

# Distribution of genetic variation underlying adult migration timing in steelhead of the Columbia River basin

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# Background

## Fish migrations

- temporal and spatial availability of resources
- cultural, economic, and ecological resource

RIVER OCEAN



Image credit: Robin Ade

## Management

### Causes of decline:

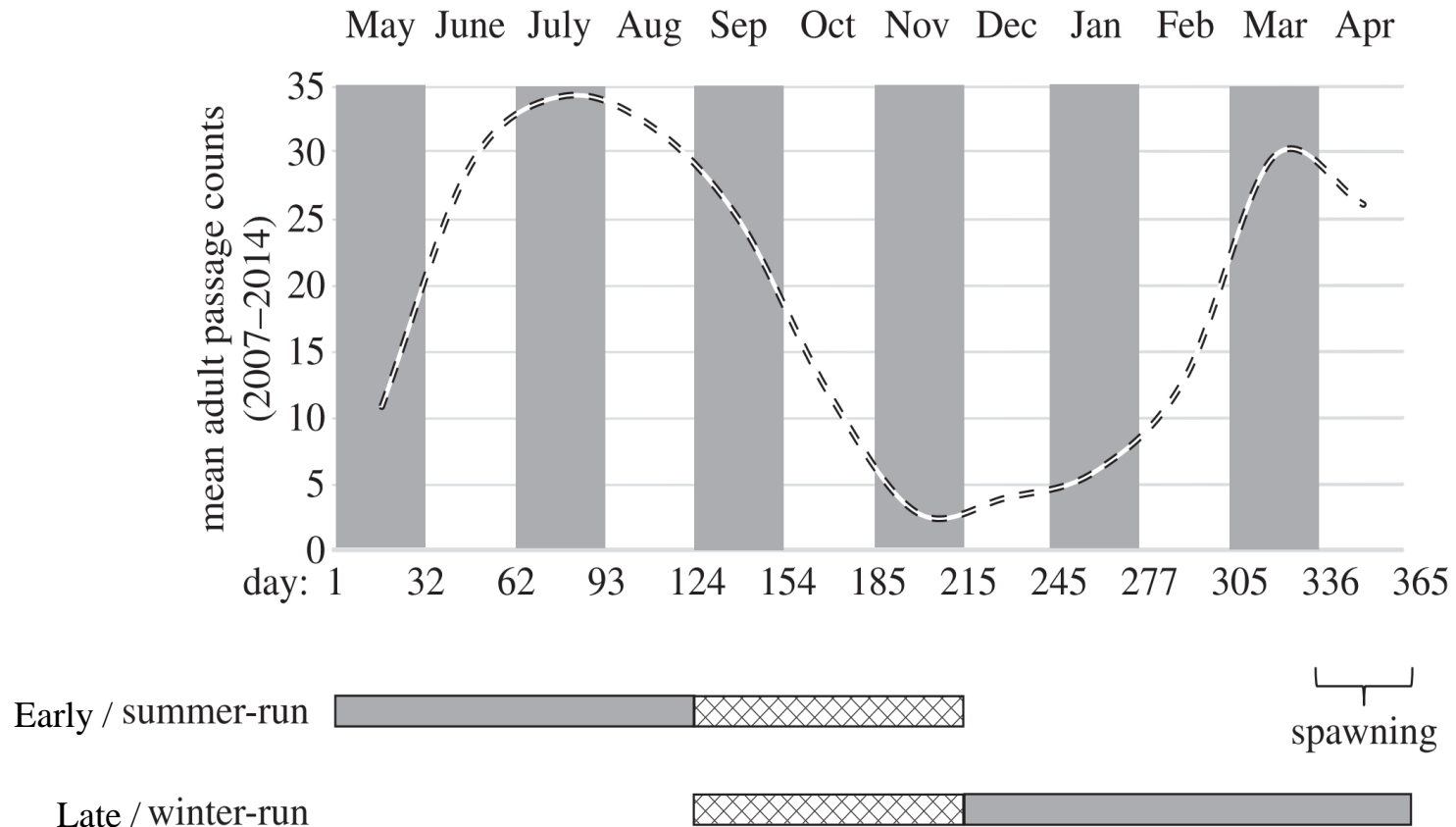
- overharvest, habitat degradation, hydroelectric dams, climate change, other anthropogenic development

### Solutions:

- Identify evolutionarily significant units (ESU)
- maintain phenotypic and genetic variation of distinct populations, such as migration timing

# Background

- Bimodal migration timing in steelhead
- Early / summer-run mature in streams and late / winter-run mature in ocean, both spawn at the same time

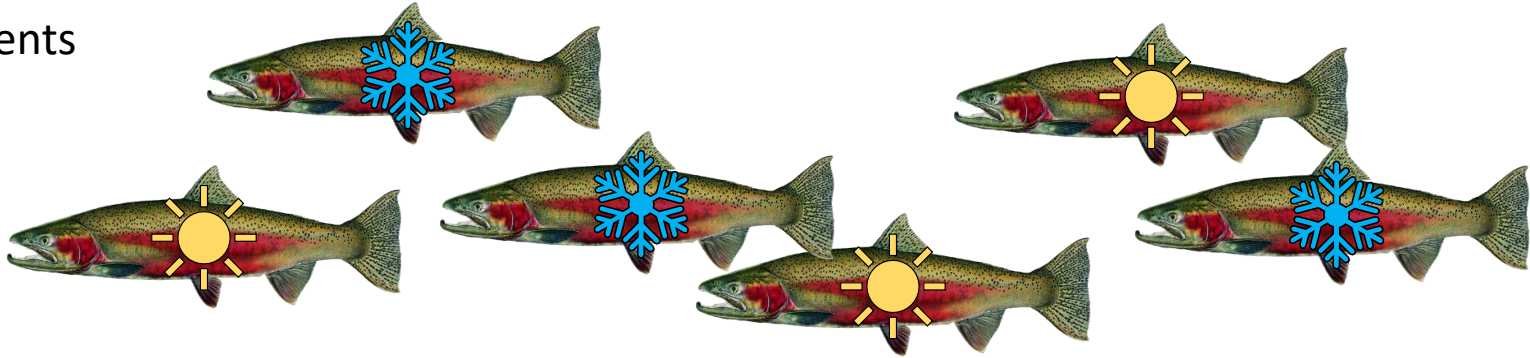


Adapted from: Hess et al. 2016

# Background

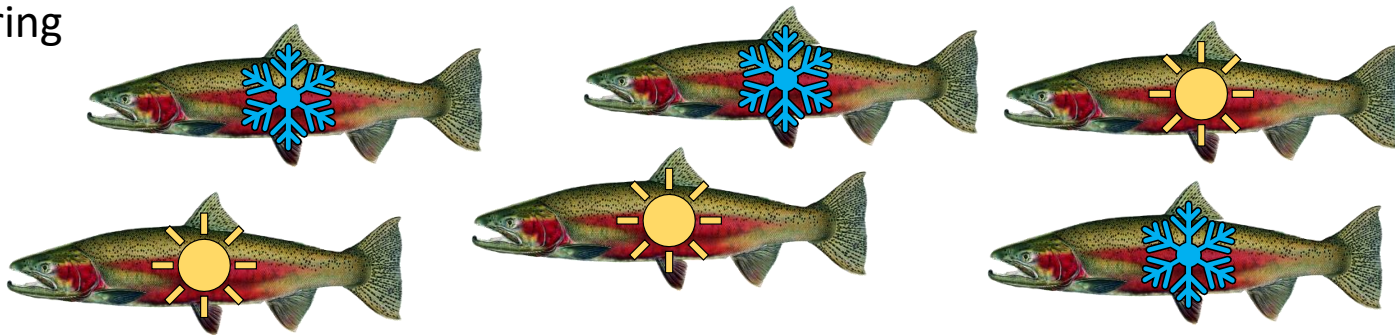
- Migration timing has genetic basis and is heritable

Parents



Equilibrium

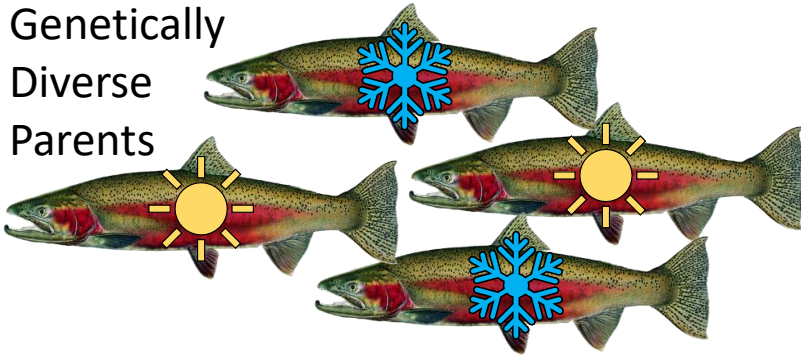
Offspring



# Background

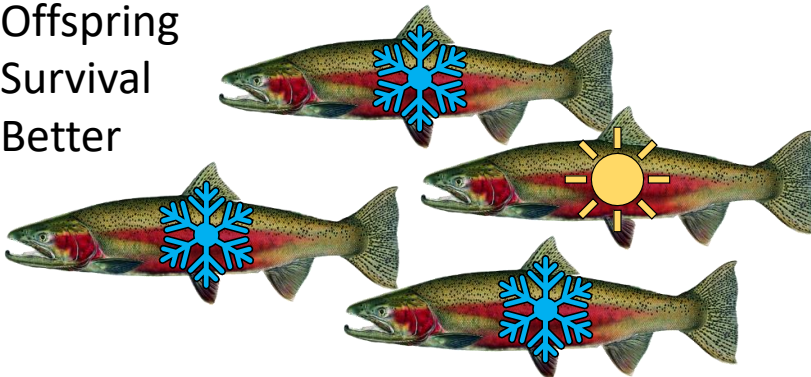
- Genetic diversity and conservation

Genetically  
Diverse  
Parents

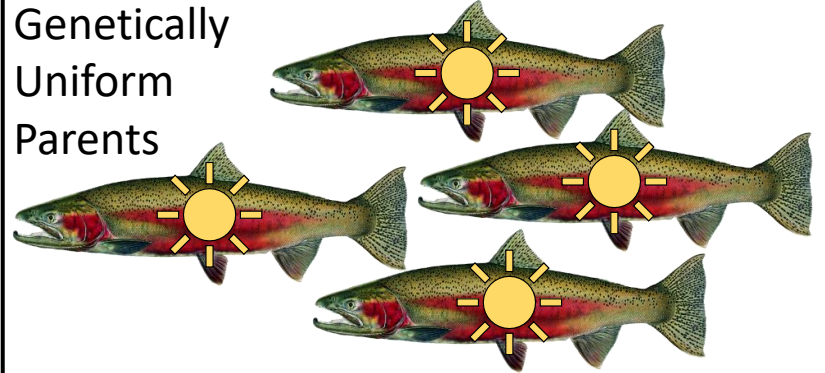


Higher stream  
temperatures

Offspring  
Survival  
Better



Genetically  
Uniform  
Parents



Higher stream  
temperatures

Offspring  
Survival  
Worse





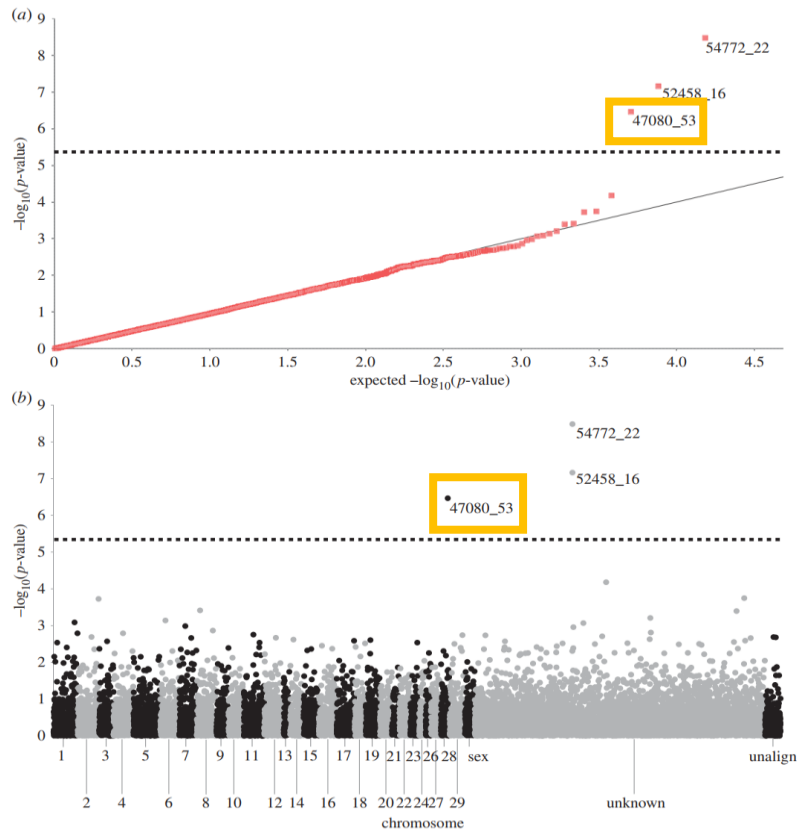
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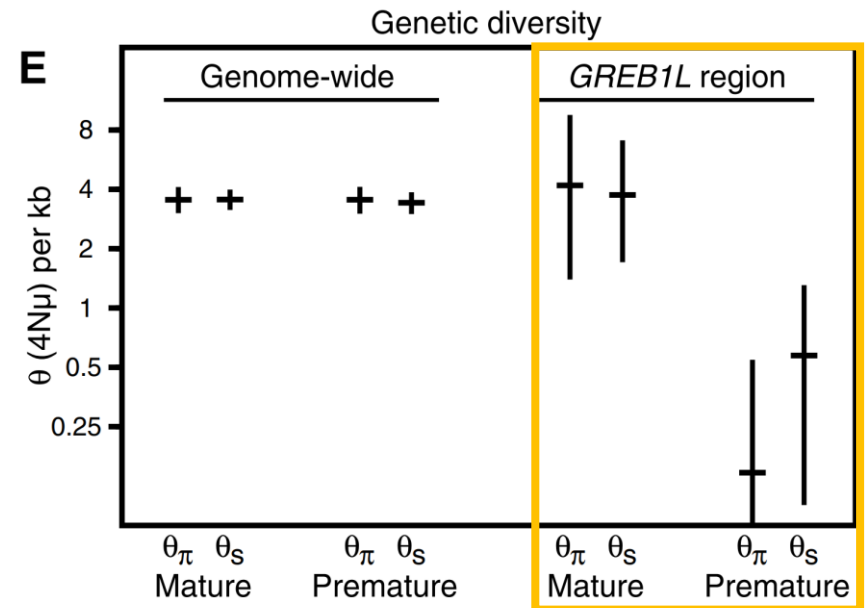
- Neutral vs. adaptive genetic markers
  - Neutral genetic markers differentiate between genetic lineages
    - coastal or inland
    - distinct populations
  - Adaptive markers can differentiate between phenotypic traits
    - migration-timing
    - sex
    - thermal-tolerances
    - age
    - etc.
- Within Populations
  - Low variation at neutral genetic markers
  - Greater variation in adaptive markers

# Background

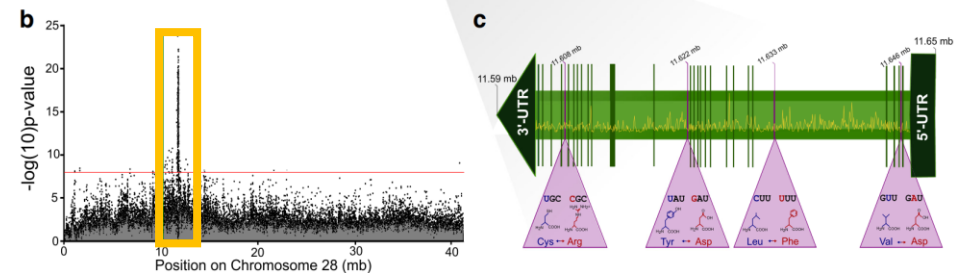
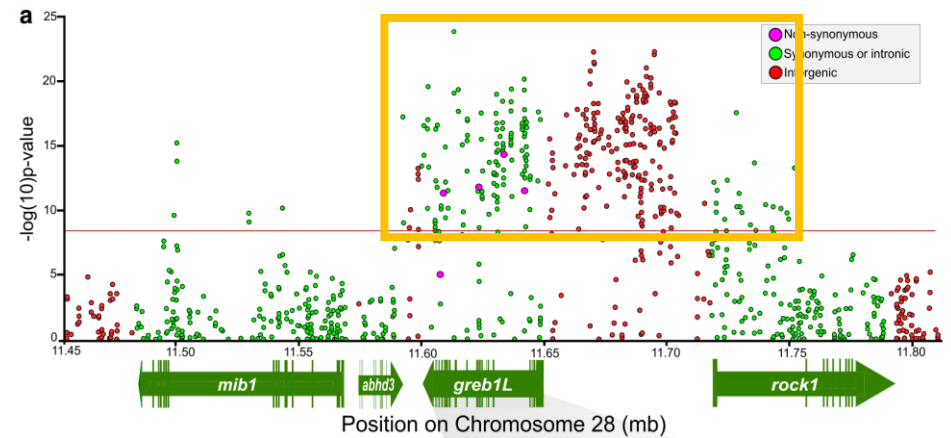
- Previous studies



Adapted from: Hess et al. 2016



Adapted from: Prince et al. 2018



Adapted from: Micheletti et al. 2018

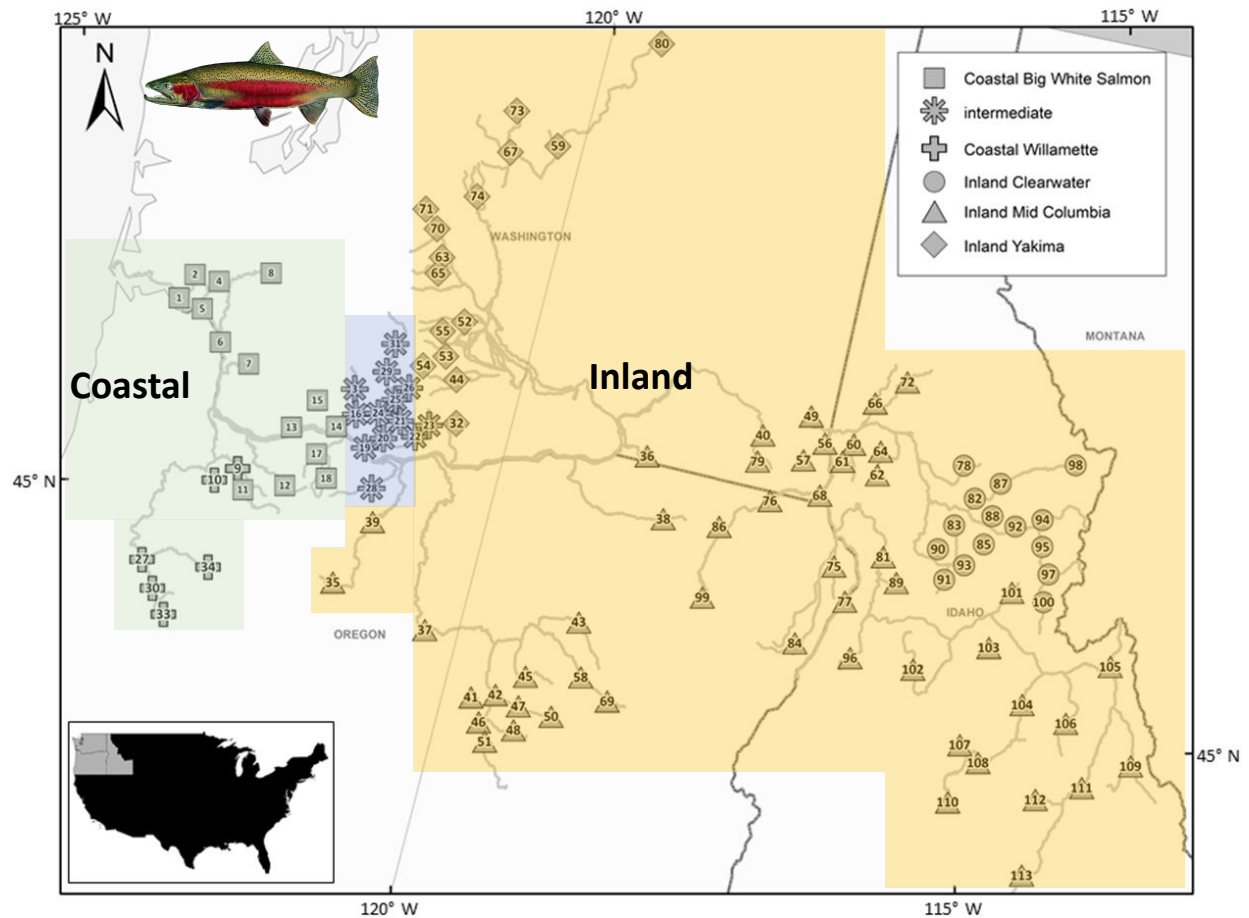
# Methods

## Sample Collection

- Inland and coastal sampled
- 1996-2018
- Electrofishing, smolt traps, weirs
- Non-lethal fin tissue

## Analyses

- Neutral marker PCA
- Migration timing genotype proportions were assessed across all collection locations
- Linkage disequilibrium (LD) within the adaptive markers to identify haplotype blocks
- Redundancy analyses (RDA) were conducted for all Columbia River basin collections to model the degree to which the variation in environmental variables explained the variation in allele frequencies of adaptive markers



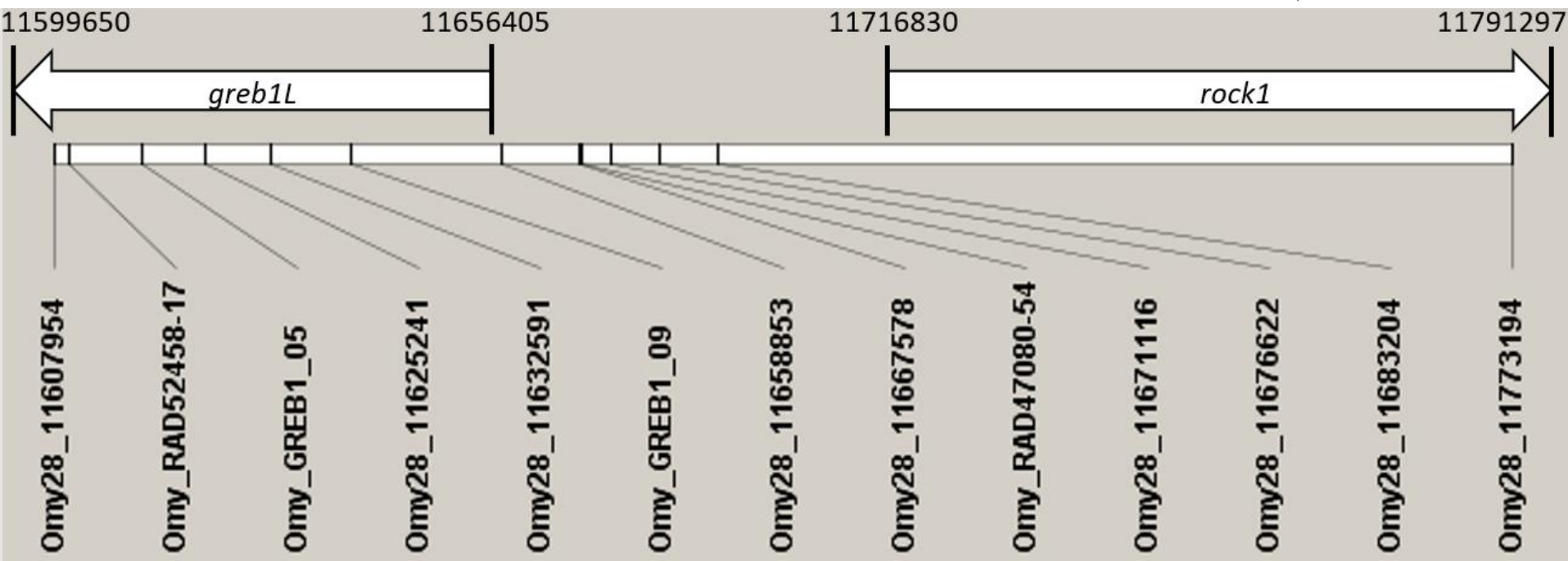
Adapted from: Collins et al. 2020



# Methods

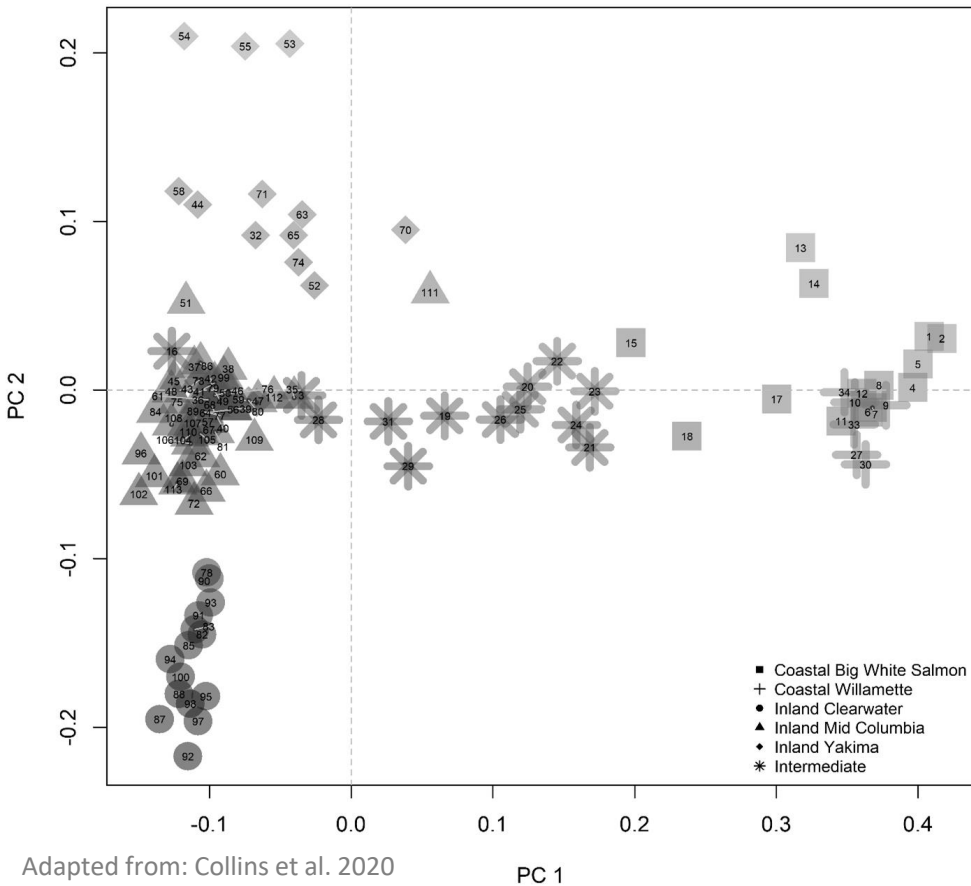
- Migration timing is heritable – genomic region of major effect
- *greb1L* – initial SNPs identified with RAD-seq methods
- More SNPs identified on *greb1L*, intergenic, *rock1* with Pool-seq methods

Adapted from: Collins et al. 2020



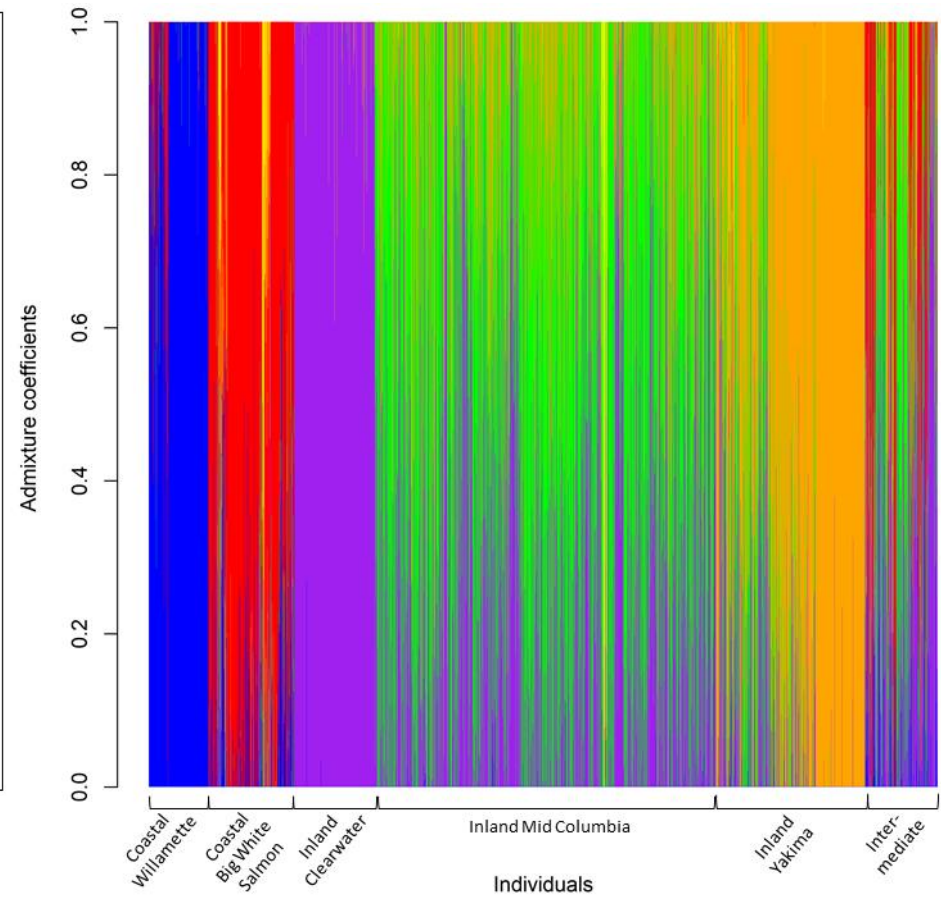
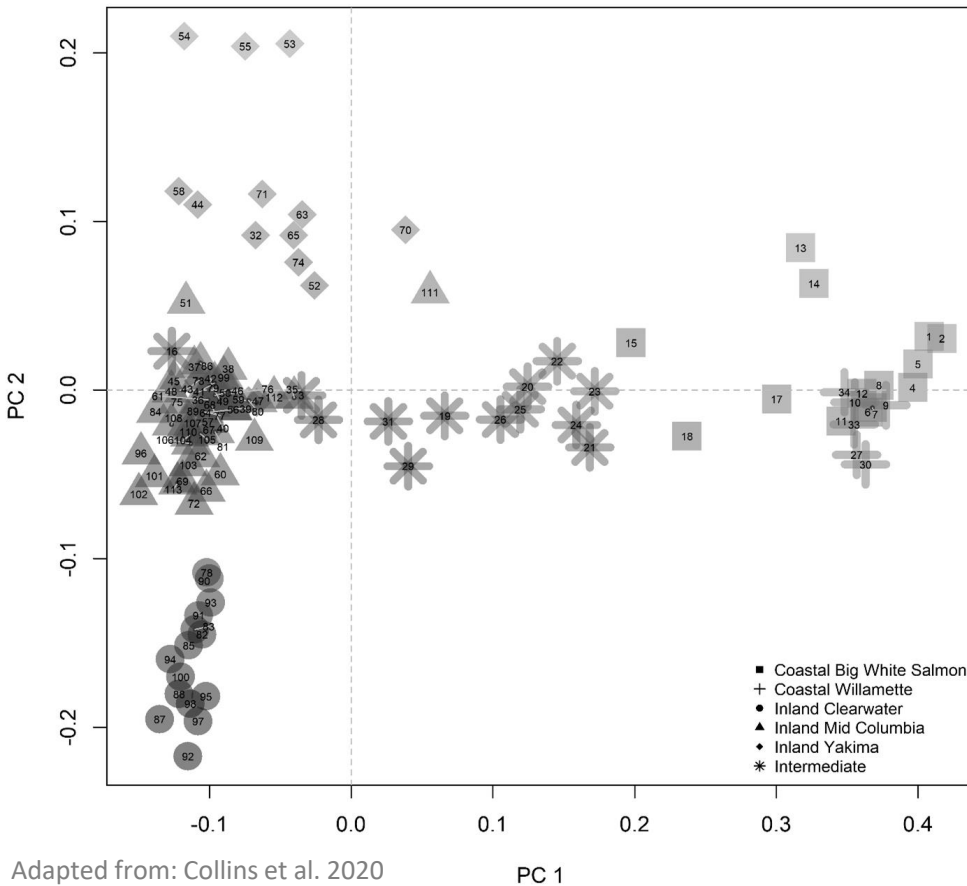
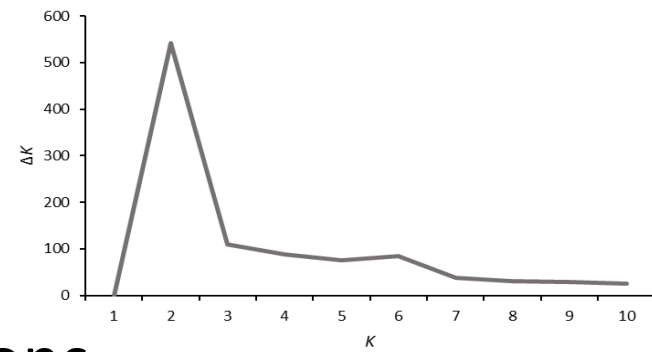
# Results

- 9,471 steelhead from 113 populations
- 226 neutral markers



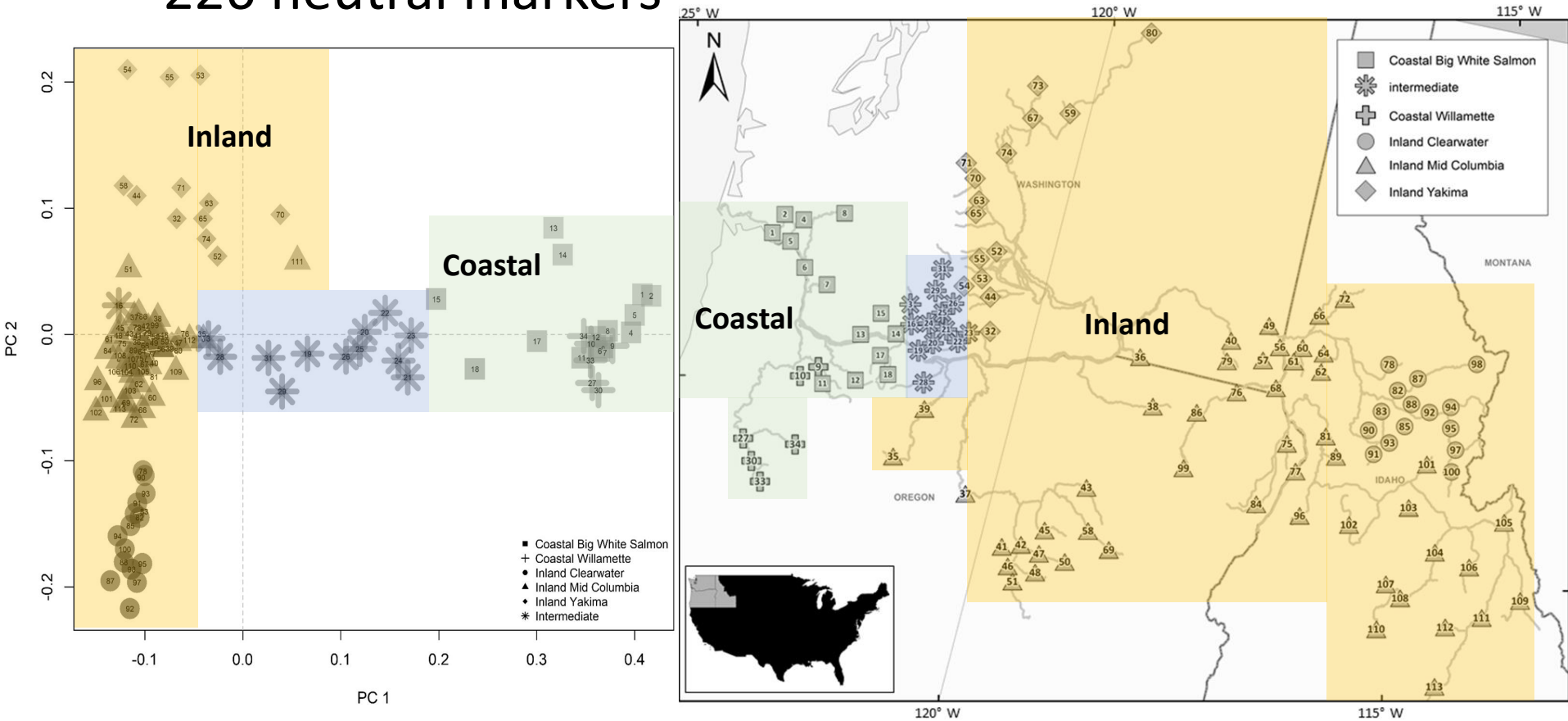
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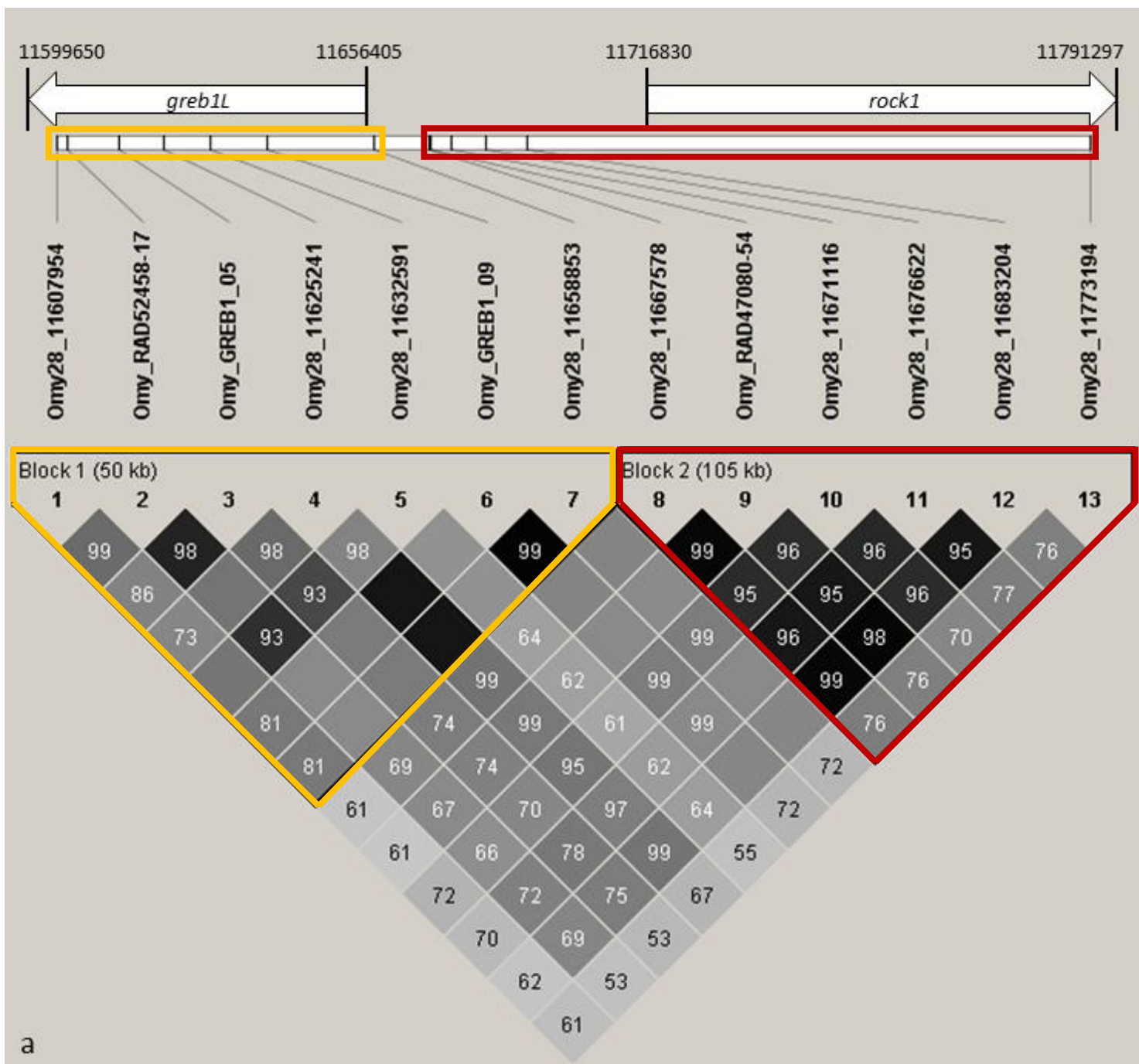


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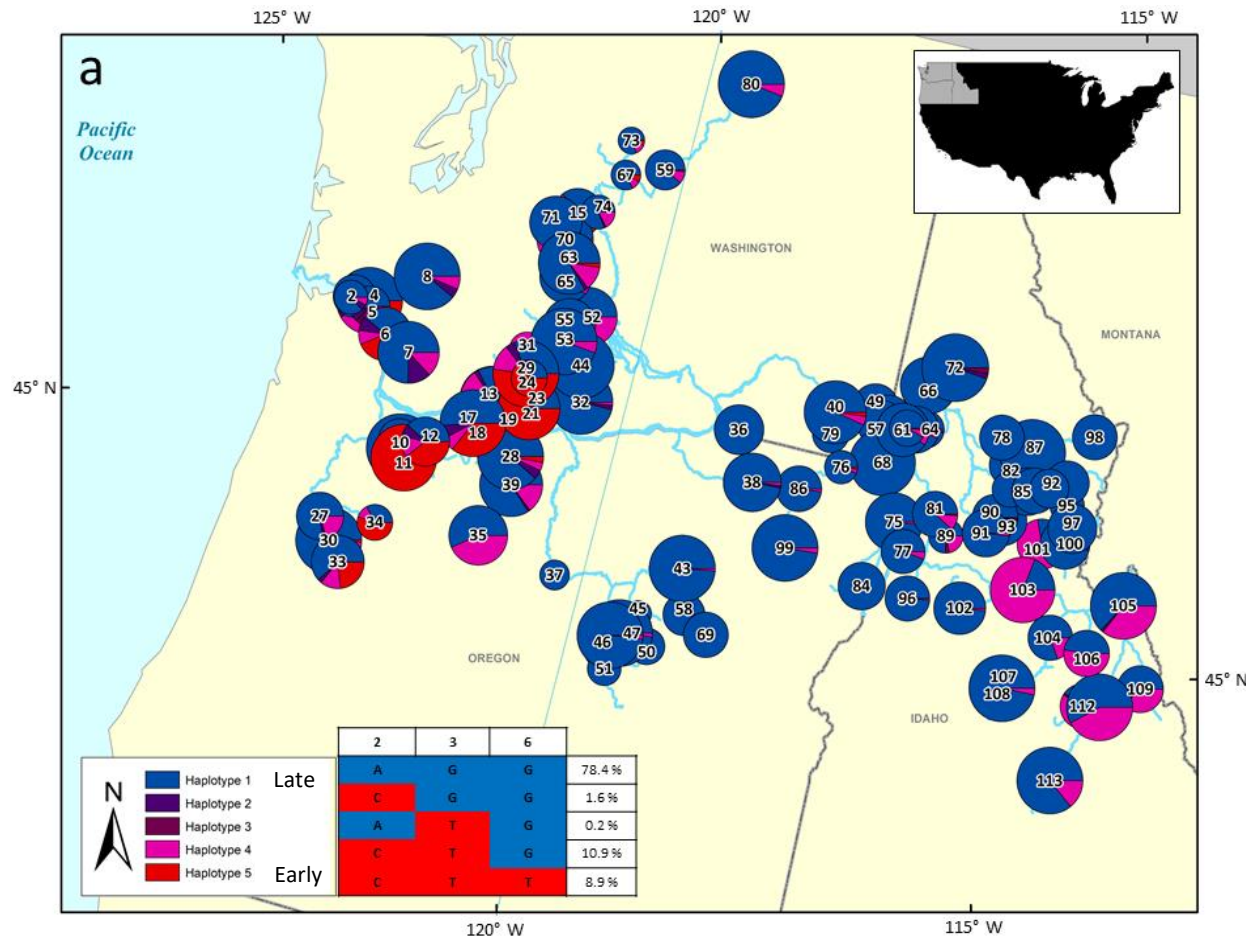
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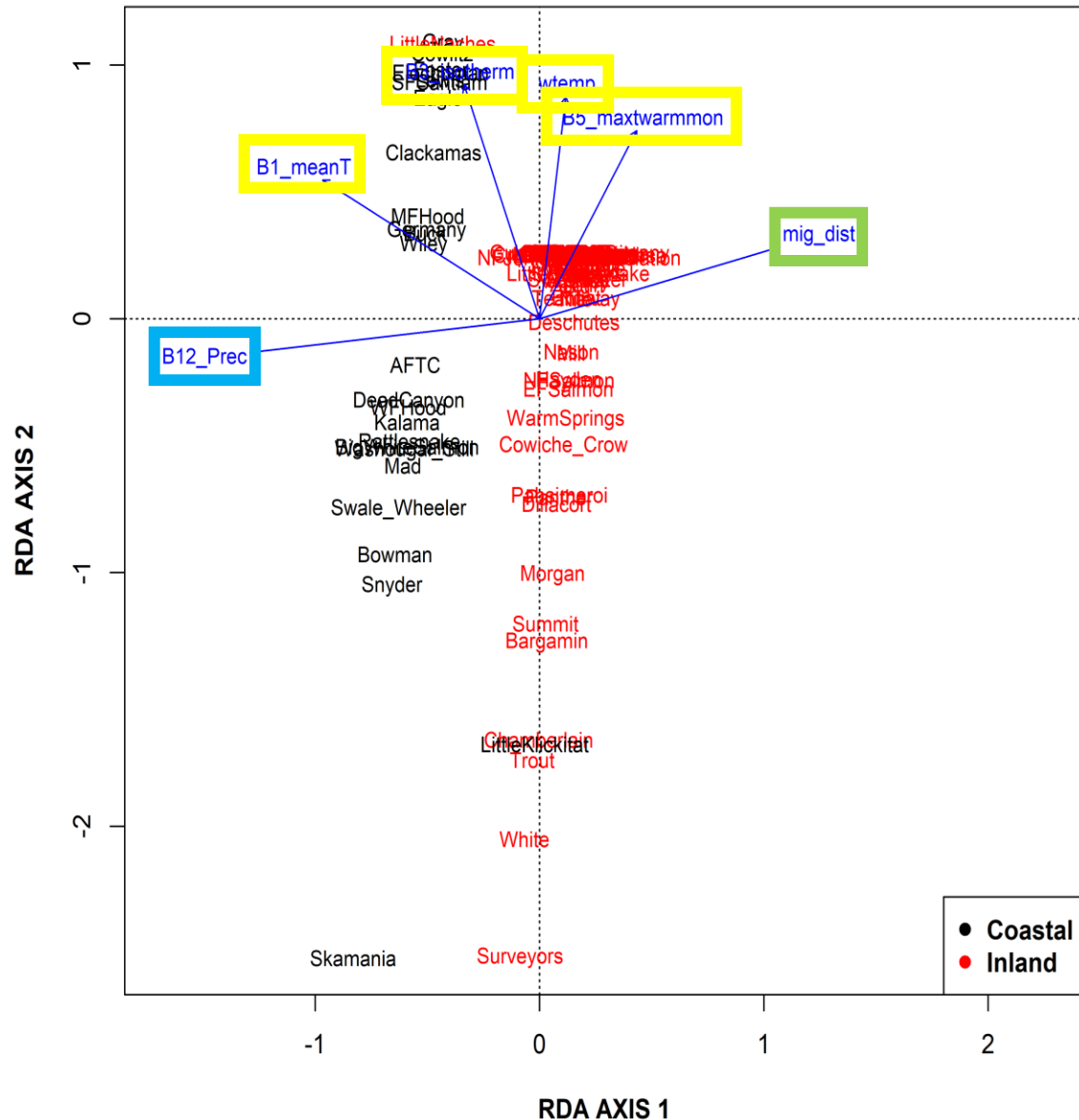
- Late returning (blue) steelhead are the most common
- Early returning (red) are rarer: Only 9 out of 113 (8%) populations had higher frequency for early migration
- More genetic diversity in coastal populations than inland
- Corresponds with observations that early returning fish have experienced the greatest decline over time
- Concerns over loss of variation over time



Adapted from: Collins et al. 2020

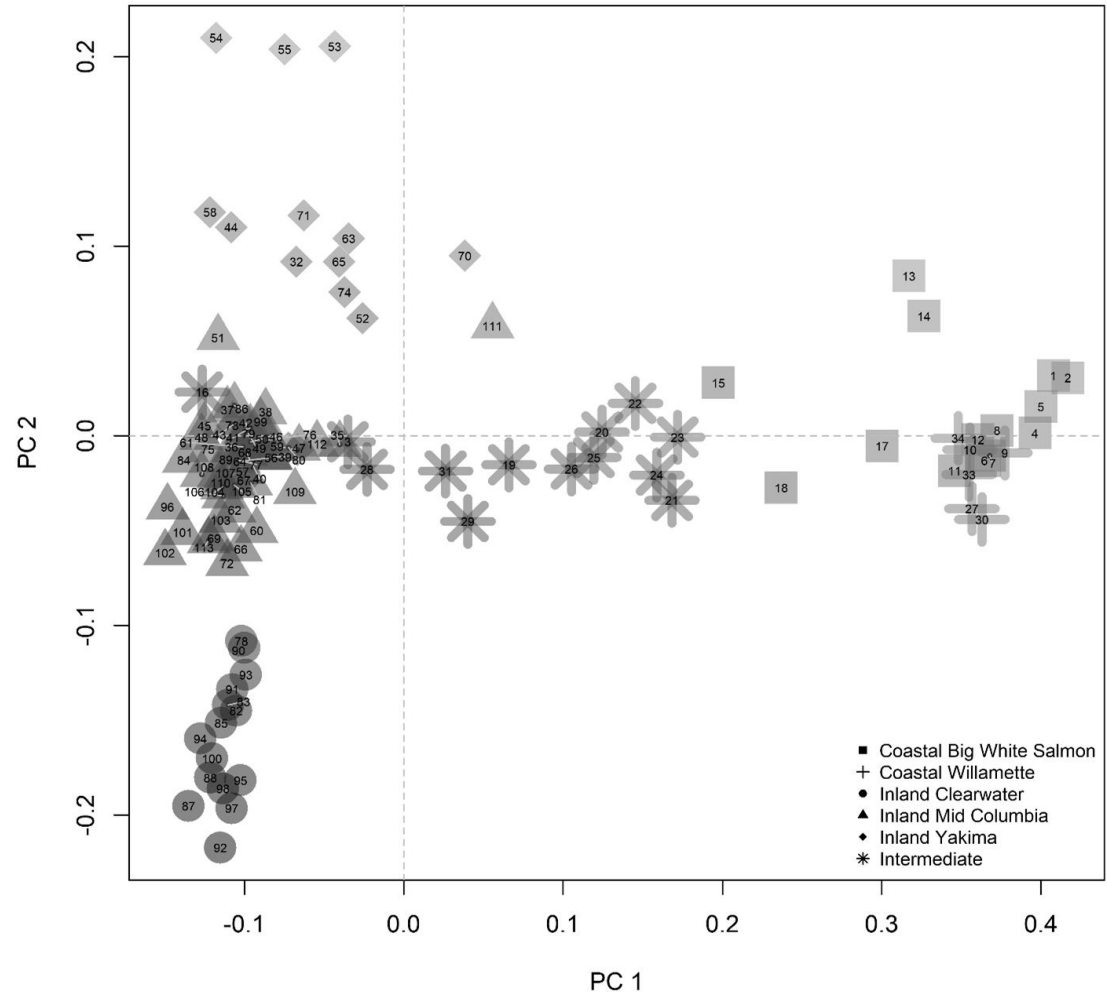
# Results

- Analysis to find environmental factors that drive genetic variation associated with migration timing:
  - Migration distance
  - Temperature
  - Precipitation
- Significant relationships between environmental variables and genetics suggest that these may be environmental drivers leading to local adaptation among populations.



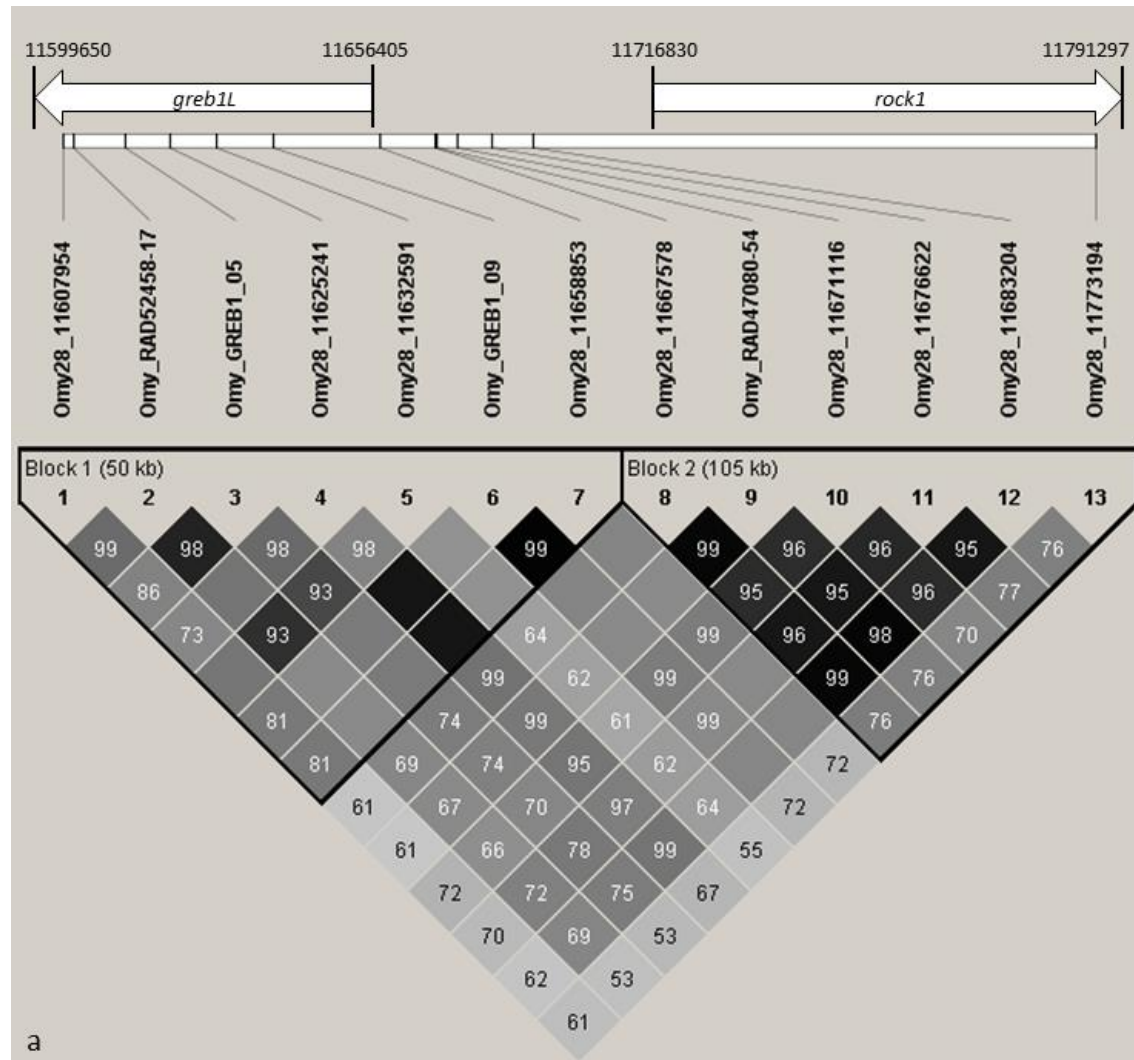
# Conclusions

- Neutral marker analyses of population structure, supported and improved upon previous findings



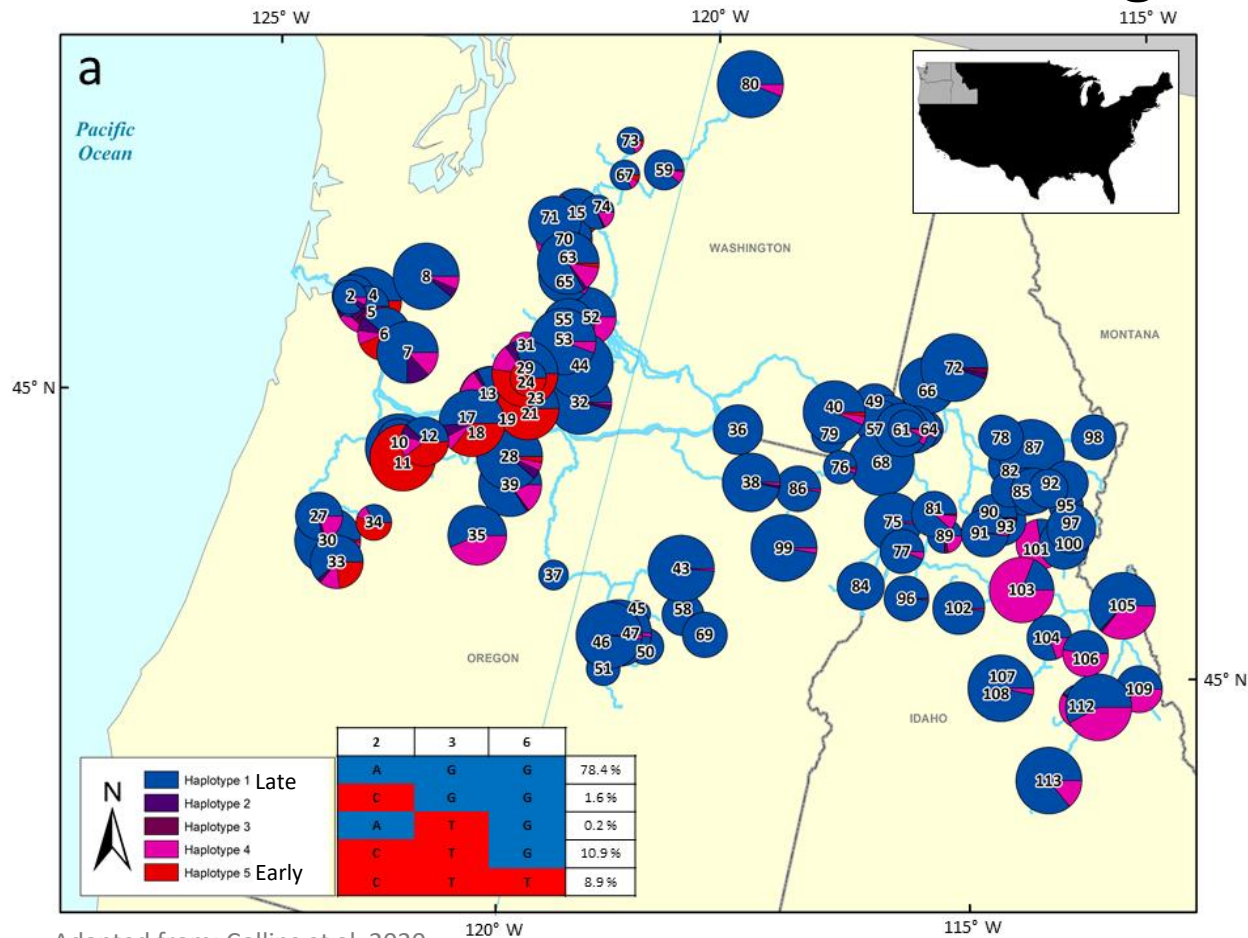
# Conclusions

- We determined linkage blocks for 13 adaptive markers associated with migration timing



# Conclusions

- Different heterozygote haplotypes were found to be predominant in coastal versus inland lineages.

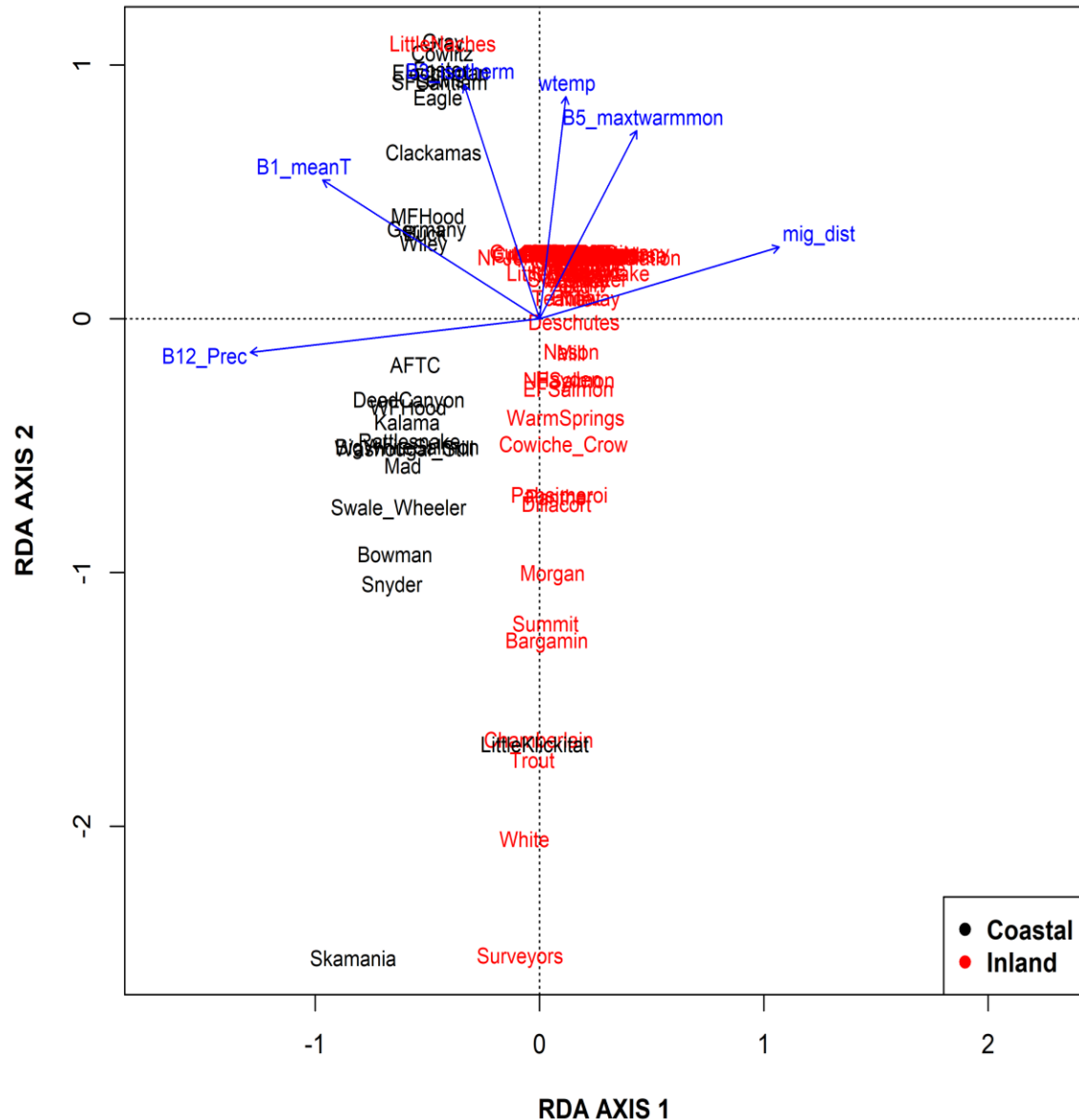


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# Conclusions

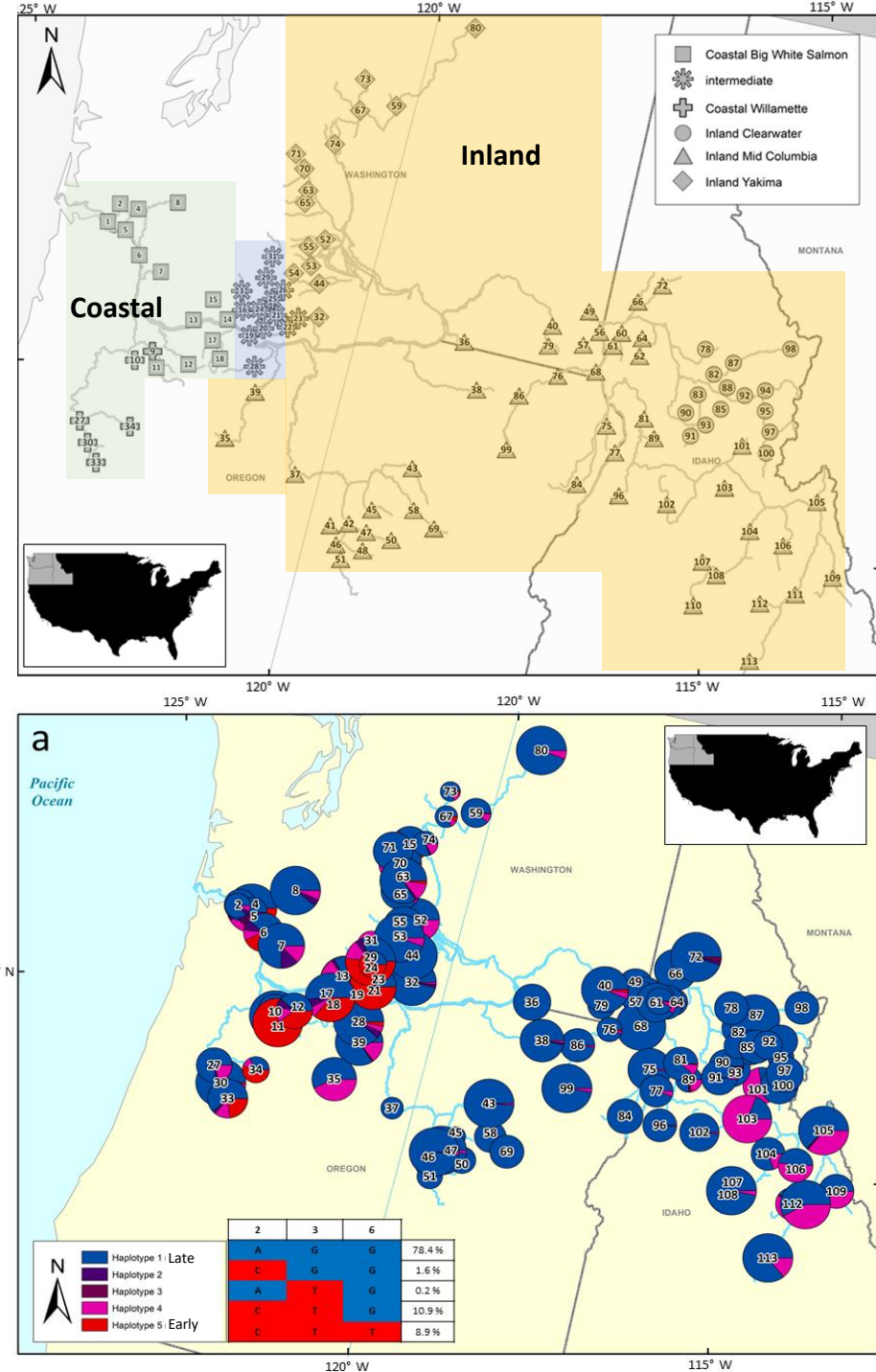
- Adaptive marker variation revealed the importance of temperature and precipitation



# Conclusions

## Monitor Genetic Diversity

- Maintain or improve underlying genetic variation for native fish species in Columbia River to provide broader life history diversity for populations to endure stochastic environments
- Combination of genetic markers
  - Monitor distinct populations
  - Specific migration related traits (timing, age, sex, thermal-tolerance)



# Acknowledgments

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- Co-authors

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POWER ADMINISTRATION

