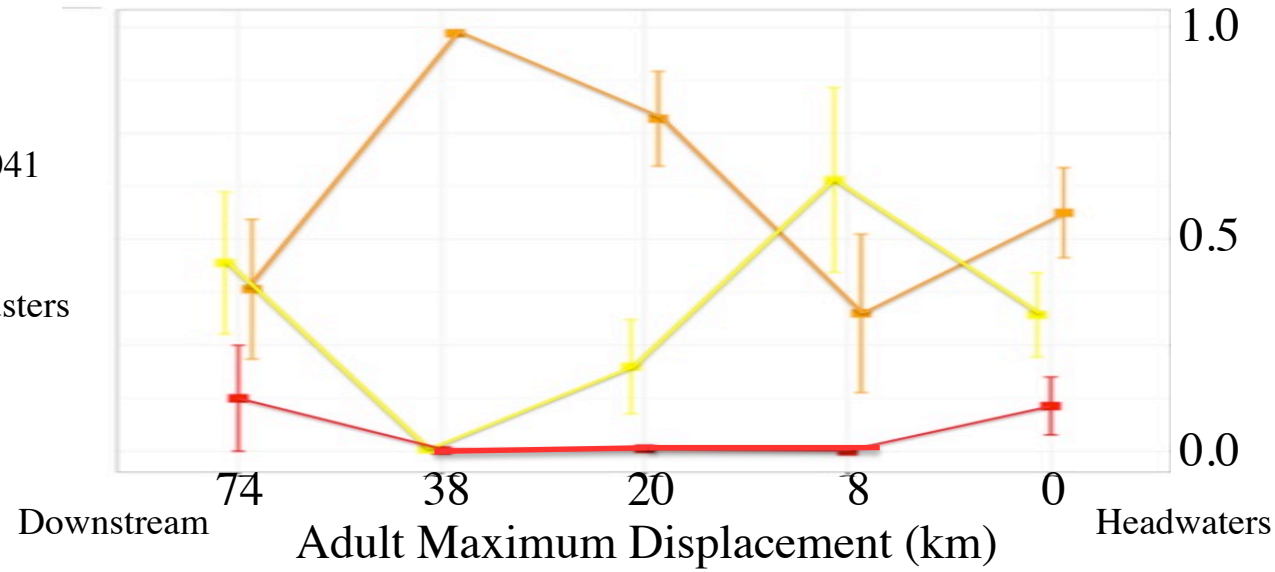
YOY ≈ Proxy for Spawning Stocks to Determine Genetic Clusters

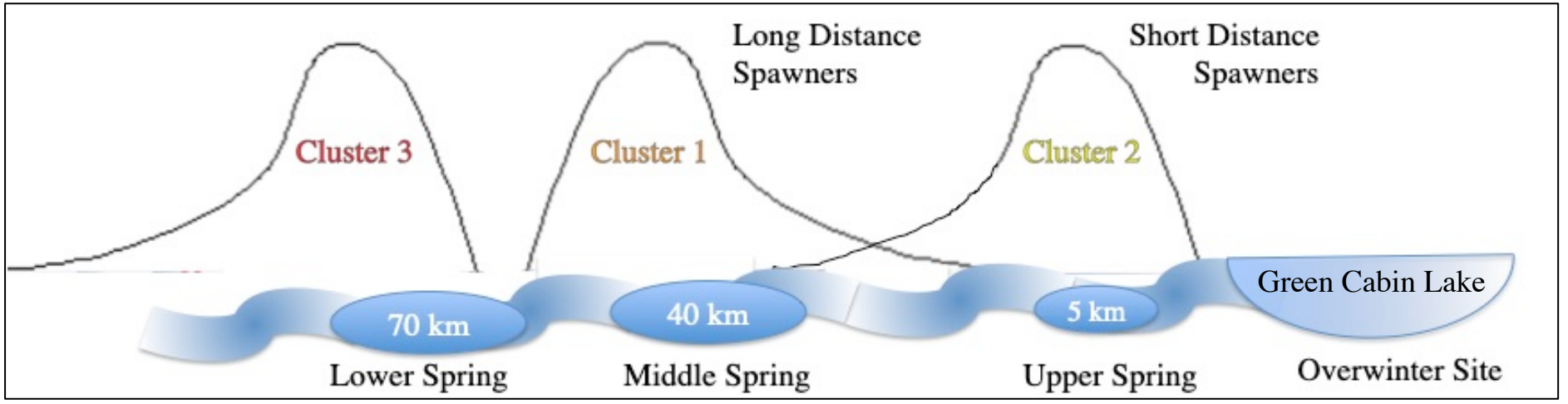
Compare Adult Trait (Migration Distance) with Genetic Assignment to Clusters

Upper reaches: Spawning stocks based on migration distance

p-values
Clusters = 0.0001
Clusters x dist. = 0.041

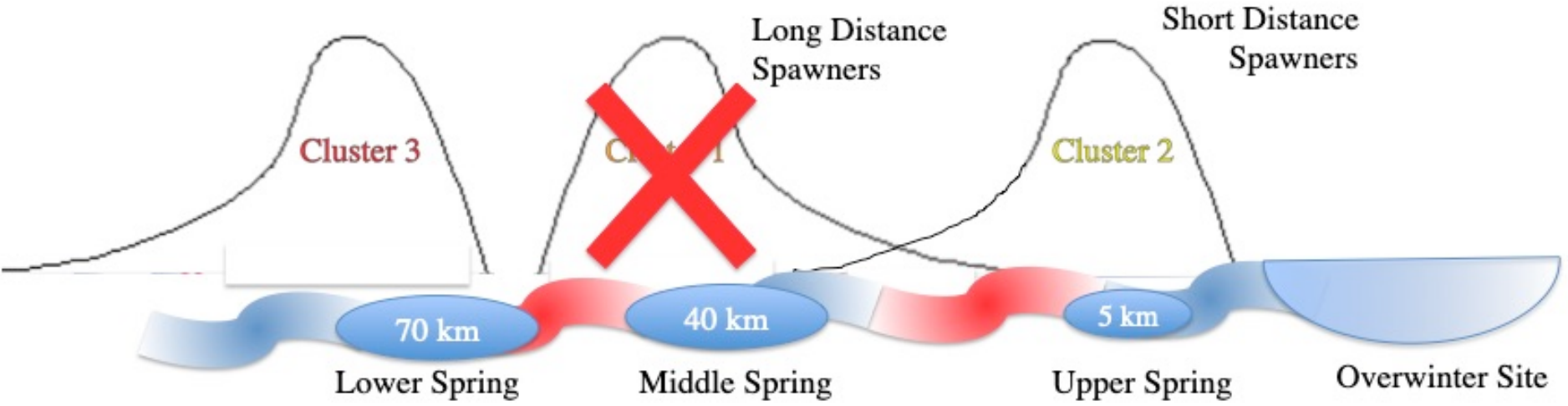
DAPC Genetic Clusters
- Kup Cluster 1
- Kup Cluster 2
- Kup Cluster 3





Lower reaches: Spawning stocks based on migration timing (temperature)

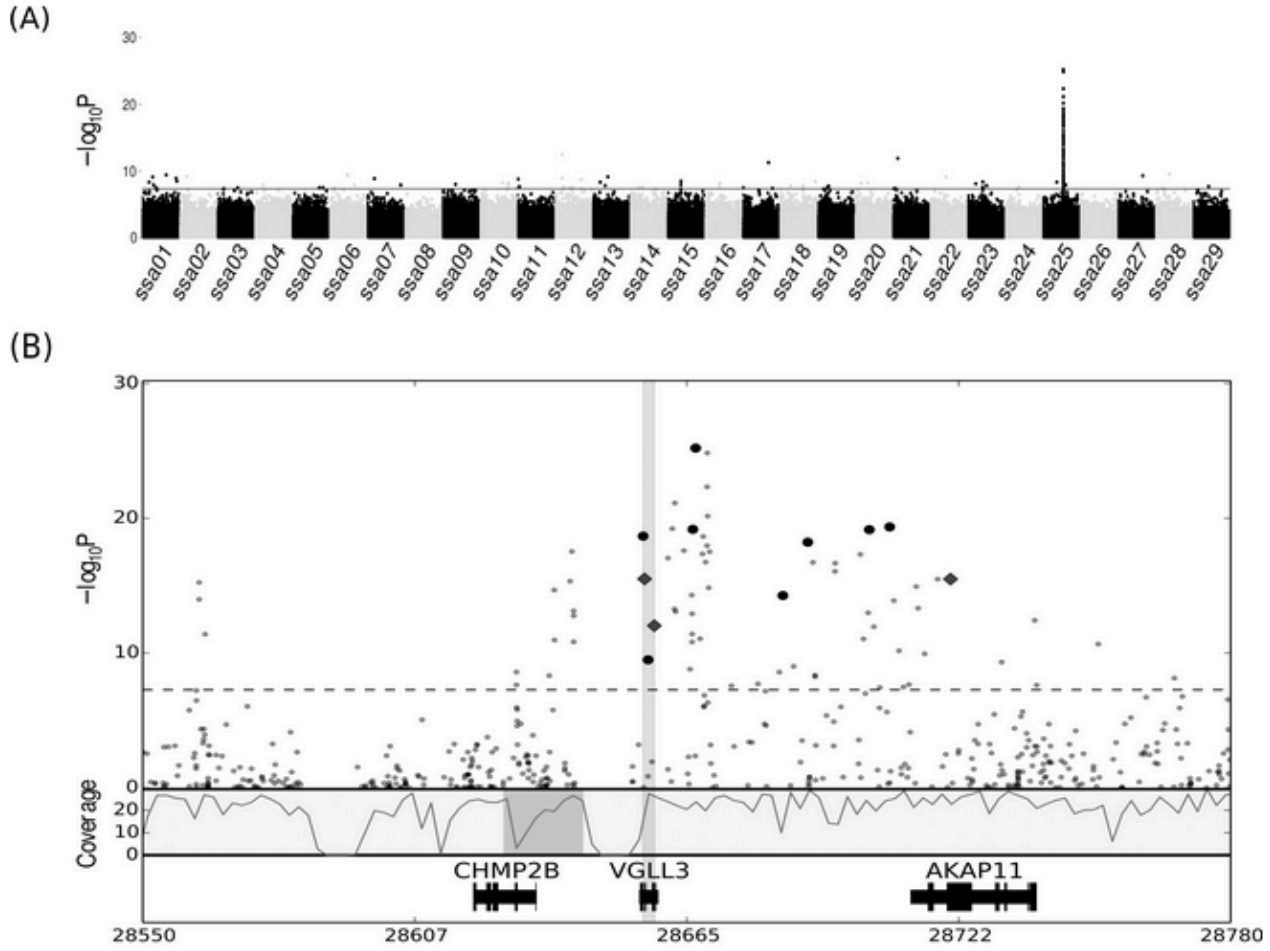
Climate Implications



Increased River Drying >> Decreased Genetic Diversity >> Increased Extinction Risk
Decreased Population Size
Increased Population Isolation

Landscape Genomics
Signatures of Selection Across the Genome

i.e. Atlantic Salmon – Age at Maturity Gene (shown)
and Chinook Salmon – Migration Gene



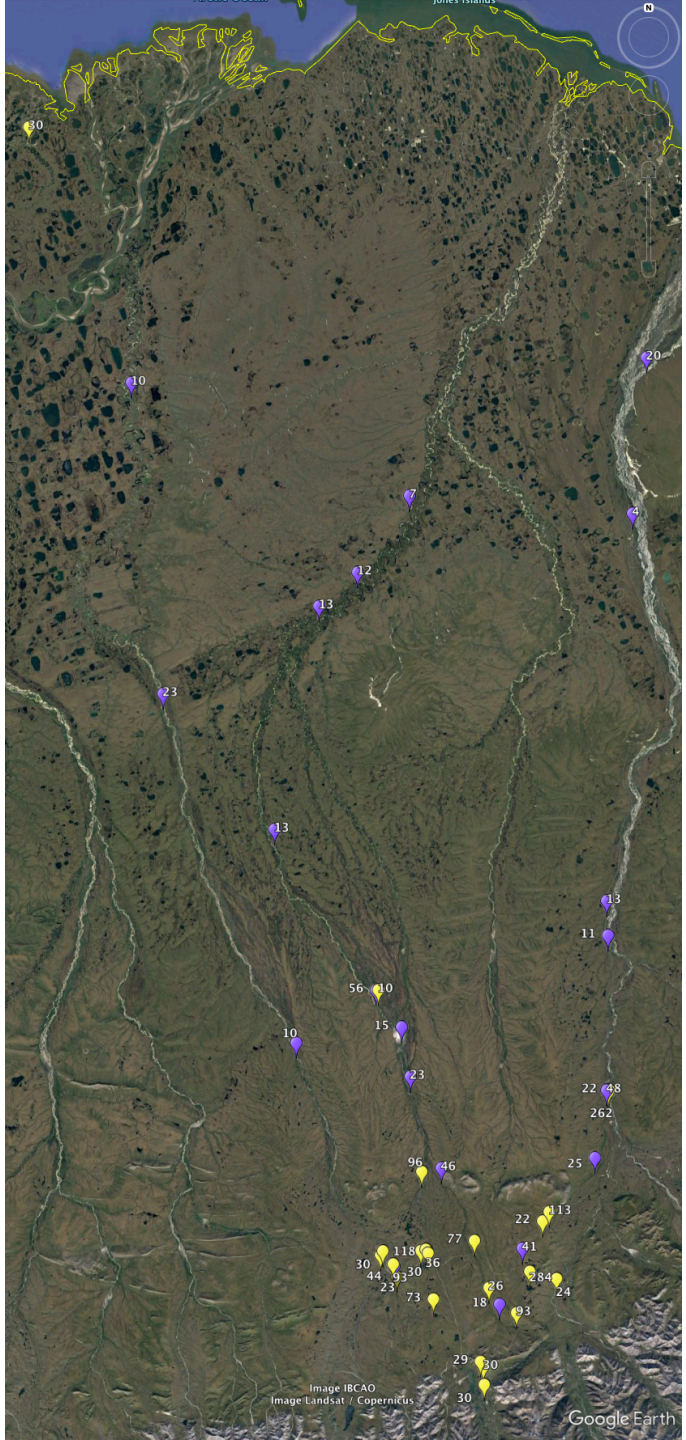
Physical position along the genome (kb)

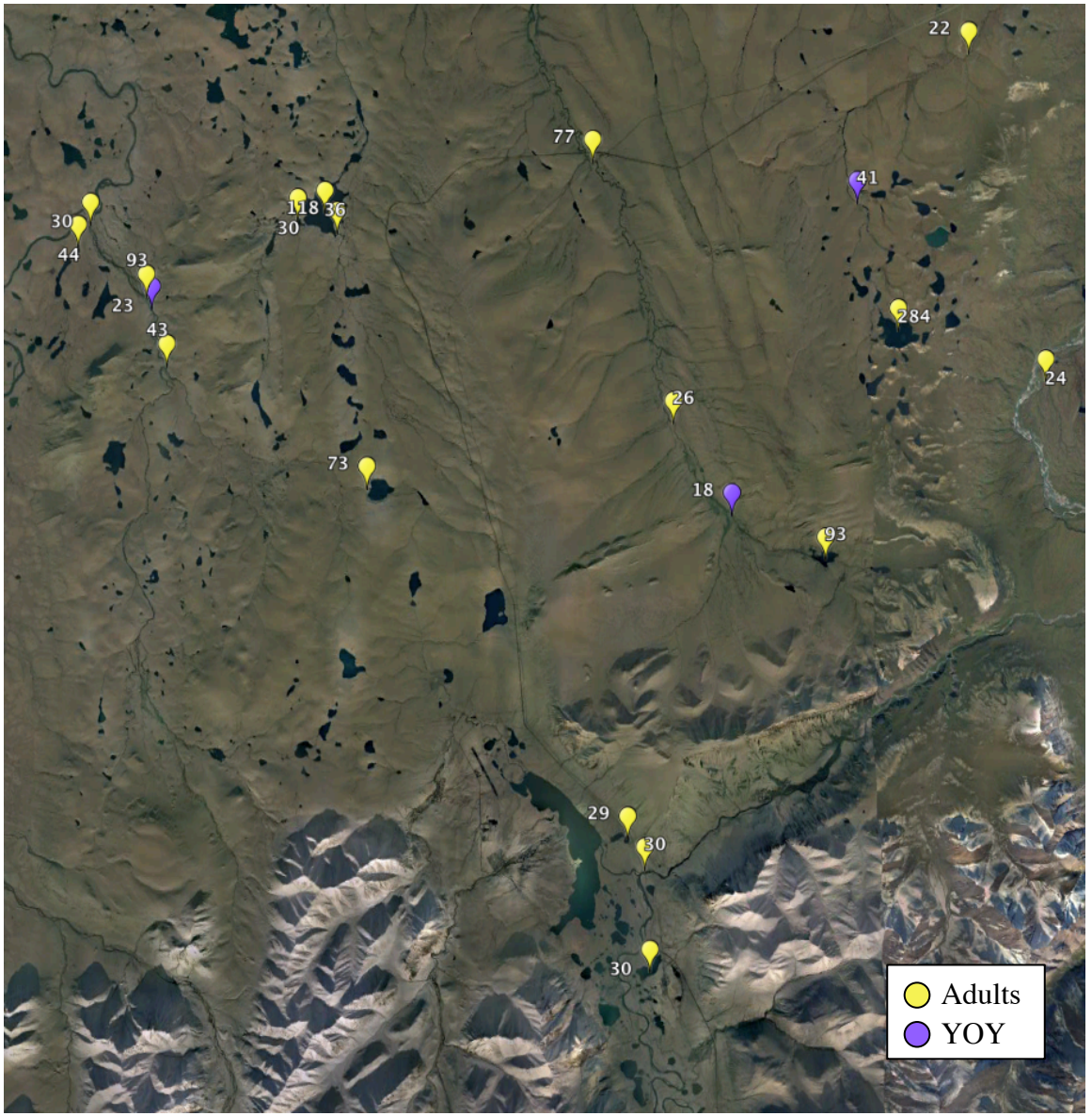
doi: https://doi.org/10.1371/journal.pgen.1005628.g002

Ayllon et al. (2015) PLoS Genetics

Landscape Genomics

Numbers indicate amount of samples for each age-class available for genomics from each location.





Genomics

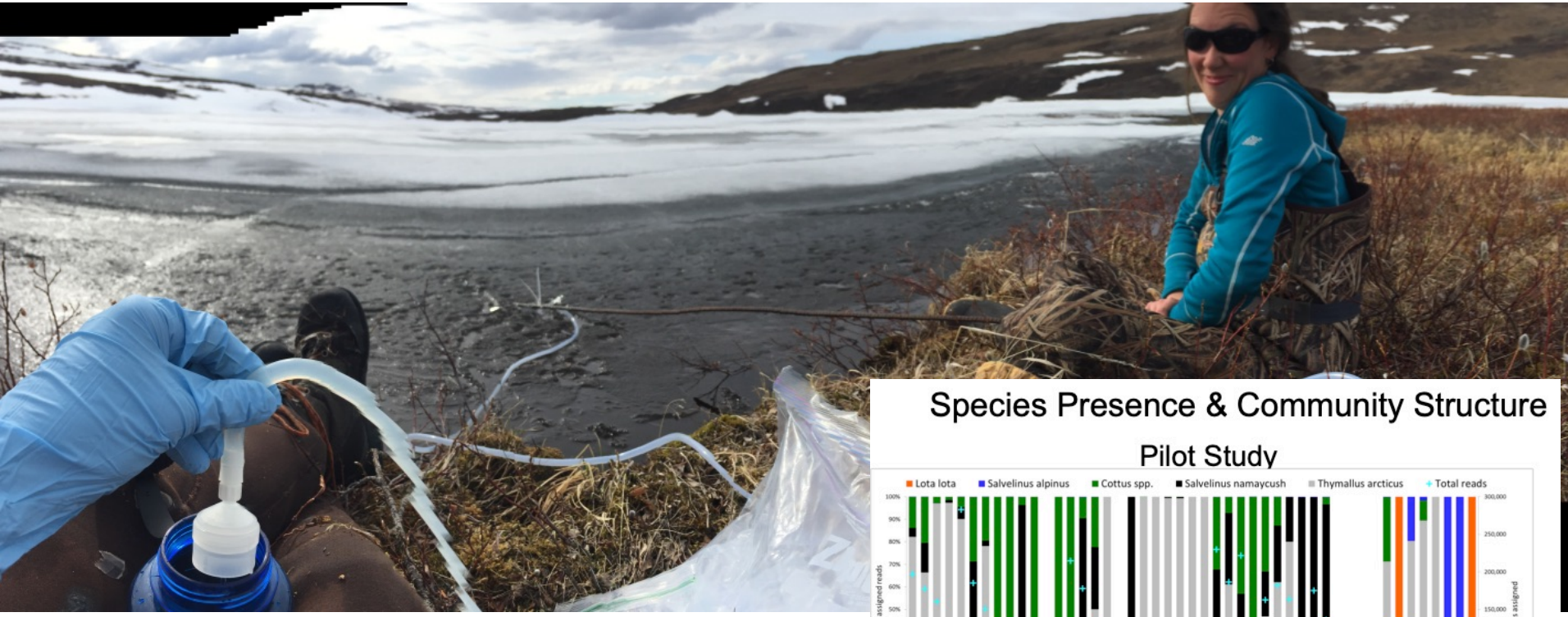

Fisher Vortex Genie 2
Cat.No.12-812
Fisher Scientific
FINNTIP
Thermo
GOLDEN
Dear Mark Urban,
This is to inform you that the library QC report for your order 1811KHP-0138 is ready.
The report indicates this order has passed the library QC, and we are ready to move on to the next step.
Please download the report from link below. Let us know if you have any questions or concerns.
Link : NGS Library QC 1811KHP-0138 181203E-057.pdf
Sincerely,
Macrogen Clinical Laboratory

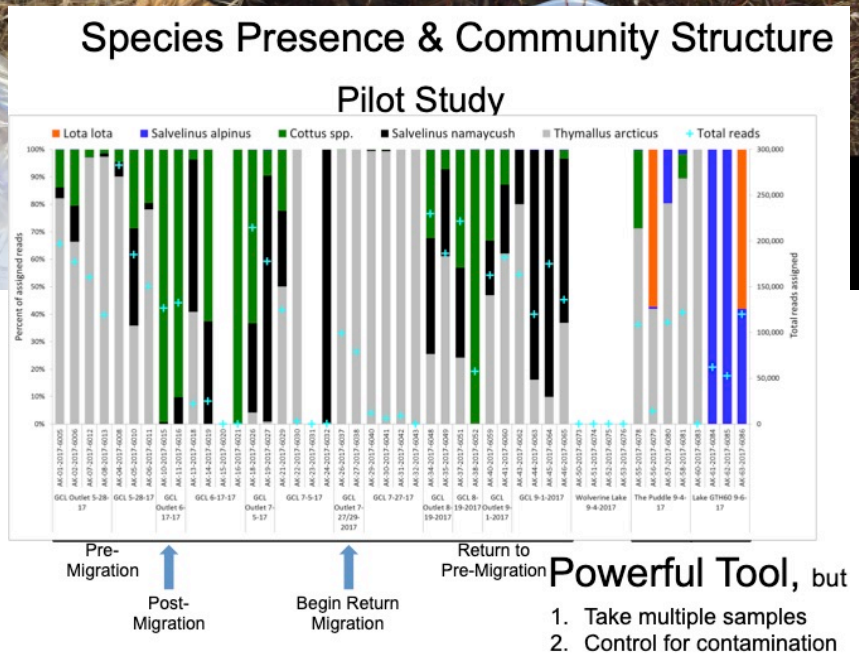
CG Exp. and Genomics Inform Climate Adaptation

1. Identifying Genetic Traits Under Selection
2. Identify Populations at Risk
3. Evaluate Management Options, i.e. Potential for Genetic Rescue

eDNA and aDNA

ArcLTER & USFWS





Acknowledgements


Questions