Anthropogenic Habitat Alteration Leads to Rapid Loss of Adaptive Variation and Restoration Potential in Wild Salmon Populations

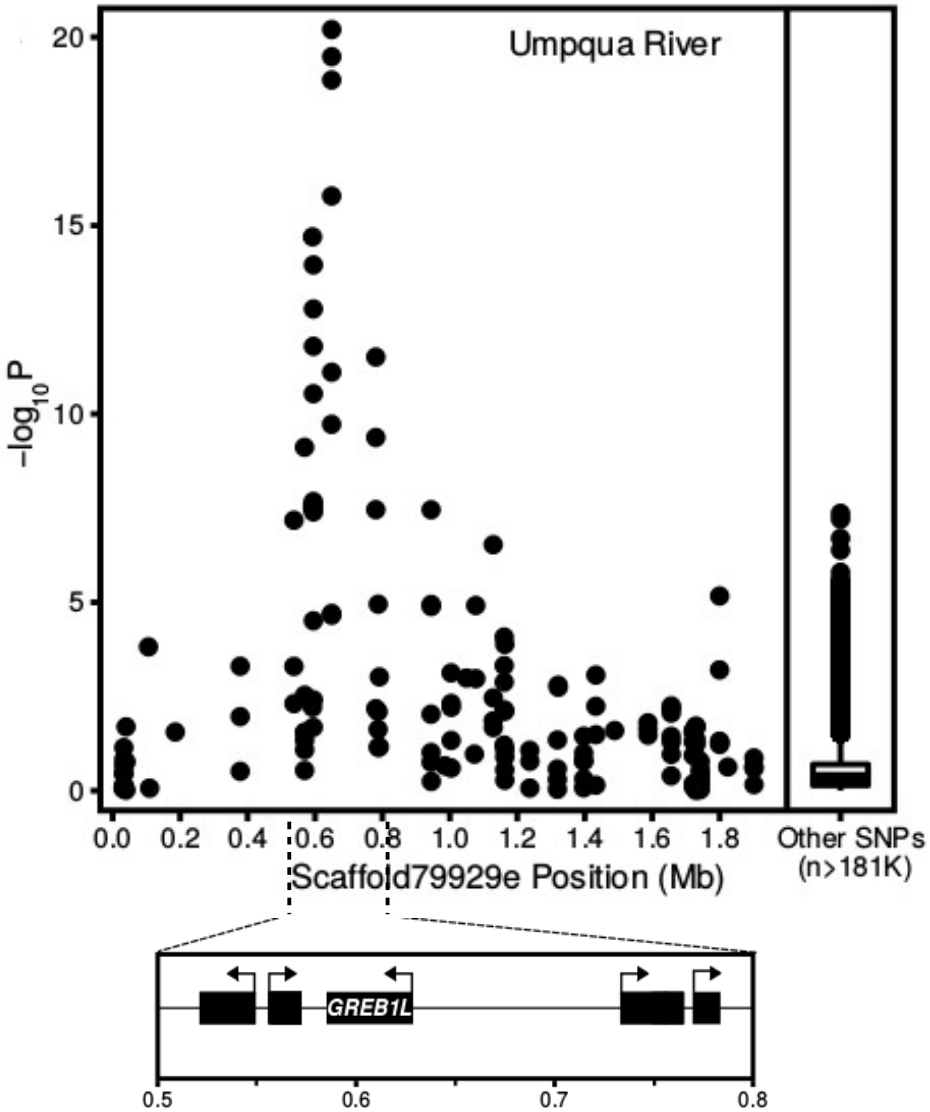
Tasha Q. Thompson

Outline

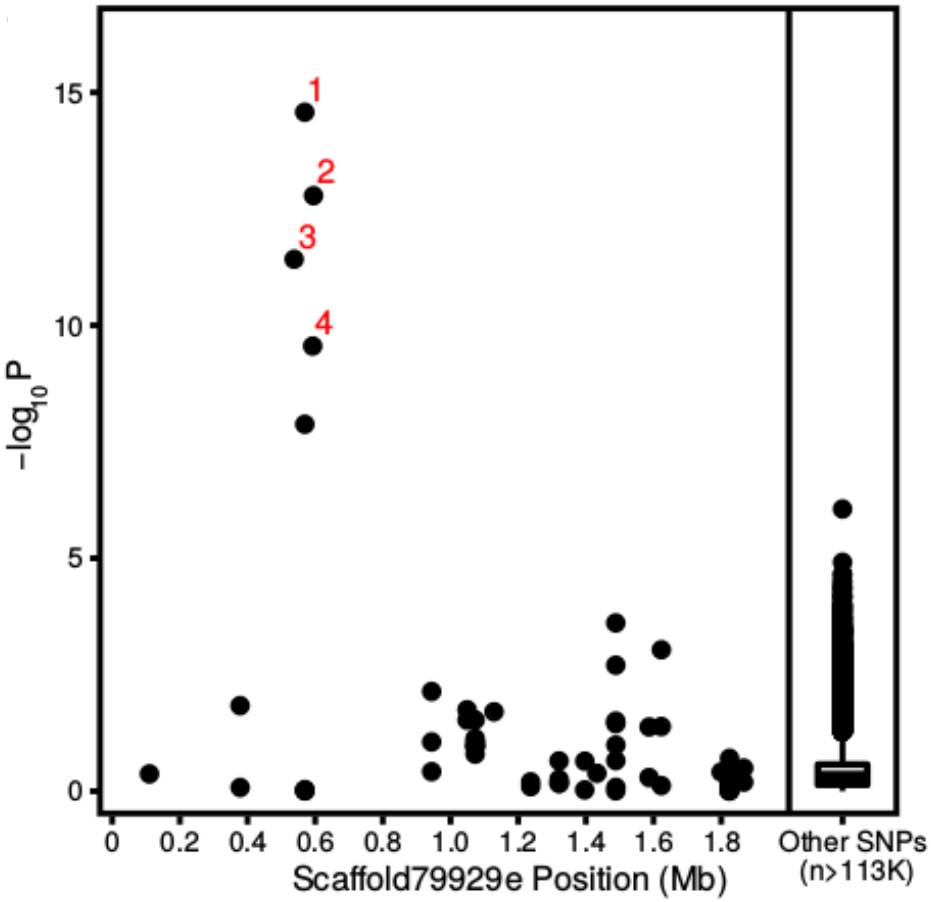
- Marker discovery
- Marker validation
- Applications for monitoring Salmon River spring-run Chinook
- Applications for upper Klamath restoration

Previous study identified a genetic region strongly associated with premature vs. mature migration in steelhead and Chinook

Steelhead



Chinook

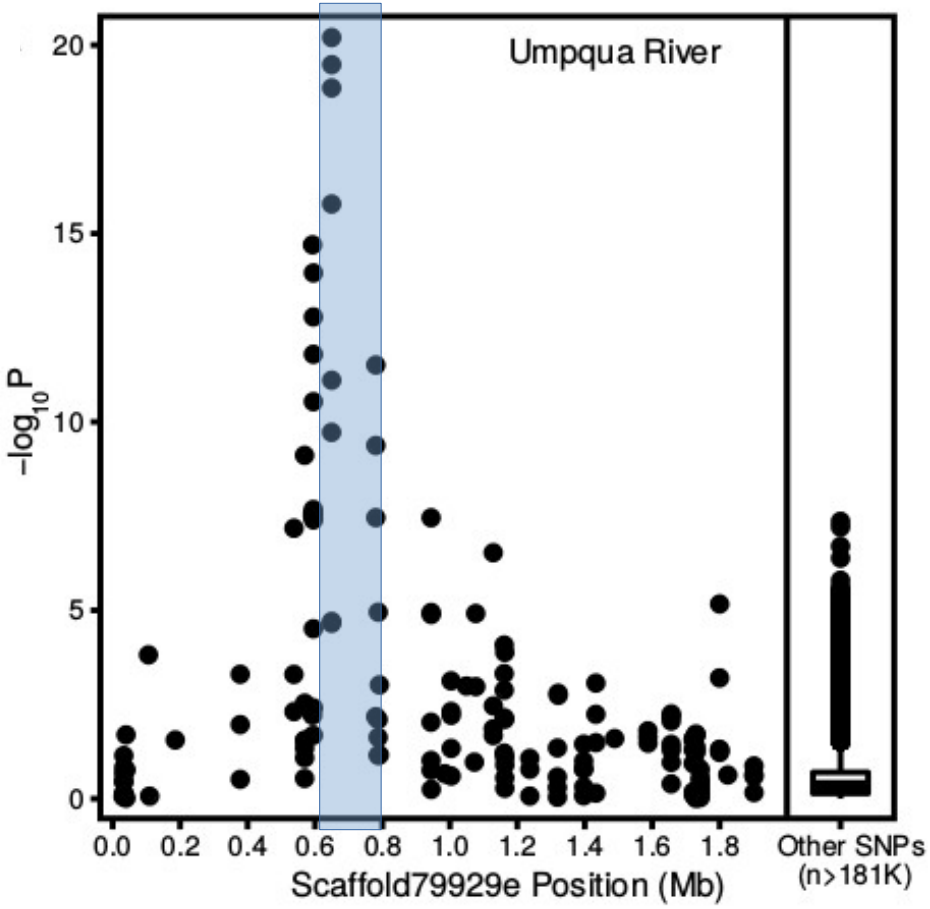


GREB1L region

Prince *et al.* 2017

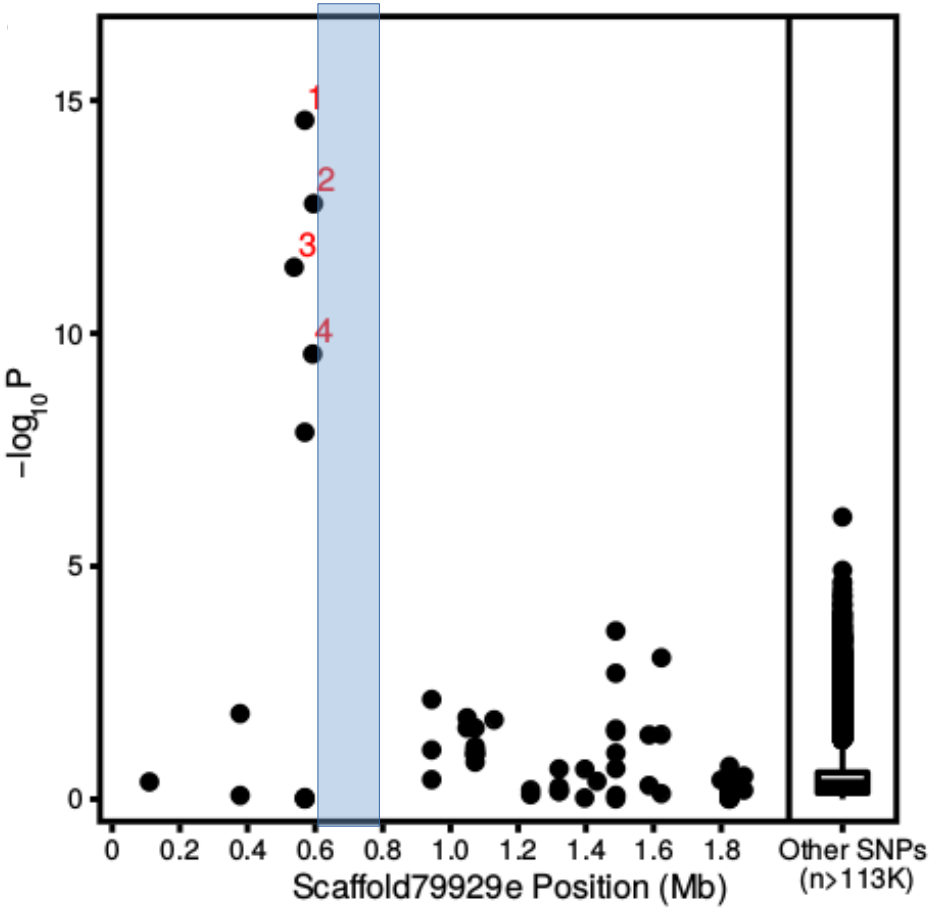
Chinook analysis was lower resolution and had missing data in region with highest association in steelhead

Steelhead



GREB1L region

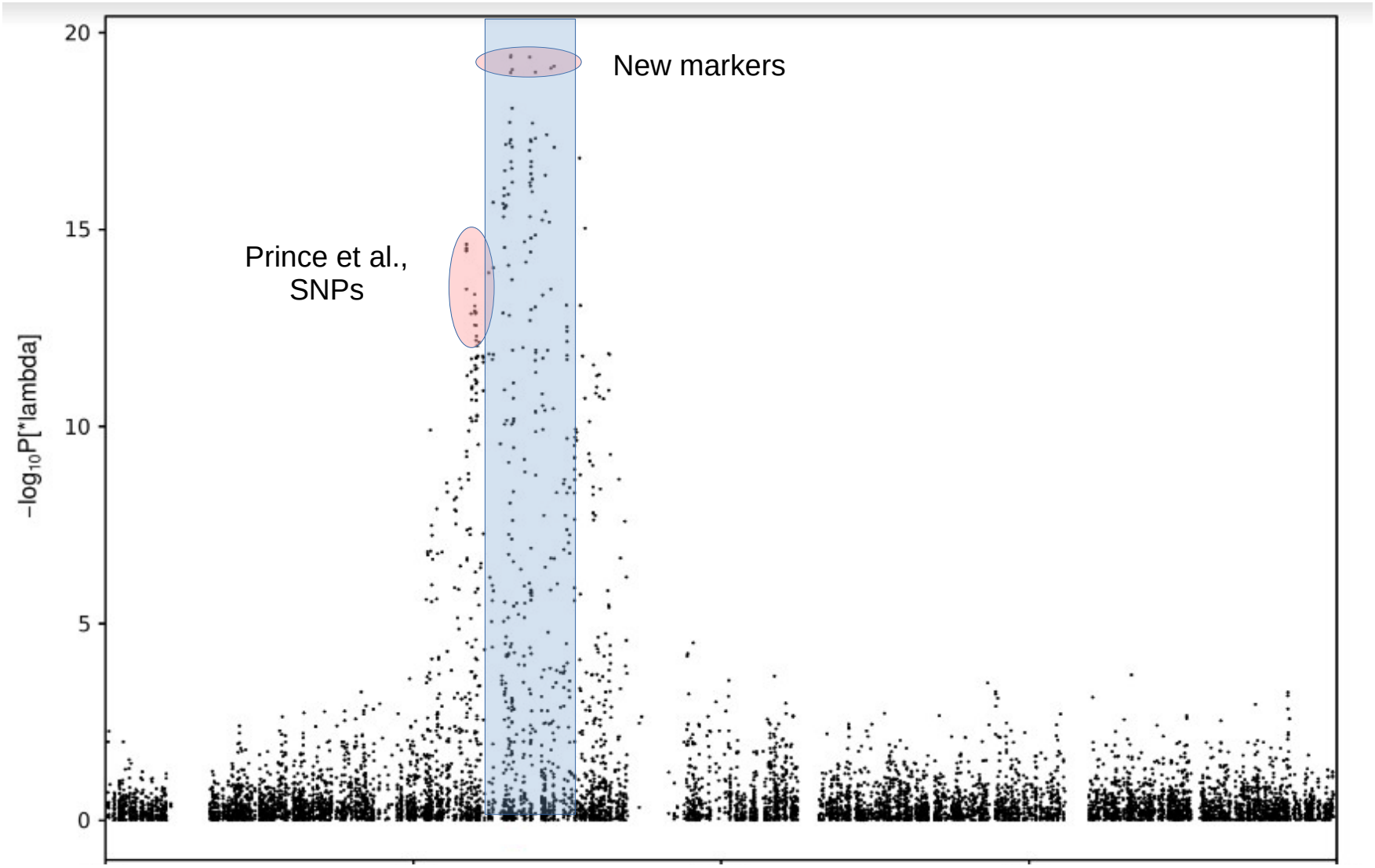
Chinook



GREB1L region

Prince *et al.* 2017

Higher-resolution analysis of *GREB1L* region in Chinook revealed SNPs with stronger associations



GREB1L region

Chinook

Top marker from initial association

Top markers from higher-resolution analysis

Spring-run

PP=homozygous premature

PM=heterozygous

MM=homozygous mature

Fall-run

Location	Predicted phenotype	Top Prince et al. SNP	New SNP 1	New SNP 2
Nooksack River	Spring-run	PP	PP	PP
Nooksack River	Spring-run	PP	PP	PP
Nooksack River	Spring-run	PM	PM	PM
North Umpqua River	Spring-run	PP	PP	PP
North Umpqua River	Spring-run	PP	PP	PP
North Umpqua River	Spring-run	PP	PP	PP
North Umpqua River	Spring-run	PP	PP	PP
Puyallup River	Spring-run	PP	PP	PP
Puyallup River	Spring-run	PP	PP	PP
Puyallup River	Spring-run	PP	PP	PP
Puyallup River	Spring-run	PP	PP	PP
Puyallup River	Spring-run	PP	PP	PP
Rogue River	Spring-run	PP	PP	PP
Rogue River	Spring-run	PP	PP	PP
Rogue River	Spring-run	PP	PP	PP
Rogue River	Spring-run	PP	PP	PP
Salmon River	Spring-run	PP	PP	PP
Trinity River	Spring-run	PP	PP	PP
Trinity River	Spring-run	PP	PP	PP
Trinity River	Spring-run	PP	PP	PP
Trinity River	Spring-run	PP	PP	PP
Nooksack River	Fall-run	PM	MM	MM
Nooksack River	Fall-run	PM	MM	MM
Nooksack River	Fall-run	MM	MM	MM
Puyallup River	Fall-run	MM	MM	MM
Puyallup River	Fall-run	MM	MM	MM
Puyallup River	Fall-run	PM	PM	PM
Puyallup River	Fall-run	MM	MM	MM
Puyallup River	Fall-run	PM	MM	MM
Rogue River	Fall-run	PP	MM	MM
Rogue River	Fall-run	MM	MM	MM
Rogue River	Fall-run	PM	MM	MM
Rogue River	Fall-run	PM	MM	MM
Salmon River	Fall-run	PP	MM	MM
Siletz River	Fall-run	MM	MM	MM
Siletz River	Fall-run	MM	MM	MM
Siletz River	Fall-run	PM	MM	MM
Siletz River	Fall-run	MM	MM	MM
South Umpqua River	Fall-run	MM	MM	MM
South Umpqua River	Fall-run	PM	MM	MM
South Umpqua River	Fall-run	MM	MM	MM
Trinity River	Fall-run	PP	MM	MM
Trinity River	Fall-run	PM	MM	MM
Trinity River	Fall-run	PP	MM	MM
Trinity River	Fall-run	PP	MM	MM
Trinity River	Fall-run	PM	MM	MM

Thorough marker discovery is CRITICAL before asking biological questions!!

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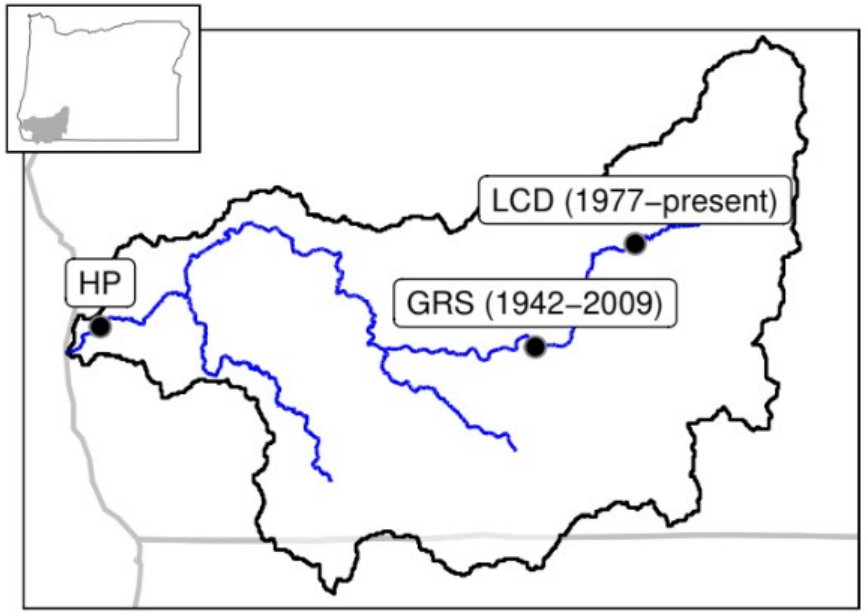
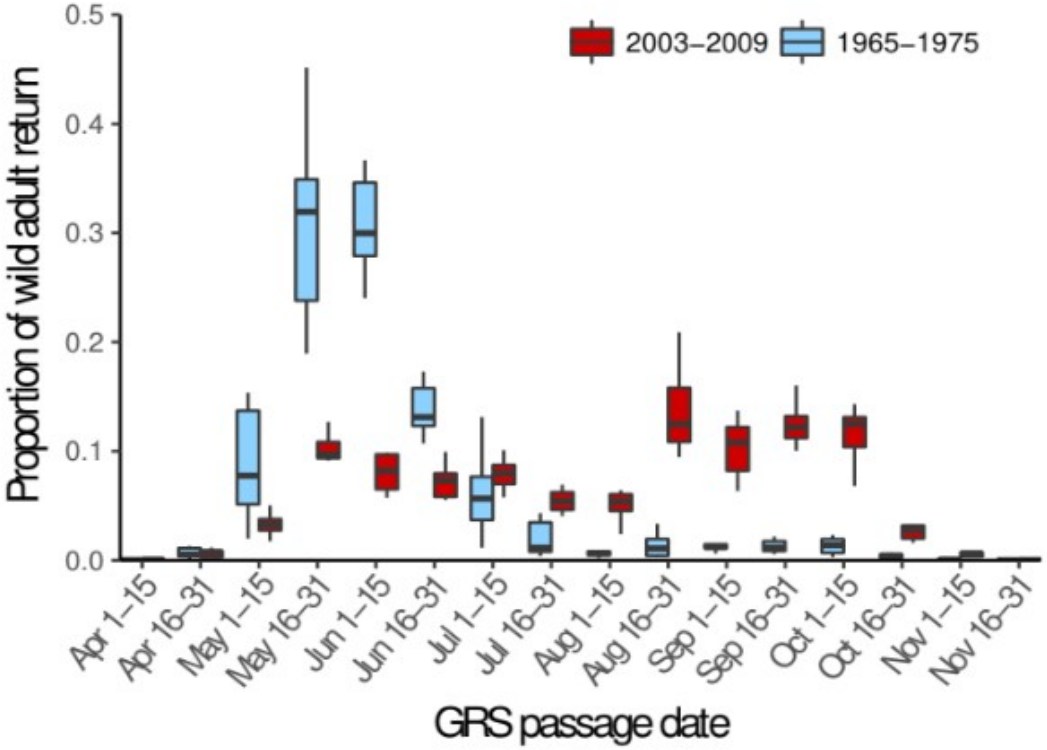
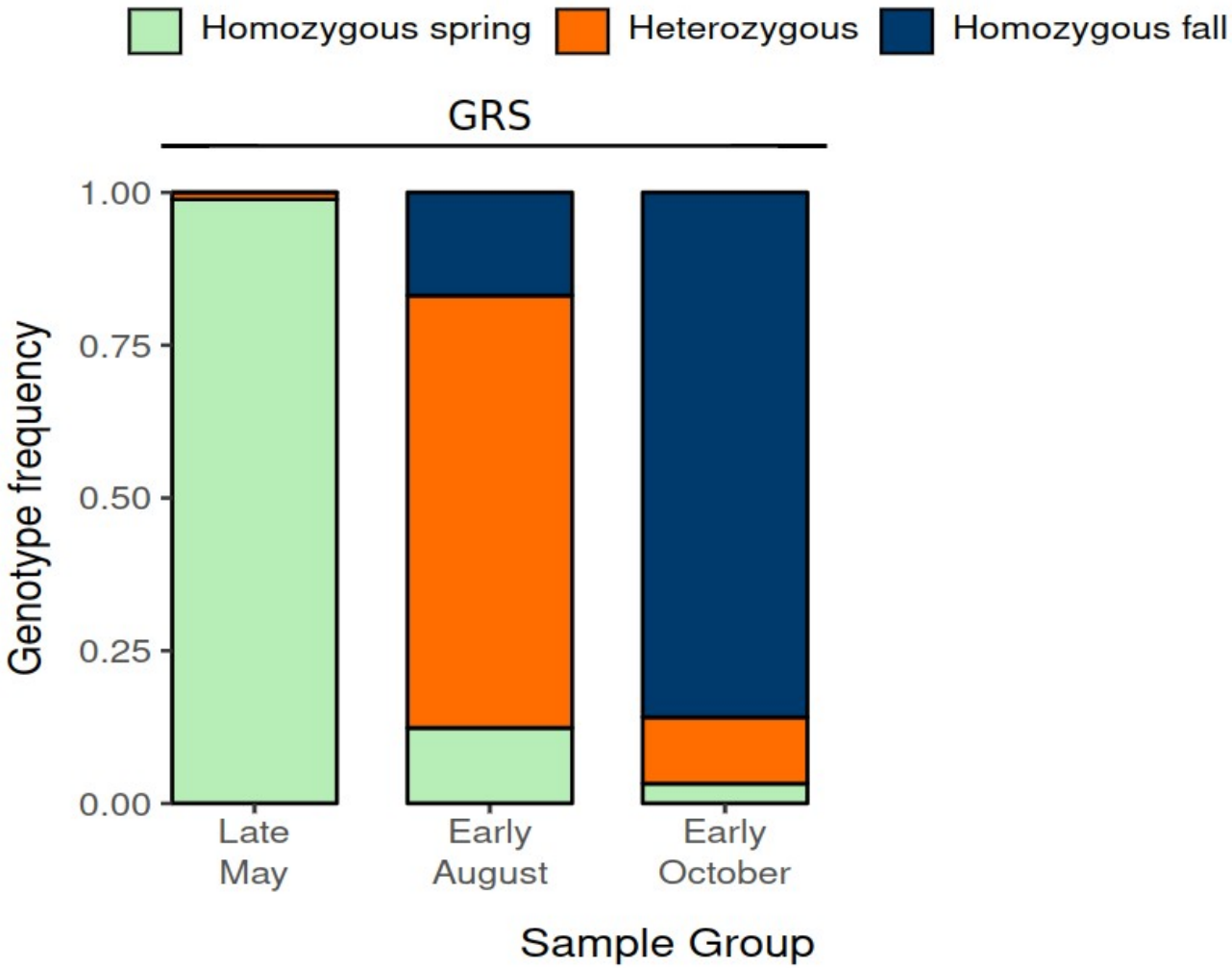
Rogue River, OR Chinook experienced a major shift in adult migration time after construction of Lost Creek Dam in 1977





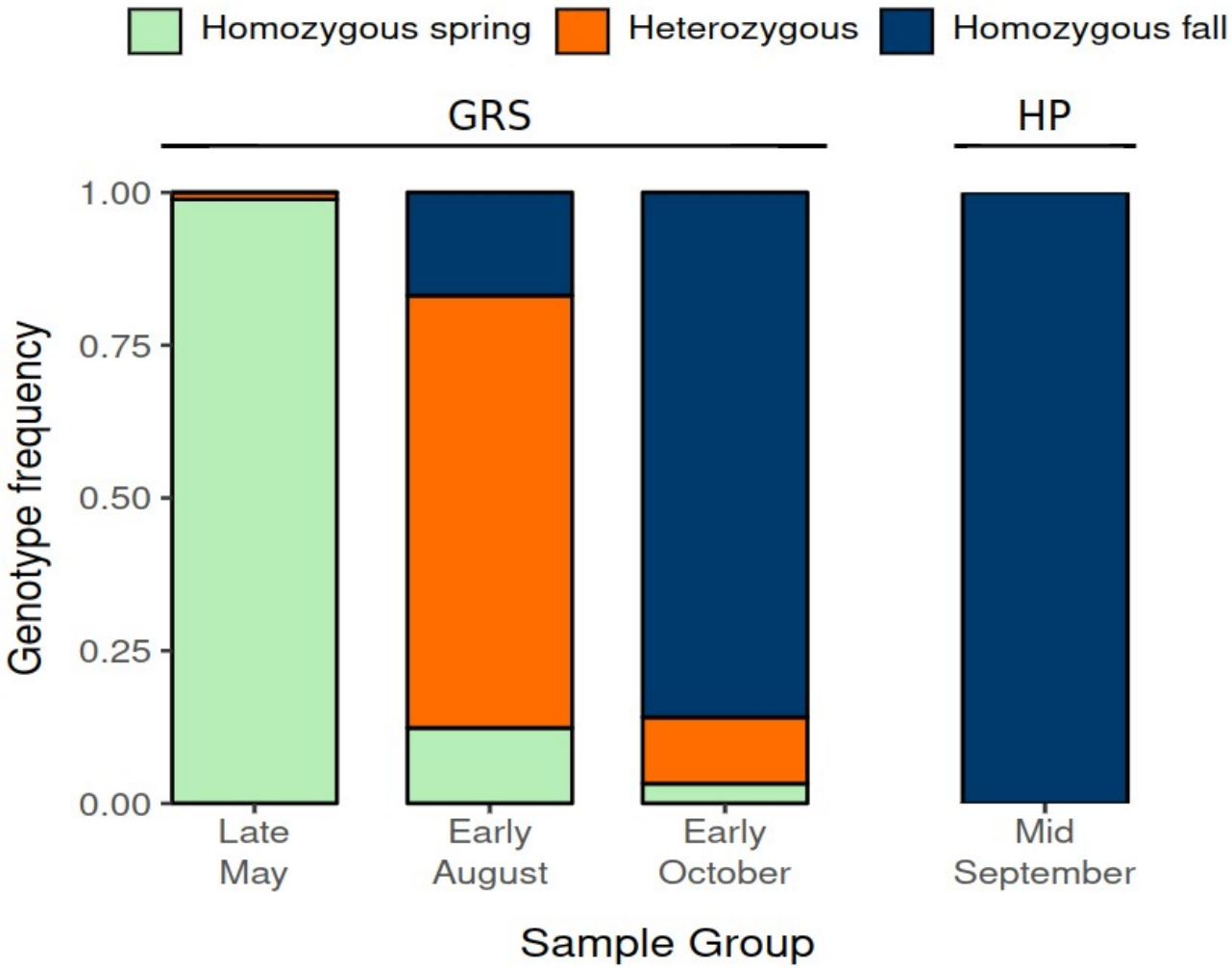
Thompson *et al.*, 2019

Genotyping Rogue River Chinook that passed GRS during three time windows reveals heterozygotes have an intermediate phenotype



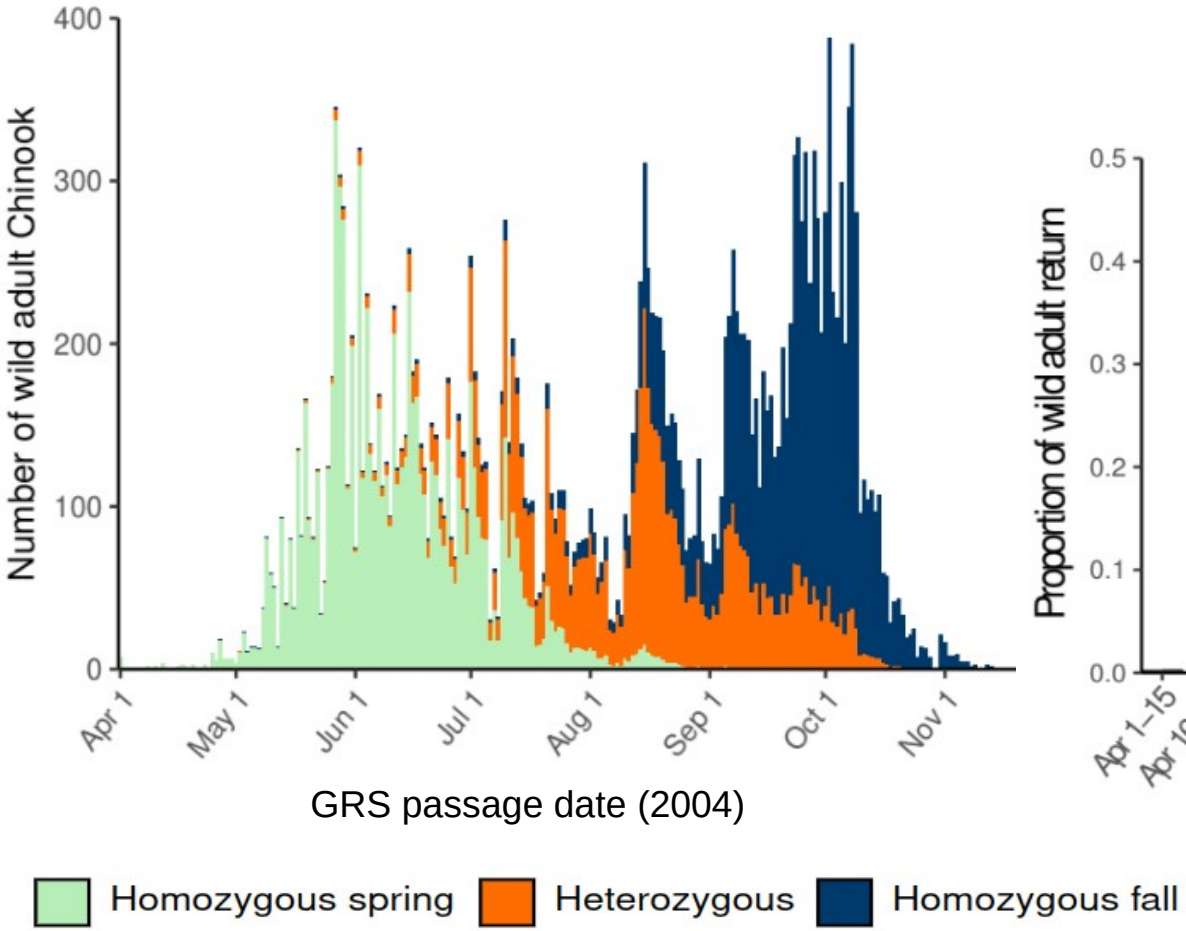
Thompson *et al.*, 2019

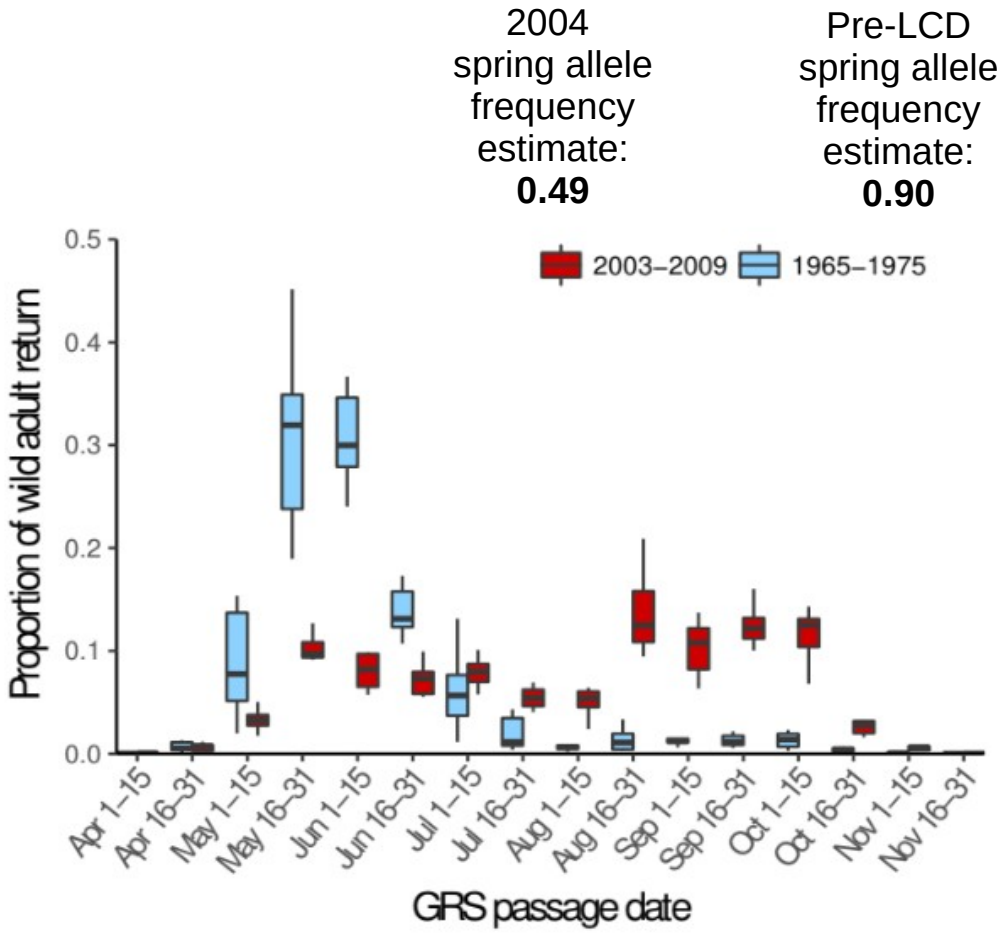
Mid-September HP results suggest homozygous-spring and heterozygous fish from GRS early-October had entered freshwater earlier in the year



Thompson *et al.*, 2019

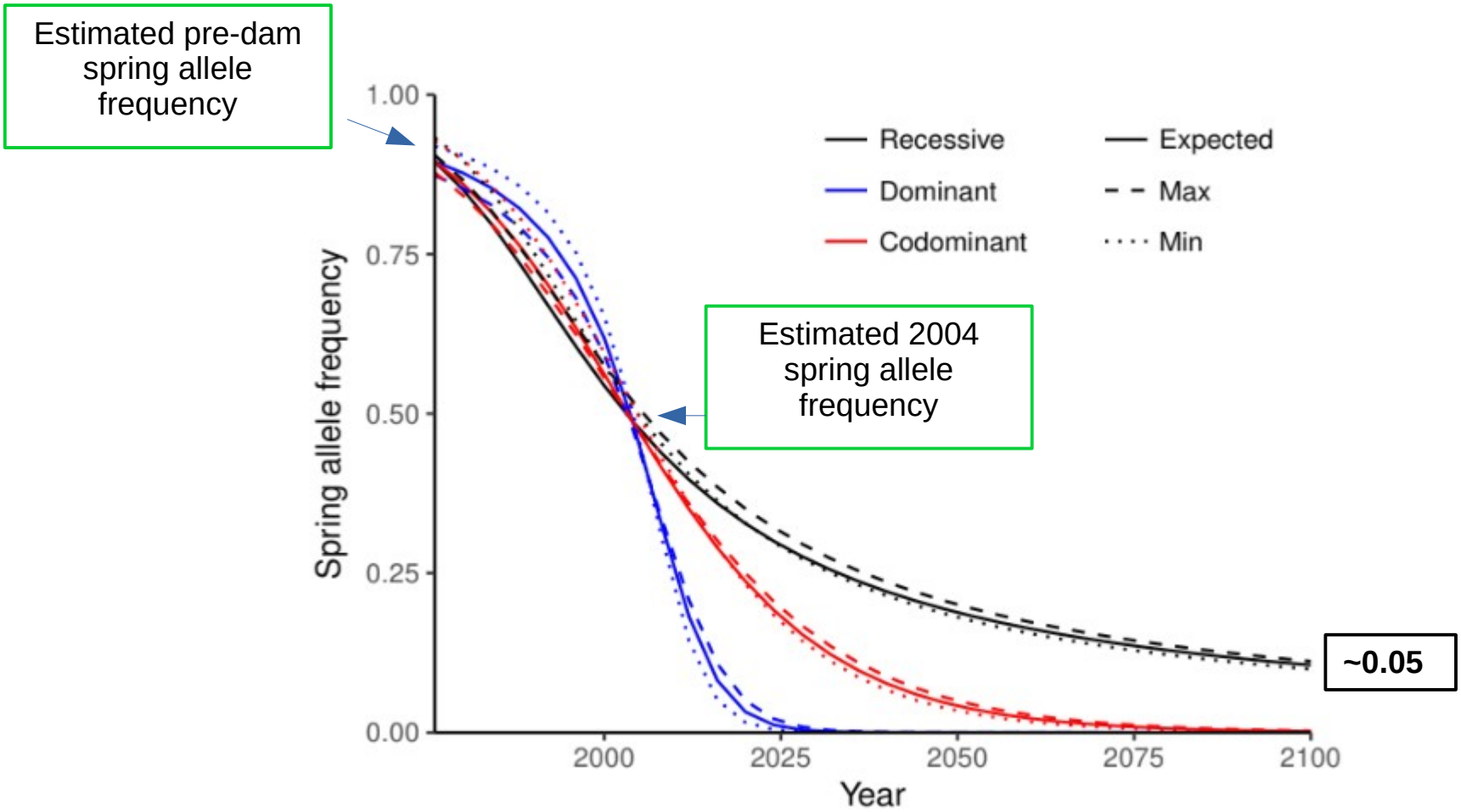
GRS genotyping results allowed us to estimate spring-run allele frequencies prior to LCD and in 2004





Thompson *et al.*, 2019

Selection modeling demonstrates negatively-selected alleles can be rapidly lost unless completely recessive with respect to fitness



Thompson et al., *in prep*

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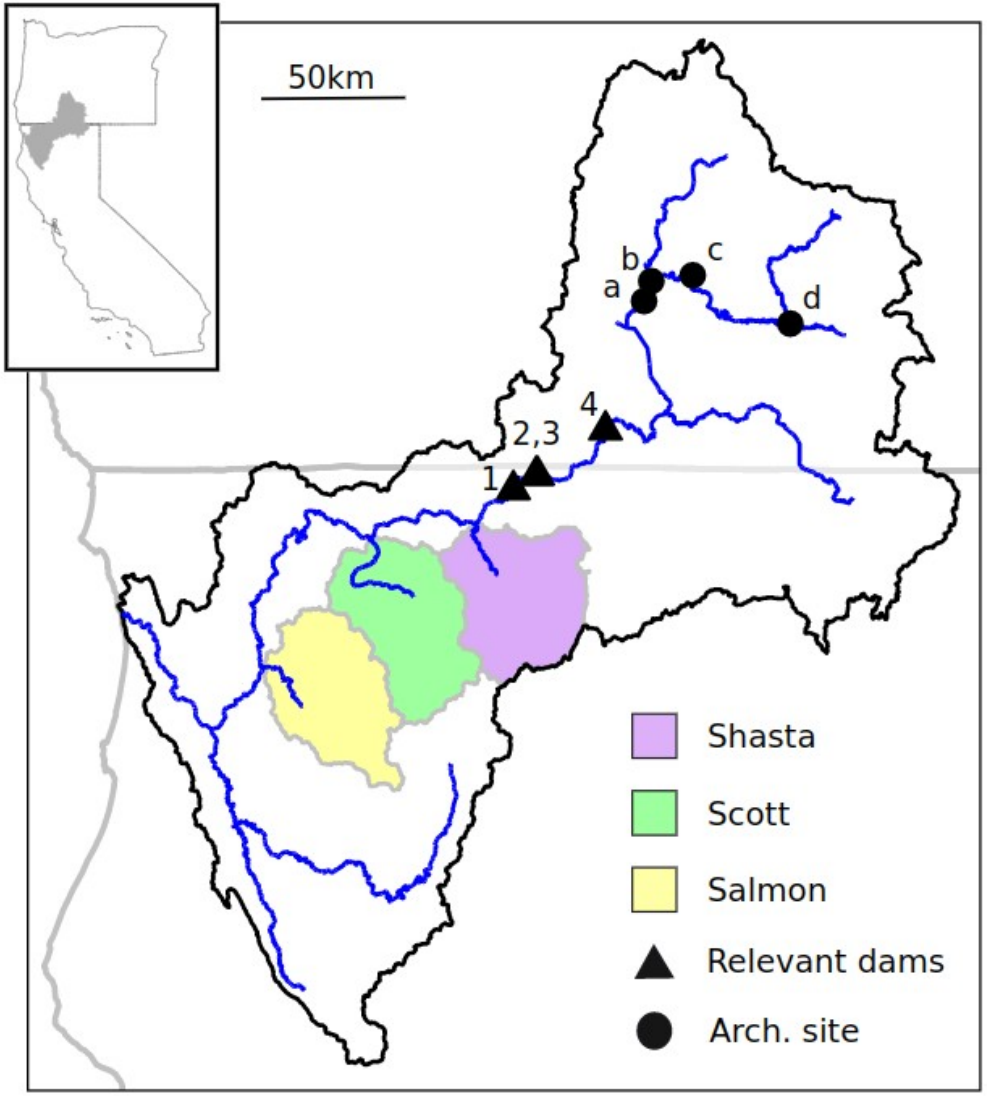
Wild spring-run Chinook have been extirpated from most of the Klamath basin



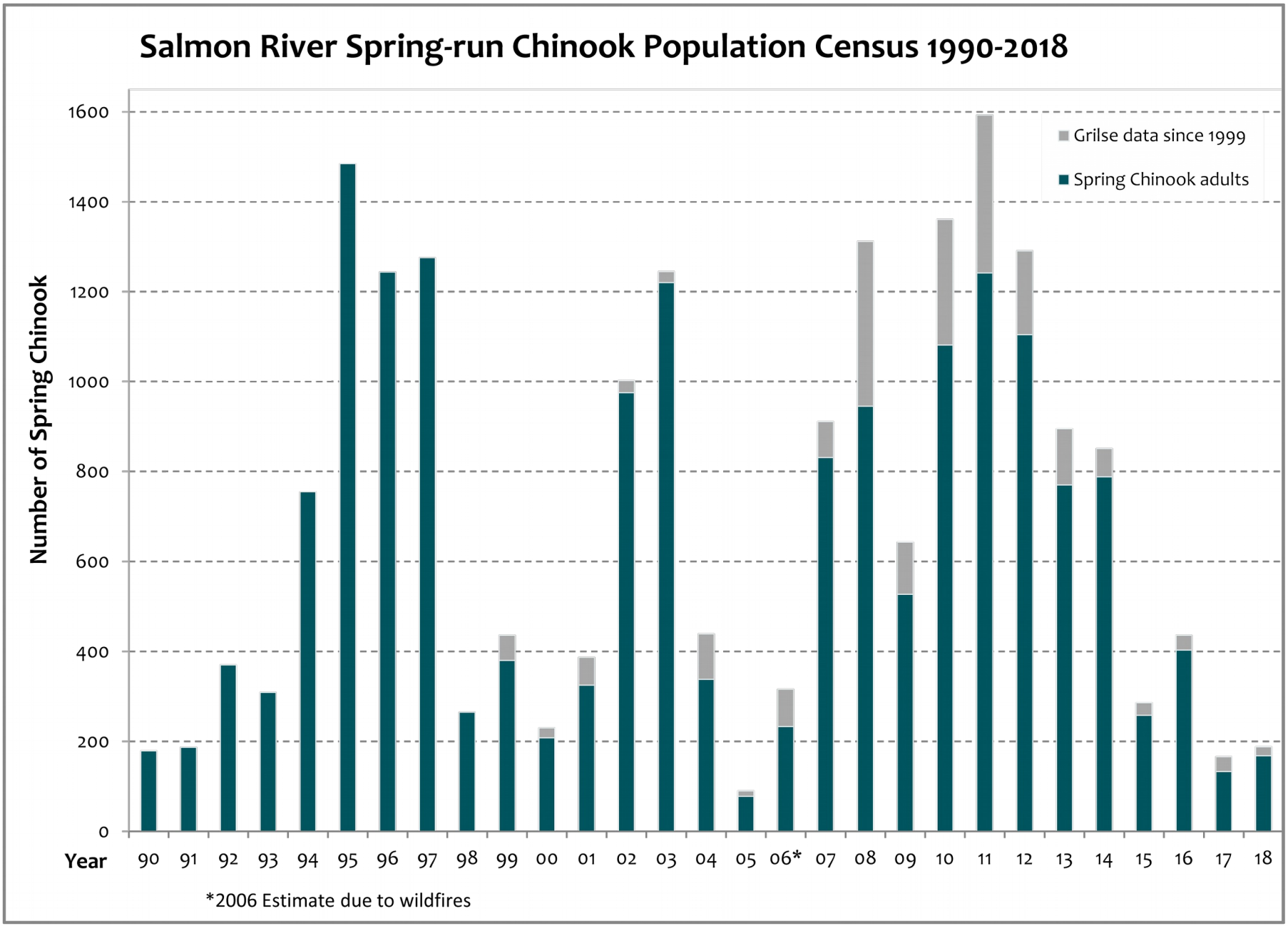
Shasta: spring Chinook extirpated in 1930's

Scott: spring Chinook extirpated in 1970's

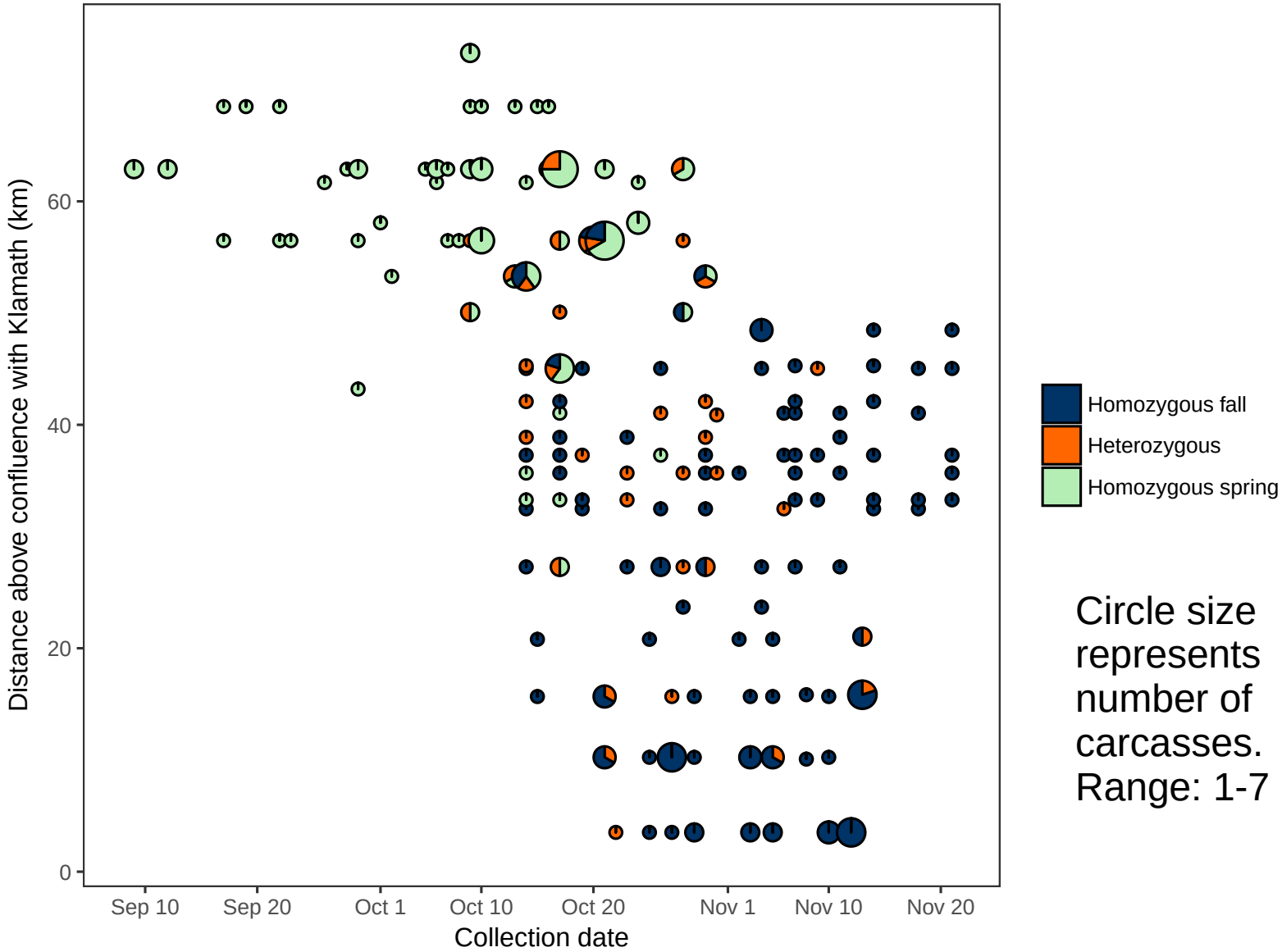
Salmon: spring Chinook still present

Thompson *et al.*, 2019

The Salmon River is the last location in the Klamath with a viable number of wild spring-run Chinook



Analysis of Salmon River, CA carcass samples reveals spatio-temporal differences between spring-run and fall-run Chinook



Circle size represents number of carcasses. Range: 1-7

Analysis of out-migrating smolts may be useful for monitoring the spring-run allele frequency in the Salmon River

Preliminary analysis:

116 smolt samples collected in 2017

Spring-run allele frequency: 0.2

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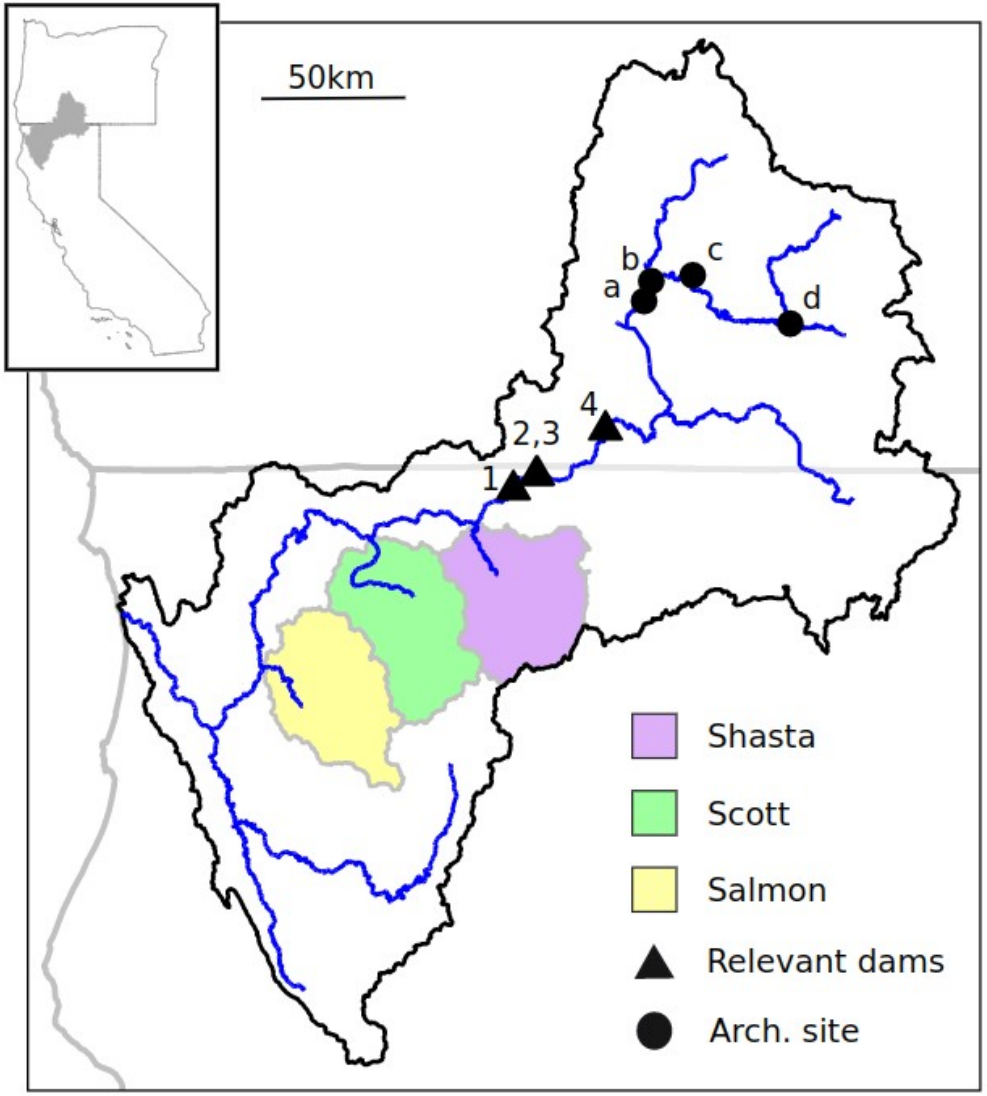
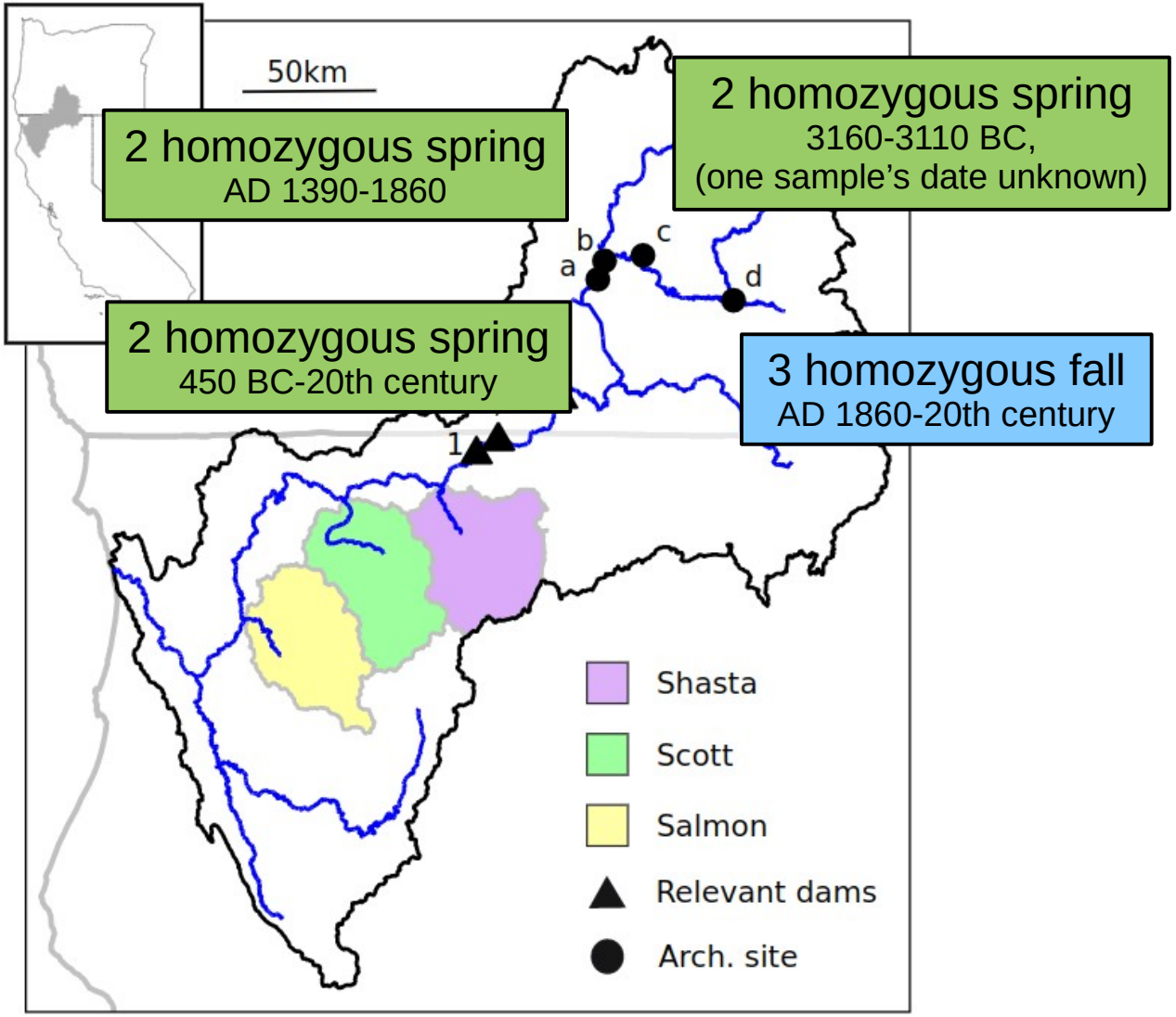
Klamath dam removal provides an unprecedented opportunity to restore Chinook to historical habitat



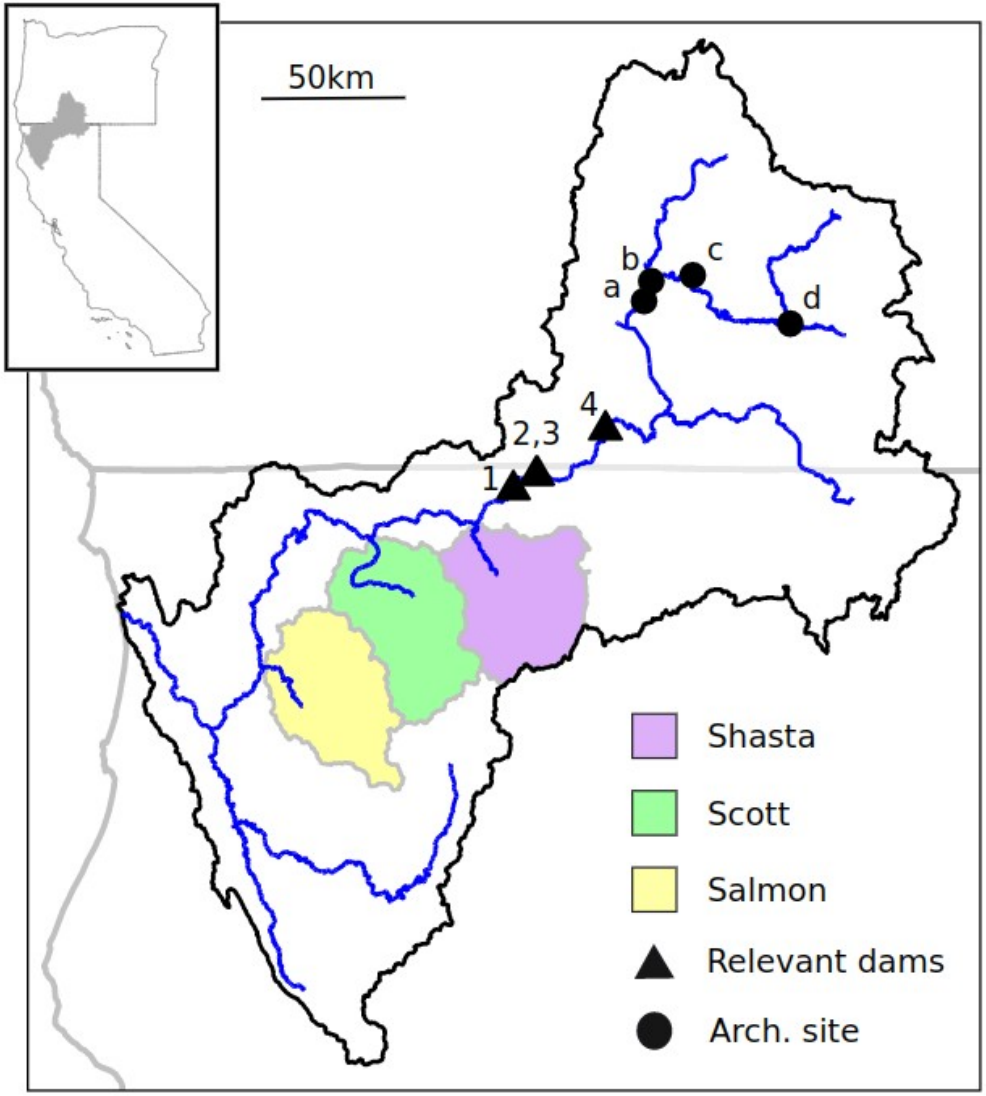
Thompson *et al.*, 2019

Historical documentation and genetic analysis of archaeological samples supports the presence of both spring-run and fall-run Chinook above the Klamath dams



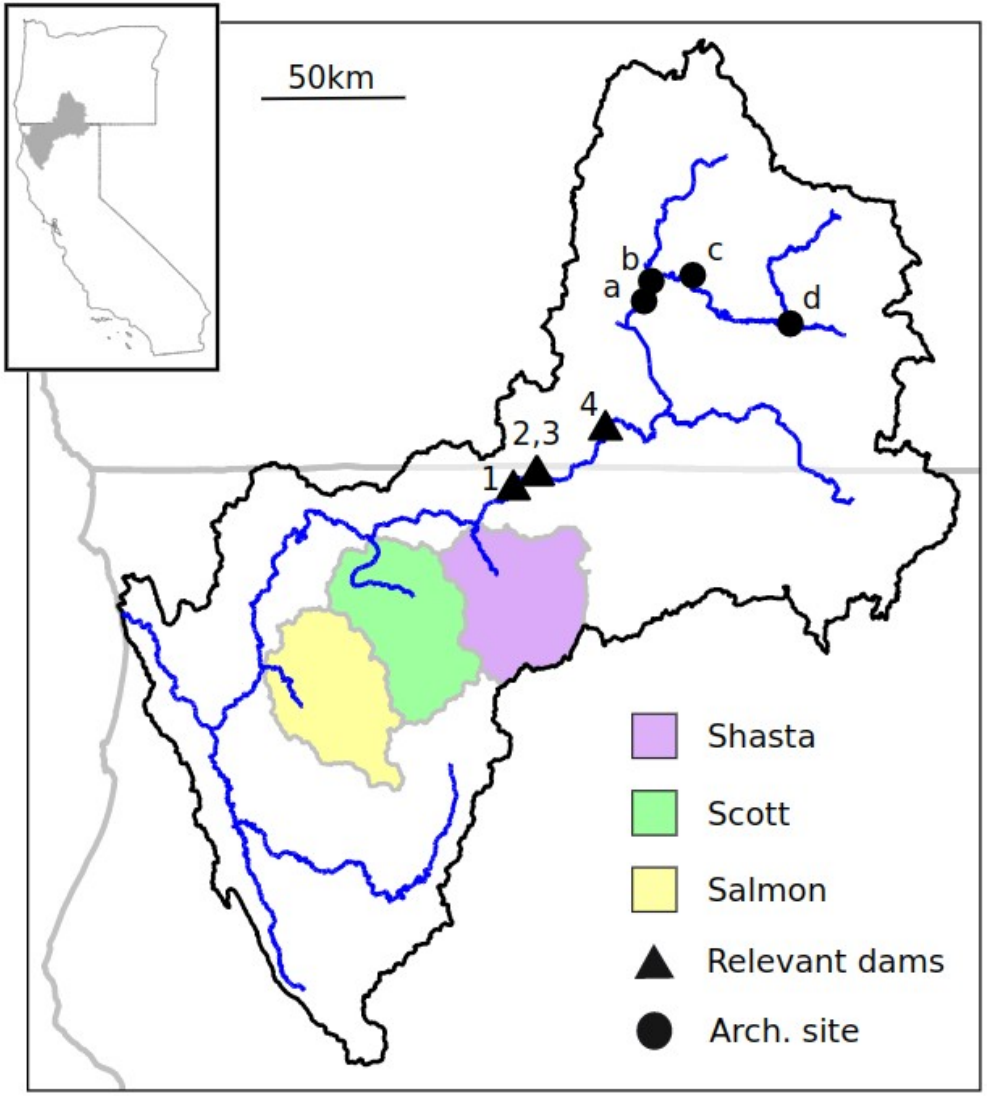
Thompson et al., *in prep*

Where are spring alleles for restoring upper Klamath spring Chinook going to come from?



Thompson *et al.*, 2019

Can heterozygotes serve as a reservoir of spring alleles to restore spring Chinook after dam removal?

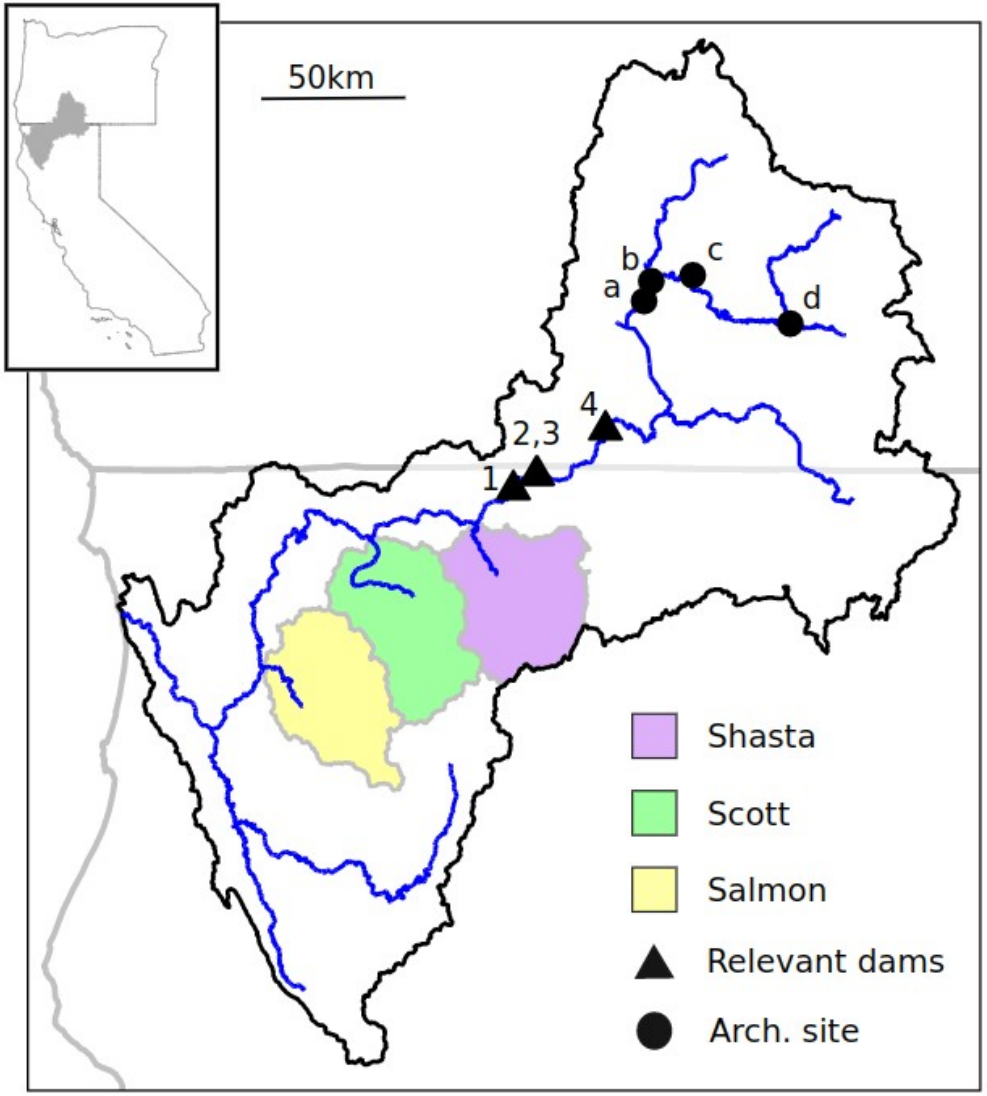


Shasta: spring Chinook extirpated in 1930's

Scott: spring Chinook extirpated in 1970's

Thompson *et al.*, 2019

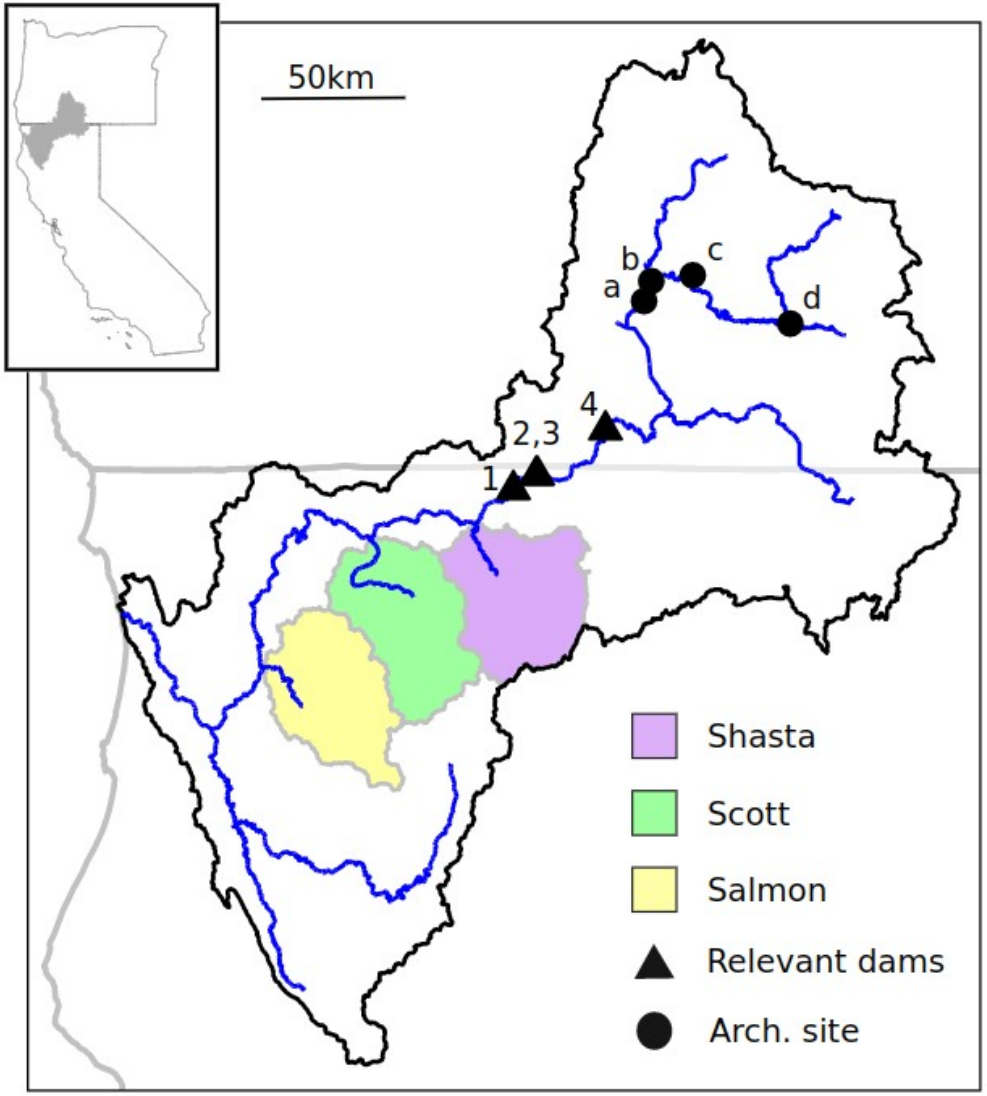
Genotyping smolt samples across juvenile outmigration period reveals spring allele frequencies in the Salmon, Shasta, and Scott



Location	Date spring Chinook last observed	Number of samples	Spring-run allele frequency
Salmon	present	116	**0.20**
Shasta	1930's	440	
Scott	1970's	432	

Thompson *et al.*, 2019

Spring alleles have not been maintained in the Shasta or Scott at frequencies that could be used to restore upper Klamath spring Chinook



Location	Date spring Chinook last observed	Number of samples	Spring-run allele frequency
Salmon	present	116	0.20
Shasta	1930's	440	**0.002 (~20 hets/year)**
Scott	1970's	432	**0.002 (~20 hets/year)**

Thompson *et al.*, 2019

Summary and conclusions

- Higher-resolution analysis of the *GREB1L* region led to discovery of new markers for migration type
- Validation of markers indicates they appear to be diagnostic for spring vs. fall migration type
- Markers could be useful for monitoring and informing spring-run management in the in the Salmon River
- Both spring and fall Chinook were found in ancient samples from above Klamath dams
- Heterozygotes are not acting as reservoirs of spring-run alleles in tributaries that have lost the spring-run phenotype
- The decline of spring-run Chinook can make restoration challenging even when the spring-run still exists in the basin

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- Michael R. Miller

- **Many, many more!!!**