

Integrating data to monitor life history diversity in Columbia Basin salmonids



Photo courtesy Aquarium of the Pacific



Stuart Willis

Columbia River Inter-Tribal Fish Commission

April 26, 2023 ITMD Meeting

Overview

- Genetics Lab Conceptual Workflow
- Steelhead age-at-maturity
 - Life history variation: age-at-first return (“maturity”)
 - Why it matters: portfolio effects and unequal harvest
 - Identifying genetic markers for age-at-maturity in steelhead
- Opportunities in conservation
 - Age at maturity markers
 - Run timing markers
 - Products and data sharing



Hagerman Genetics Lab: Common workflows

Paradigm: Putting fish back in the rivers

- Important Phenotypic Variation
- Manager Questions
- Traditional Ecological Knowledge

What genes influence a [heritable] phenotype?

Population structure/assignment

How strong is a marker-trait association?

Predict phenotypes

Whole genomic data of **distinct groups** (many genetic loci, few individuals)

Loci (genes) contributing to a trait → candidate markers

Genotypes of neutral or candidate loci (fewer genetic loci, many individuals)

Association strength & patterns

Phenotypes across time

Fishery Composition

Data sharing + promotion

Phenotypic & Environmental Data

Phenotypic & Environmental Data



Locus (plural: loci): physical location on a chromosome

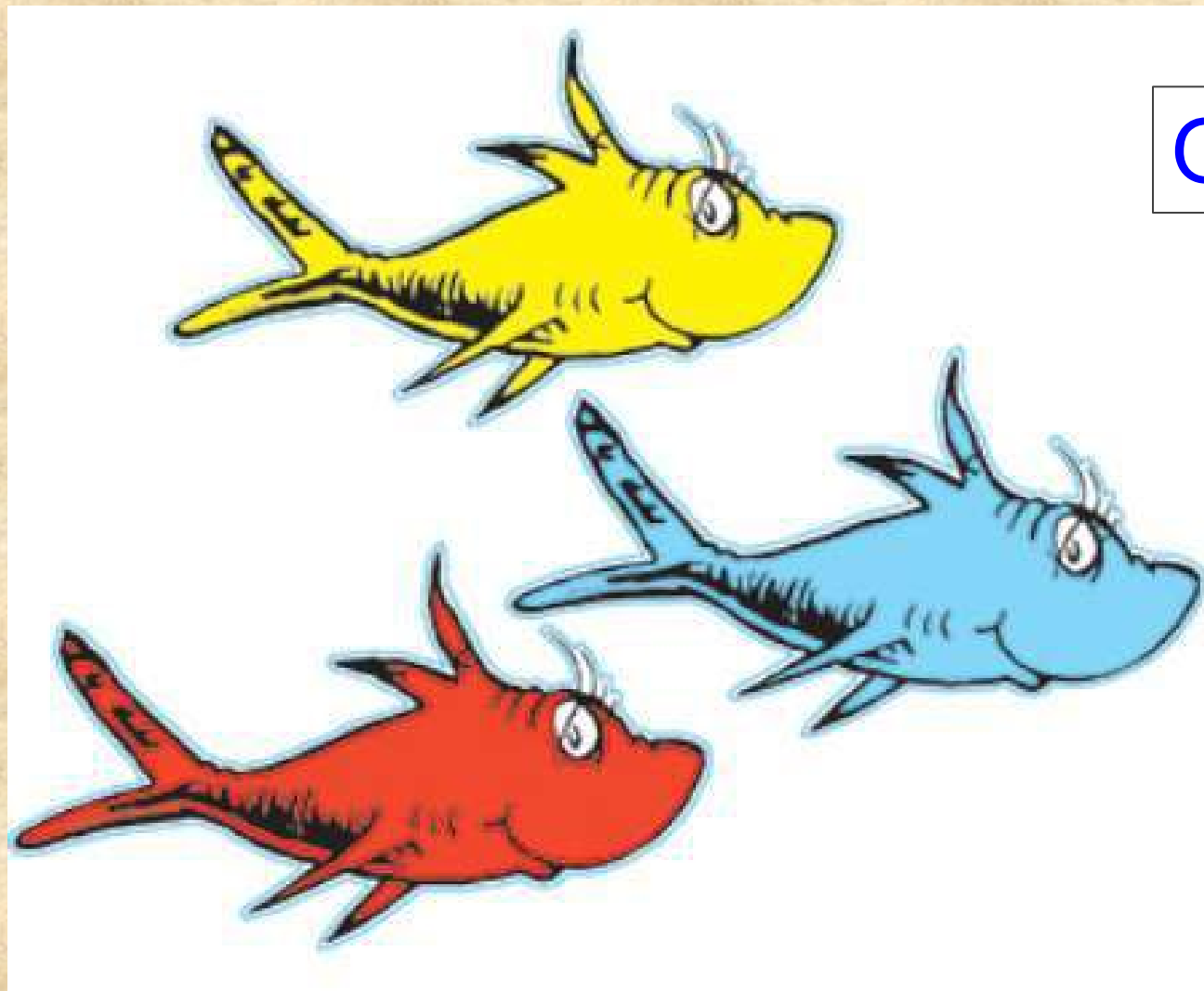
Gene: a locus exhibiting a function or effect, often coding a protein

Genotype: variants an individual has at each copy of a locus (one each from mom and dad), assessed using genetic markers

Phenotype: the physical characteristics (incl. behavior) of an individual; a.k.a. traits



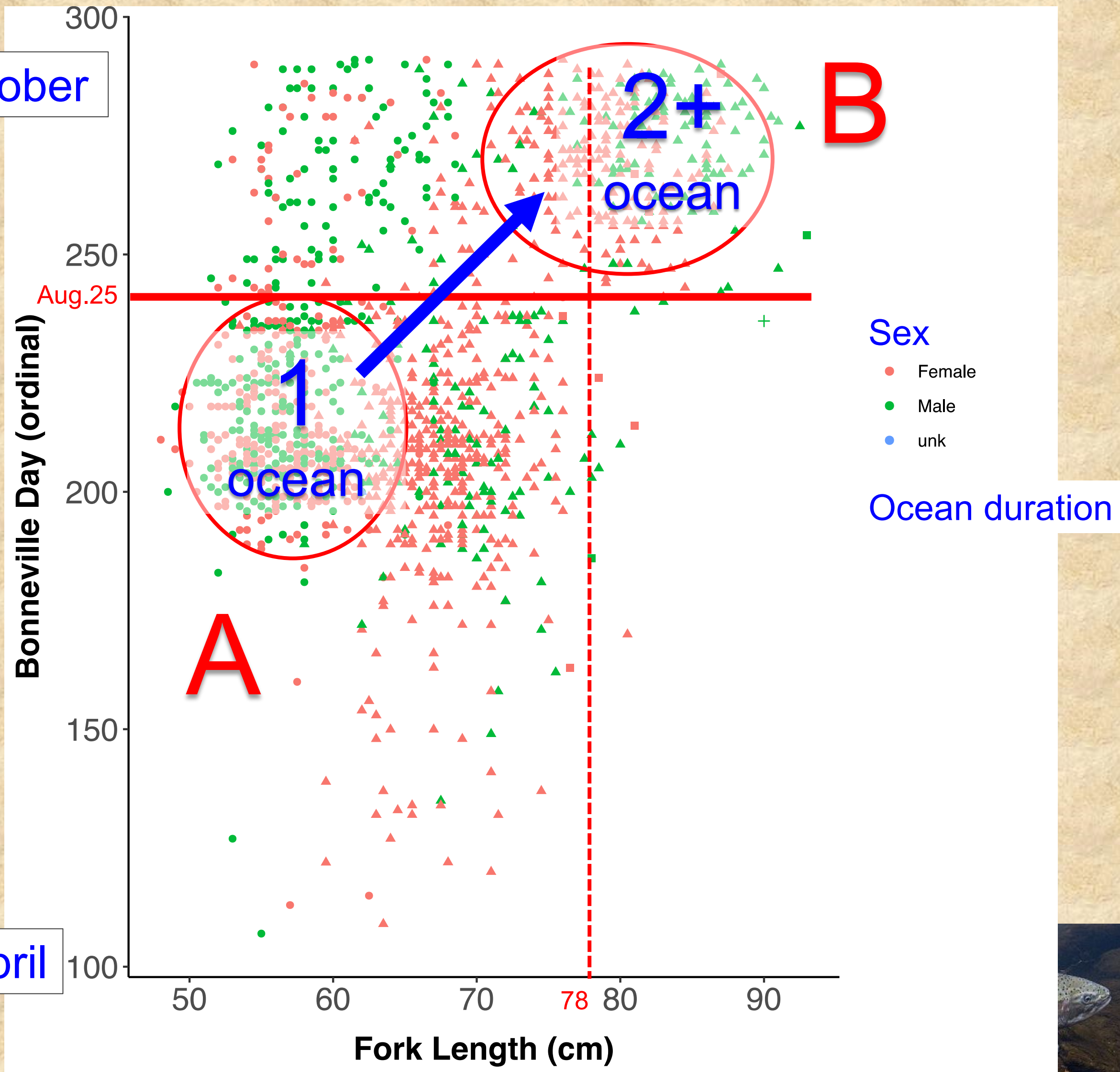
Steelhead natural history: *one size does not fit all (age/size at migration)*



October

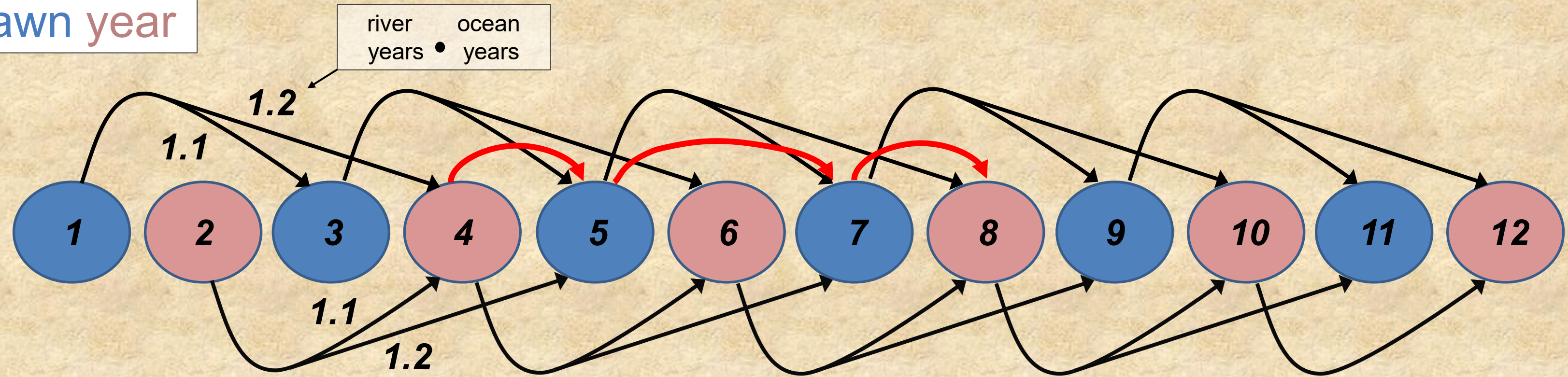
Steelhead sampled at
Bonneville Adult Fish
Facility (BONAFF)

April



Portfolio effects: *population insurance*

Spawn year



Steelhead: repeat spawners!

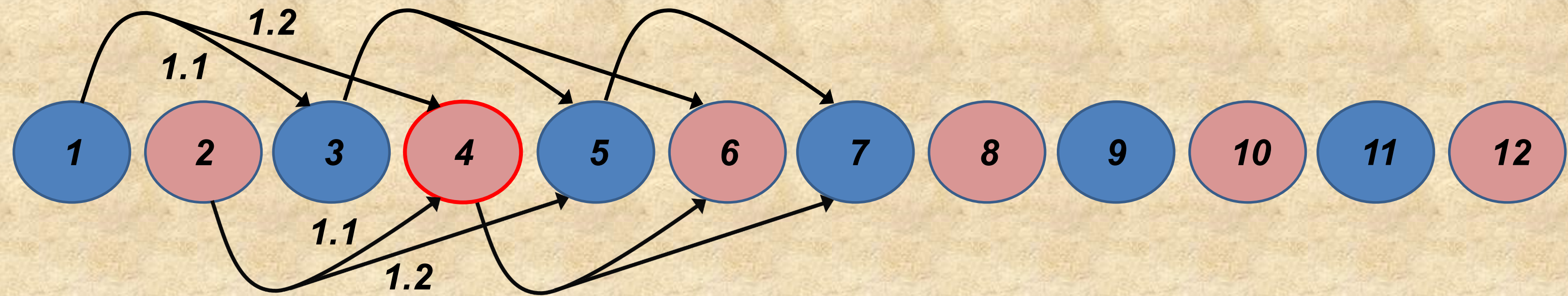


Original diagram design by Ilana Koch (Koch et al. 2018 Evolutionary Applications, 12725)



Portfolio effects: *population insurance*

Spawn year

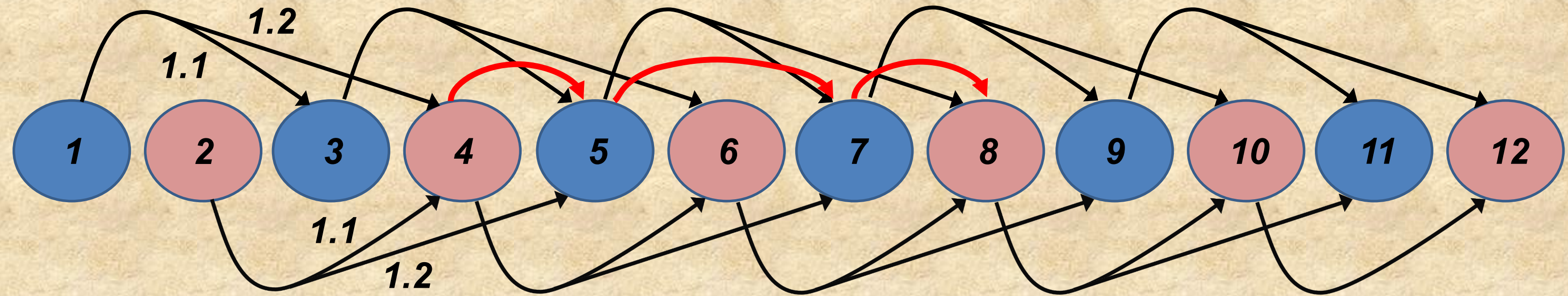


Poor migration or spawning conditions in spawn year 4



Portfolio effects: *population insurance*

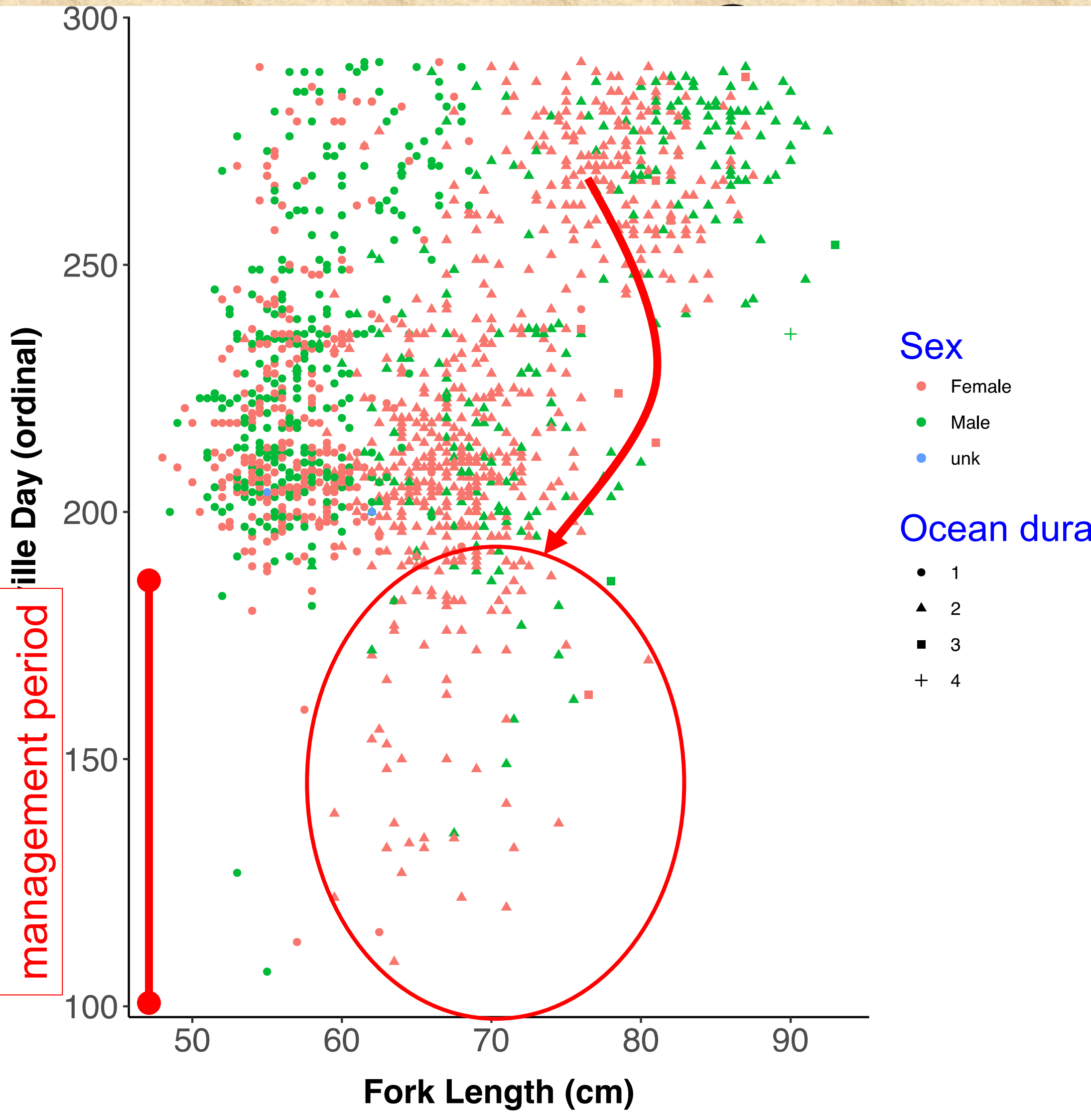
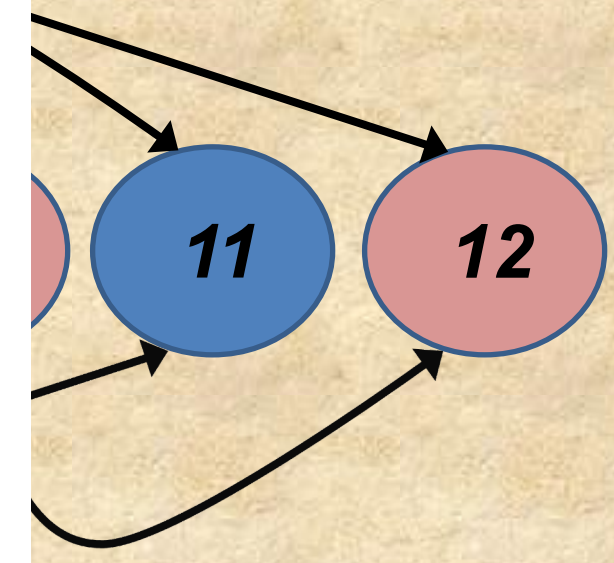
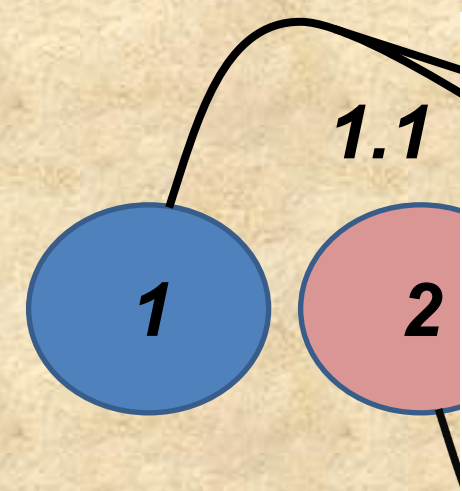
Spawn year



Portfolio effects: *population insurance*

Spawn year

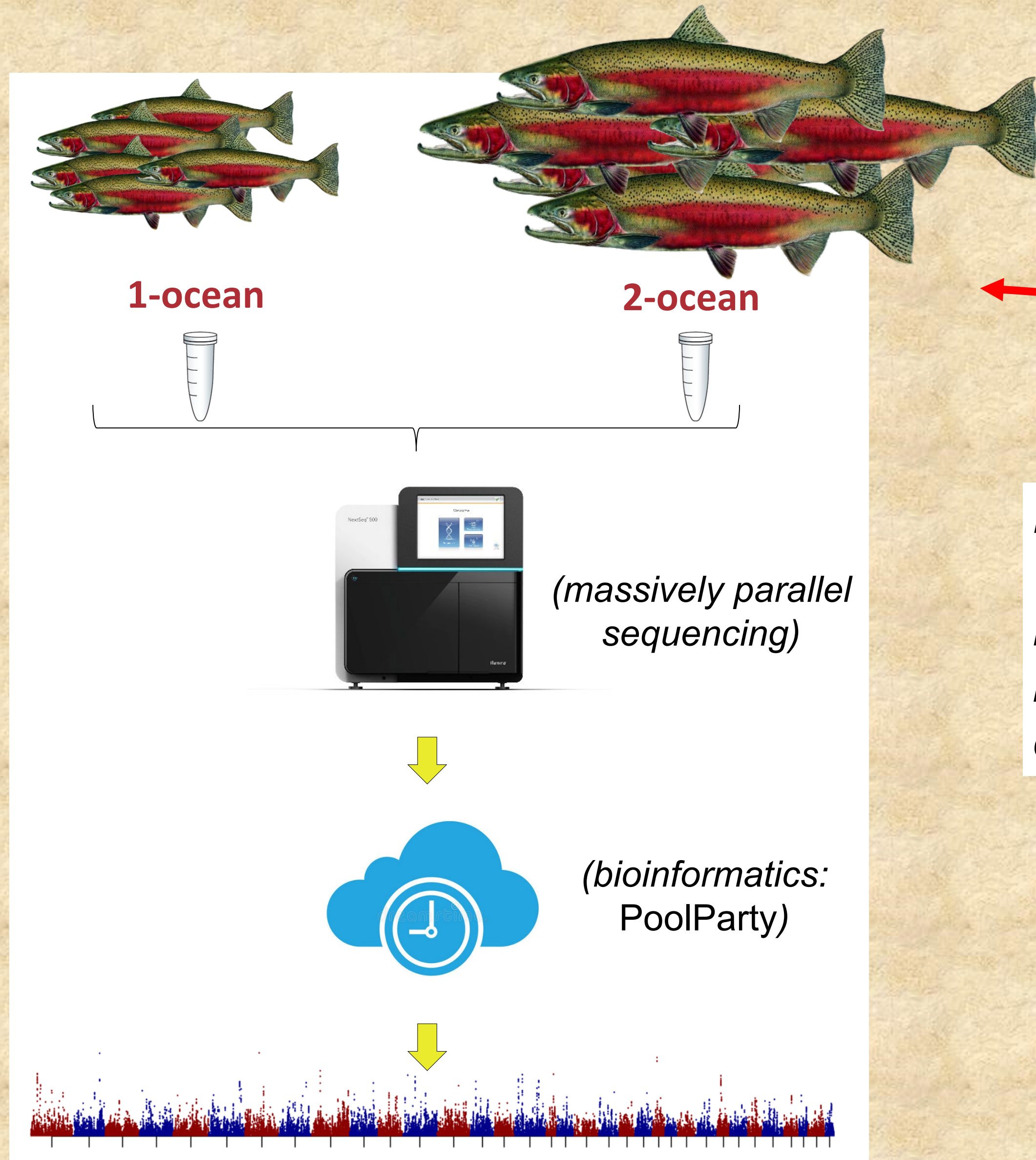
Heritability of age-at-first migration (age-at-maturity)



Original diagram design by Ilana Koch (Koch et al. 2018 Evolutionary Applications, 12725)

Loci influencing age-at-maturity

Pool-seq:
pooled
[individual-
barcoded]
whole
genomic
libraries



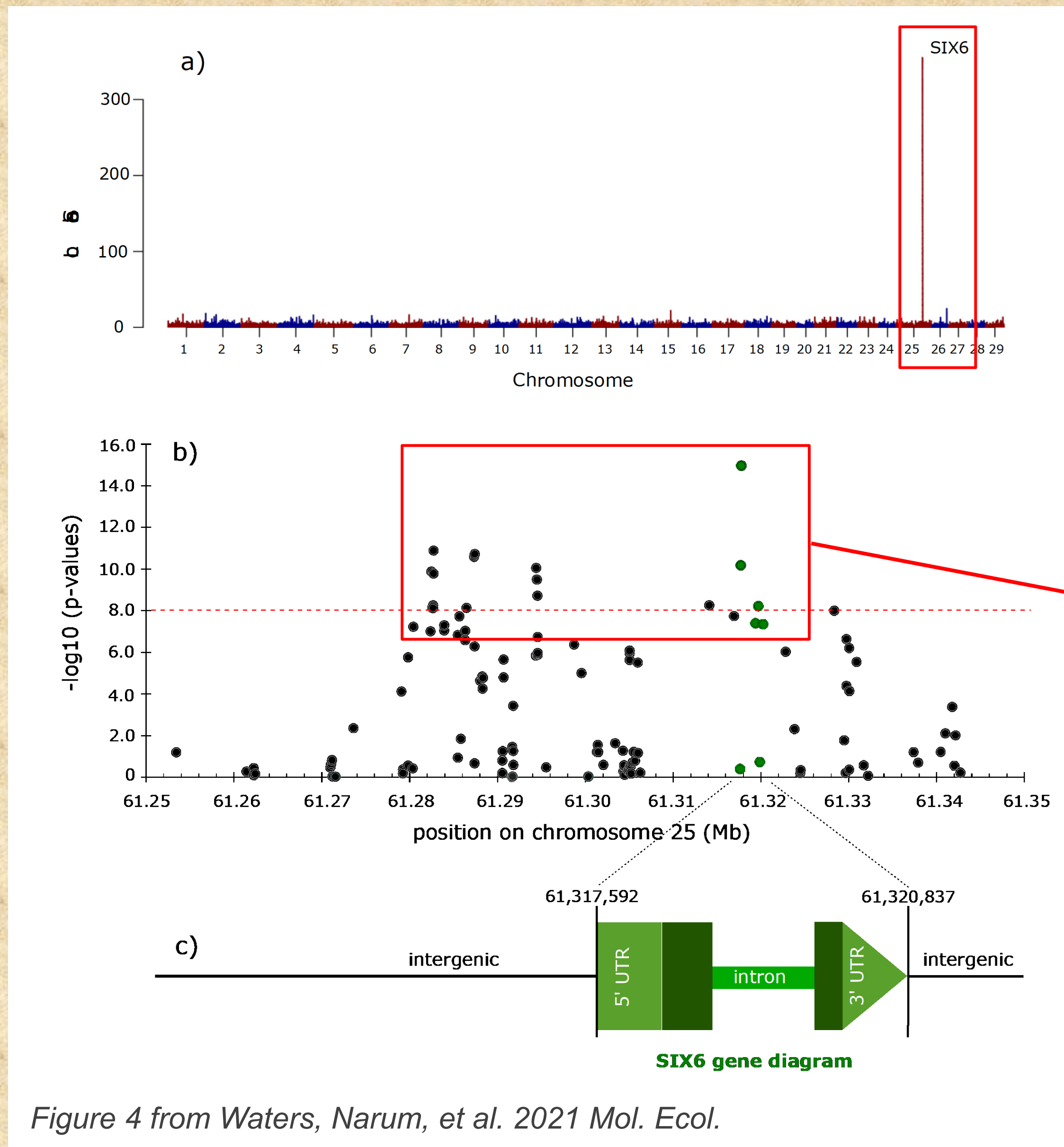
*PBT Age
(parentage
based tagging),
i.e. spawn year
of hatchery fish*



Original Figure by Shawn Narum



Genetic Markers for Age-At-Maturity



Genetic Markers for AAM

BONAFF (SY 2014-19):

Fin Clip

DIT

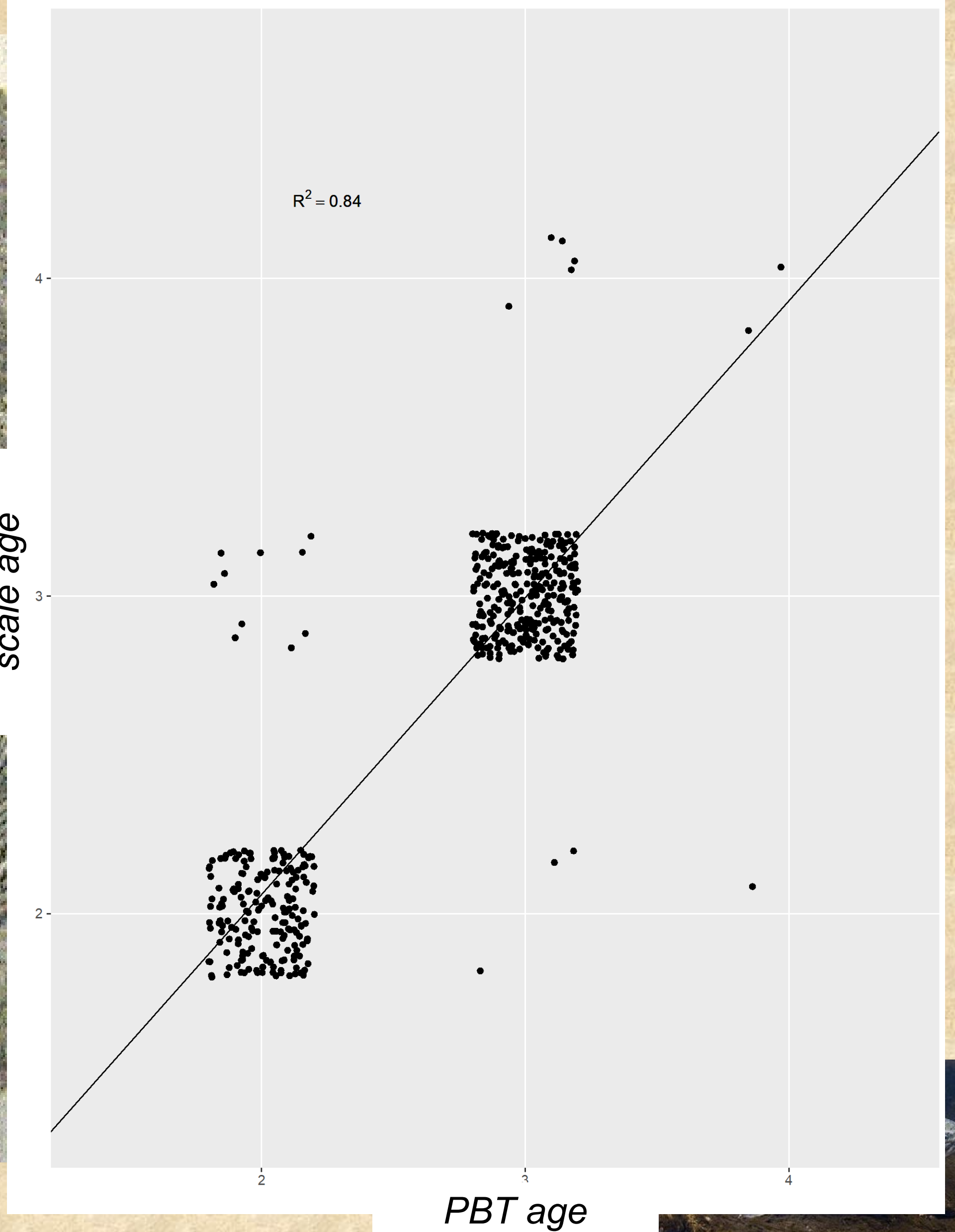
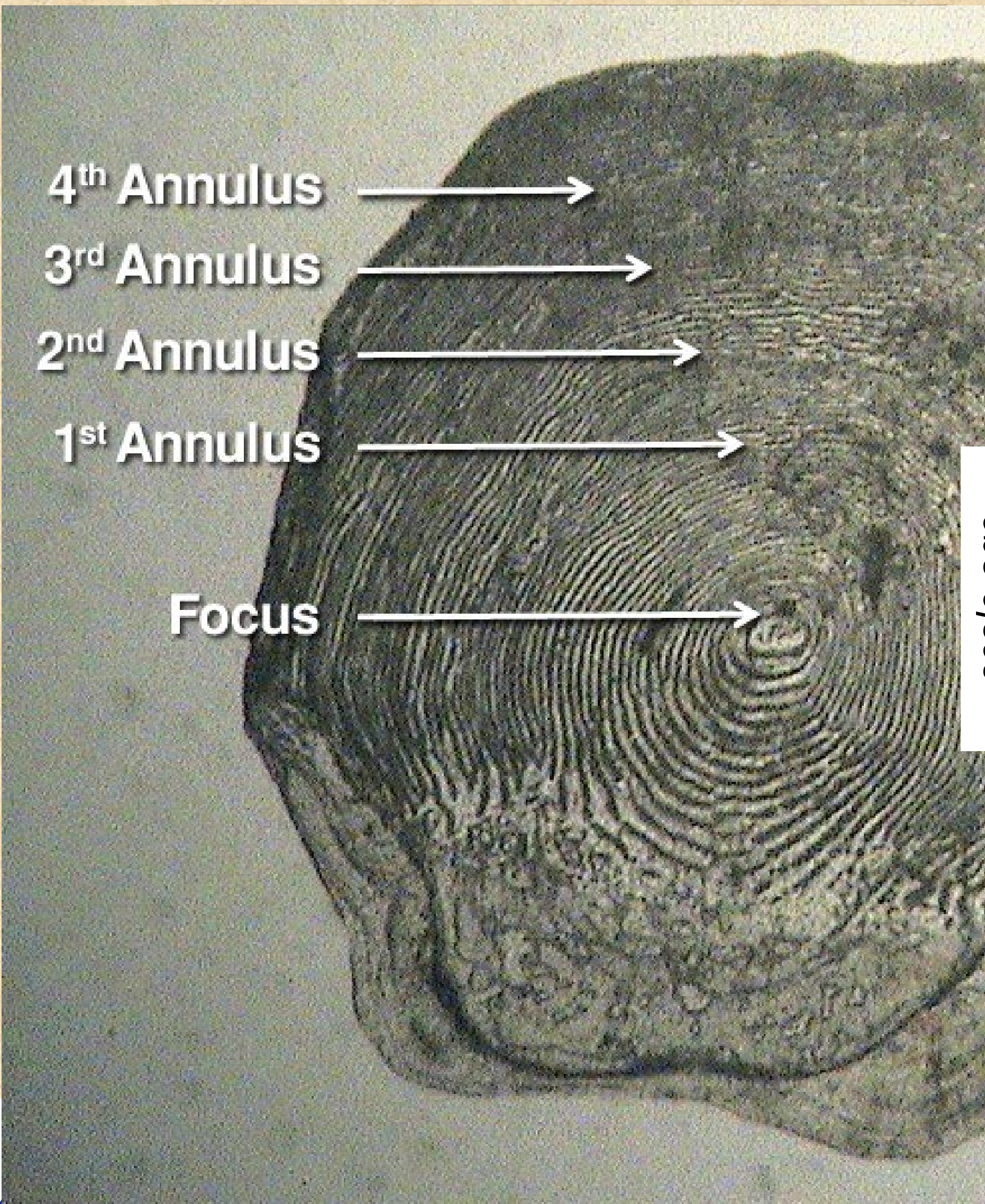


image from fishbio.com

Genetic Markers for AAM

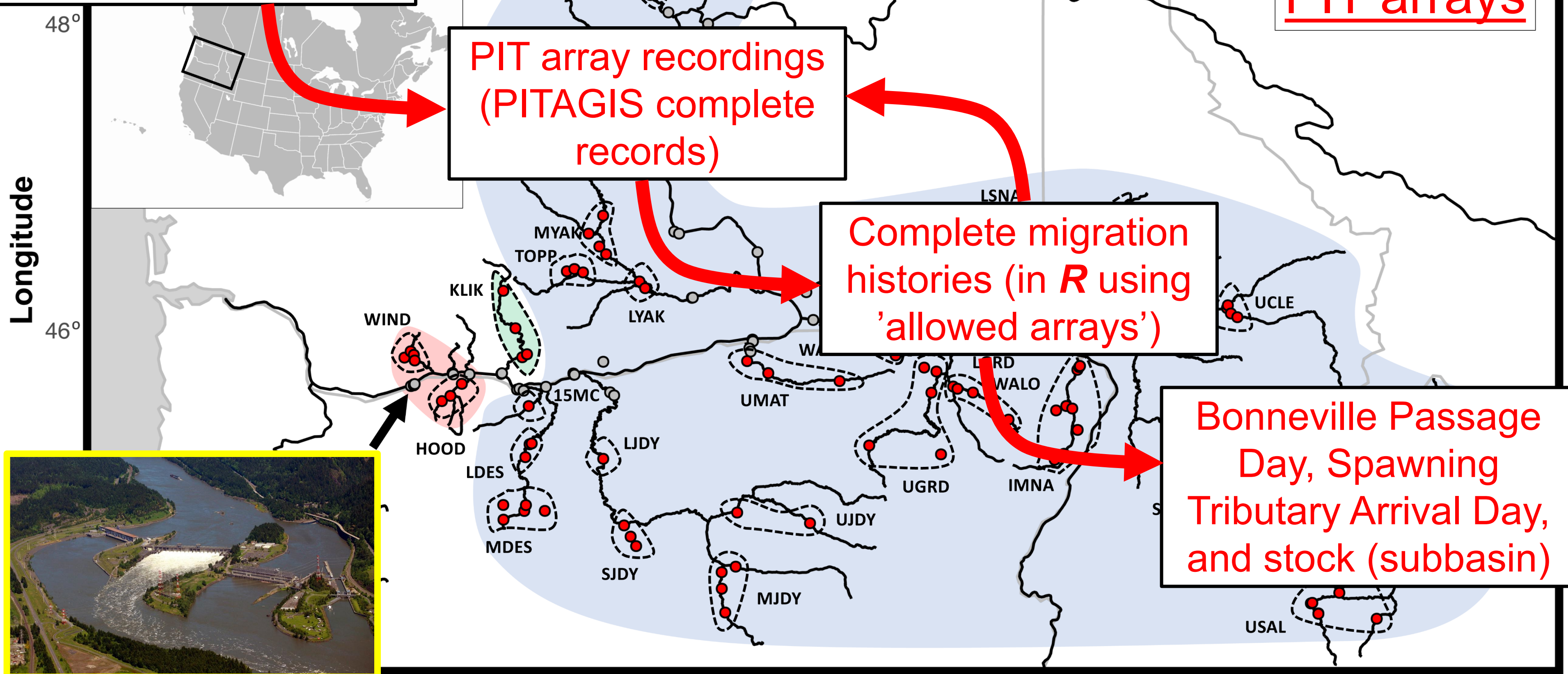
Individuals sampled at Bonneville in the right time period (H.G.L. SQL database)

Utilized PIT arrays

PIT array recordings (PITAGIS complete records)

Complete migration histories (in *R* using 'allowed arrays')

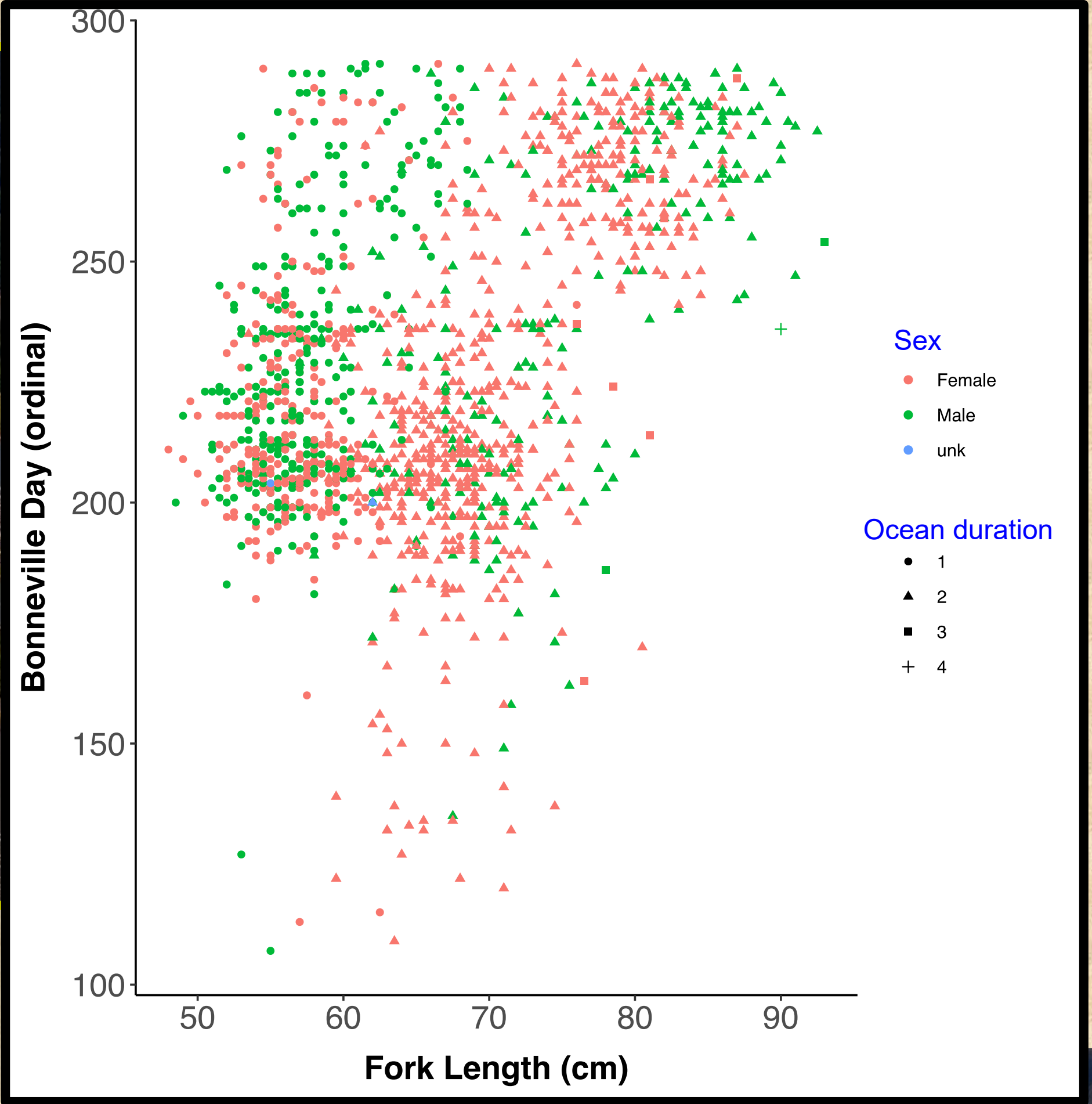
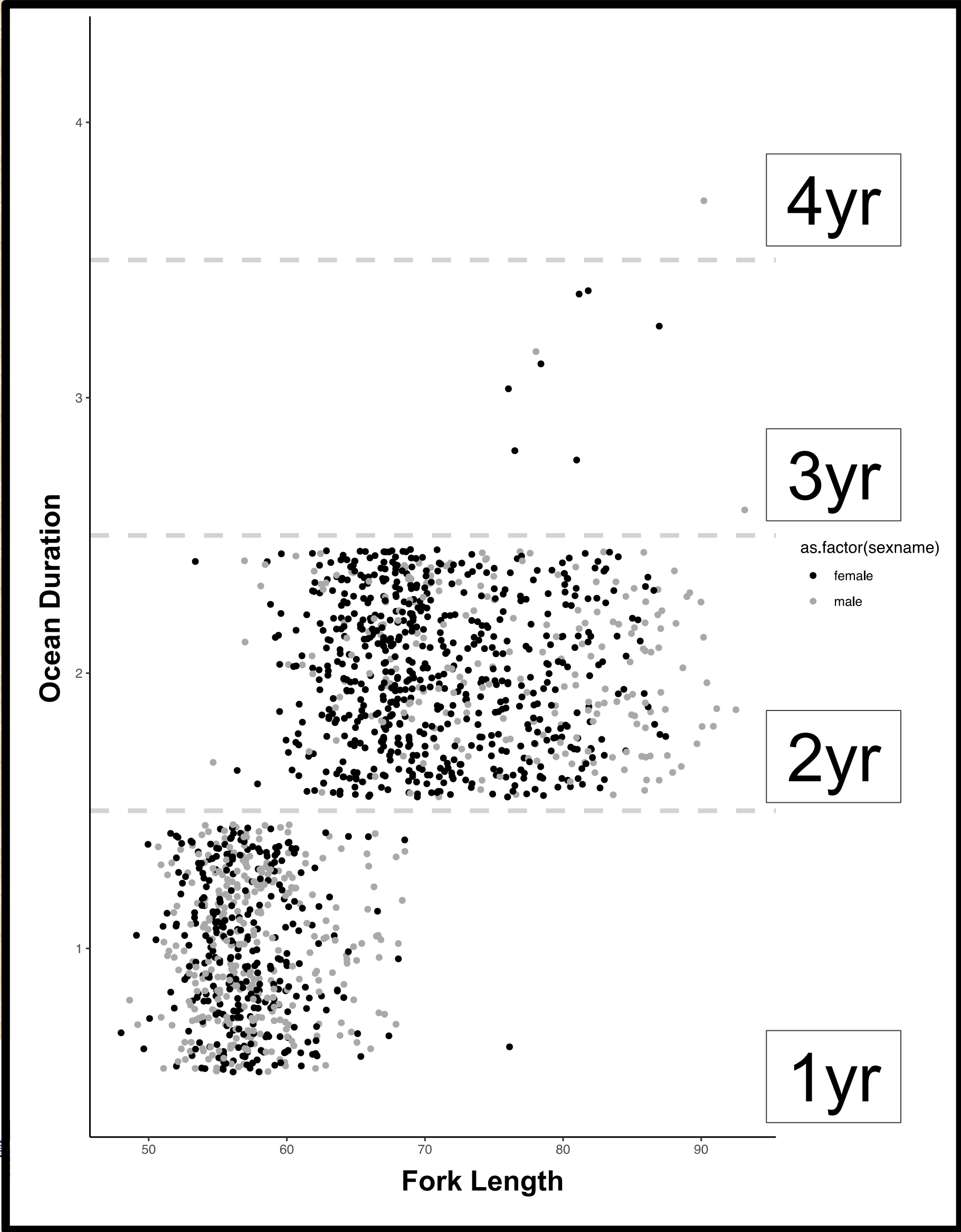
Bonneville Passage Day, Spawning Tributary Arrival Day, and stock (subbasin)



Genetic Markers for AAM

Marker interrogation

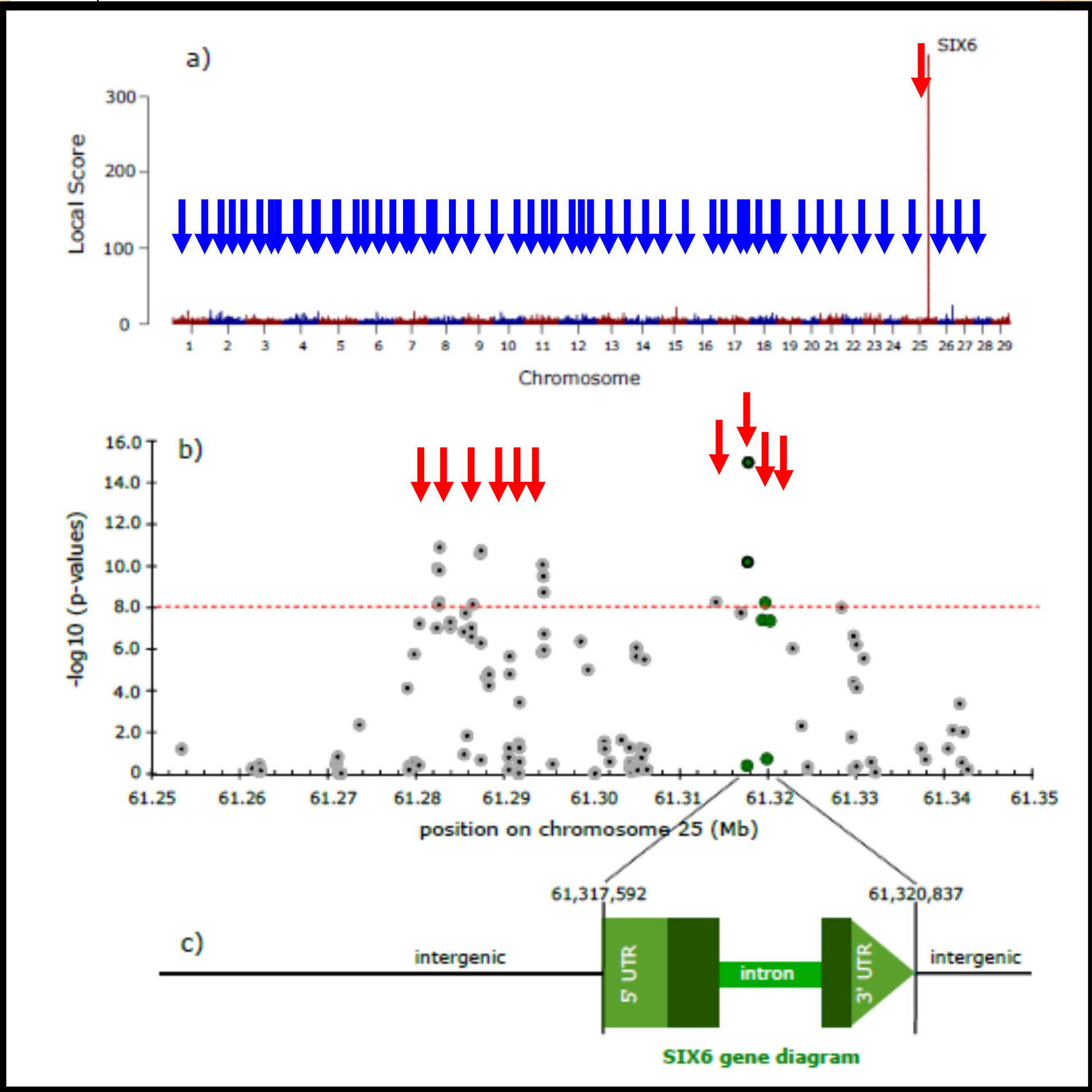
BONAFF (SY 2014-19):
Fin Clip
PIT tag *N=1,538*
Fork Length *fish*
Scale (aging)



Genetic Markers for AAM

Marker interrogation

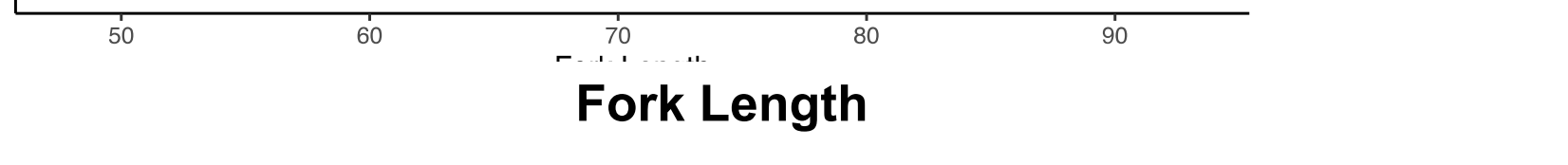
BONAFF (SY 2014-19):
 Fin Clip
 PIT tag *N=1,538*
 Fork Length *fish*
 Scale (aging)



Genotype * covariates = fork length or ocean duration

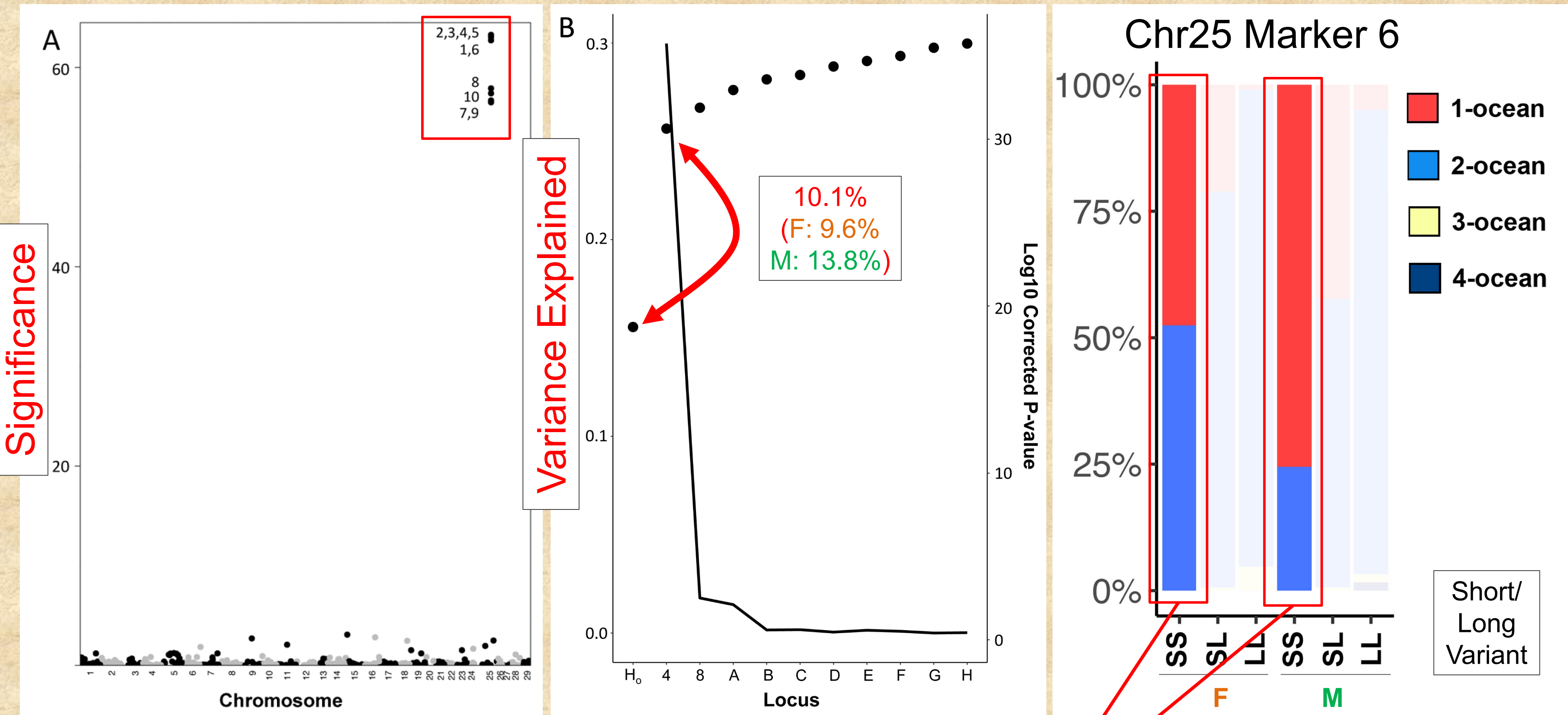
↑

- sex (genetic)
- migration phenology
- kinship
- population structure



Genetic Markers for Age-at-maturity

Results: SIX6 gene markers explain >10% of ocean age variation in a sex-specific manner

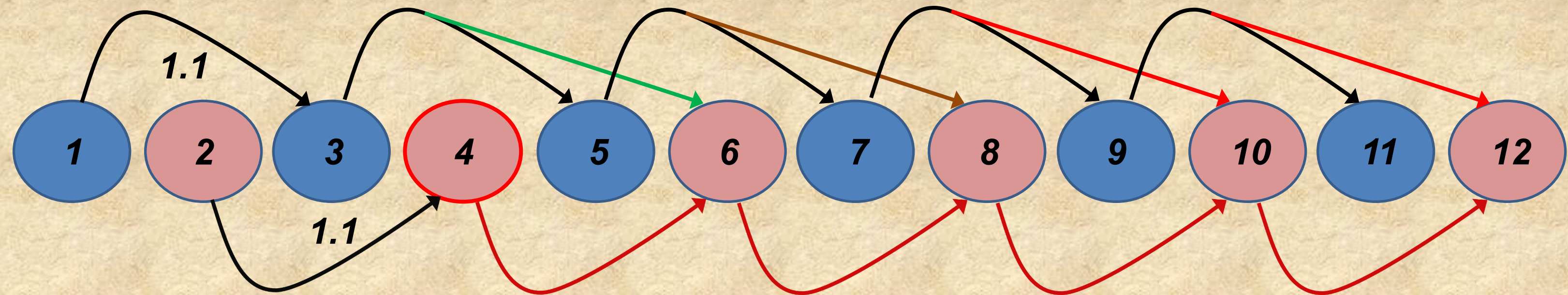


Genotype-aware genomic tests



Portfolio effects: *population insurance*

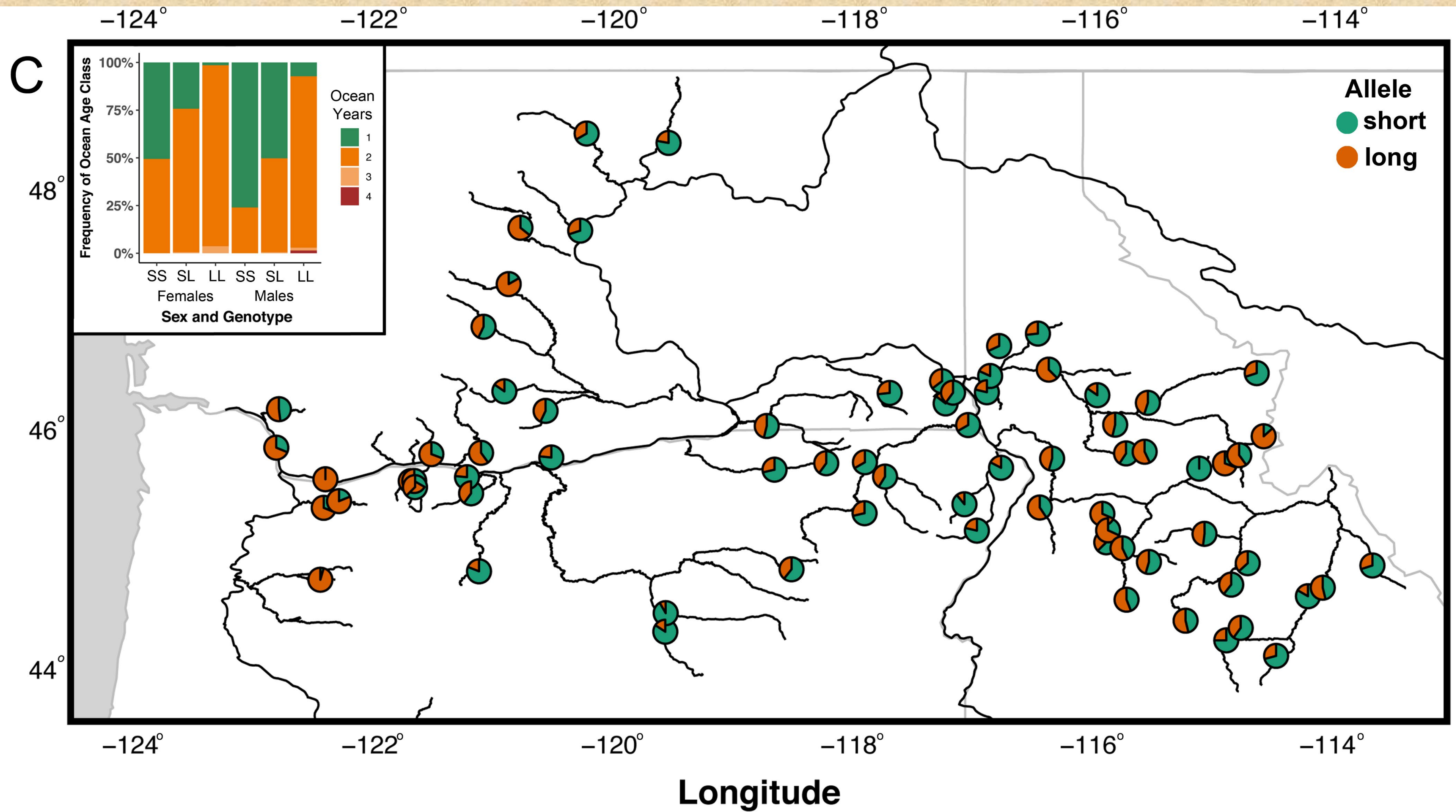
Spawn year



Gene of large effect
Conservation implications?

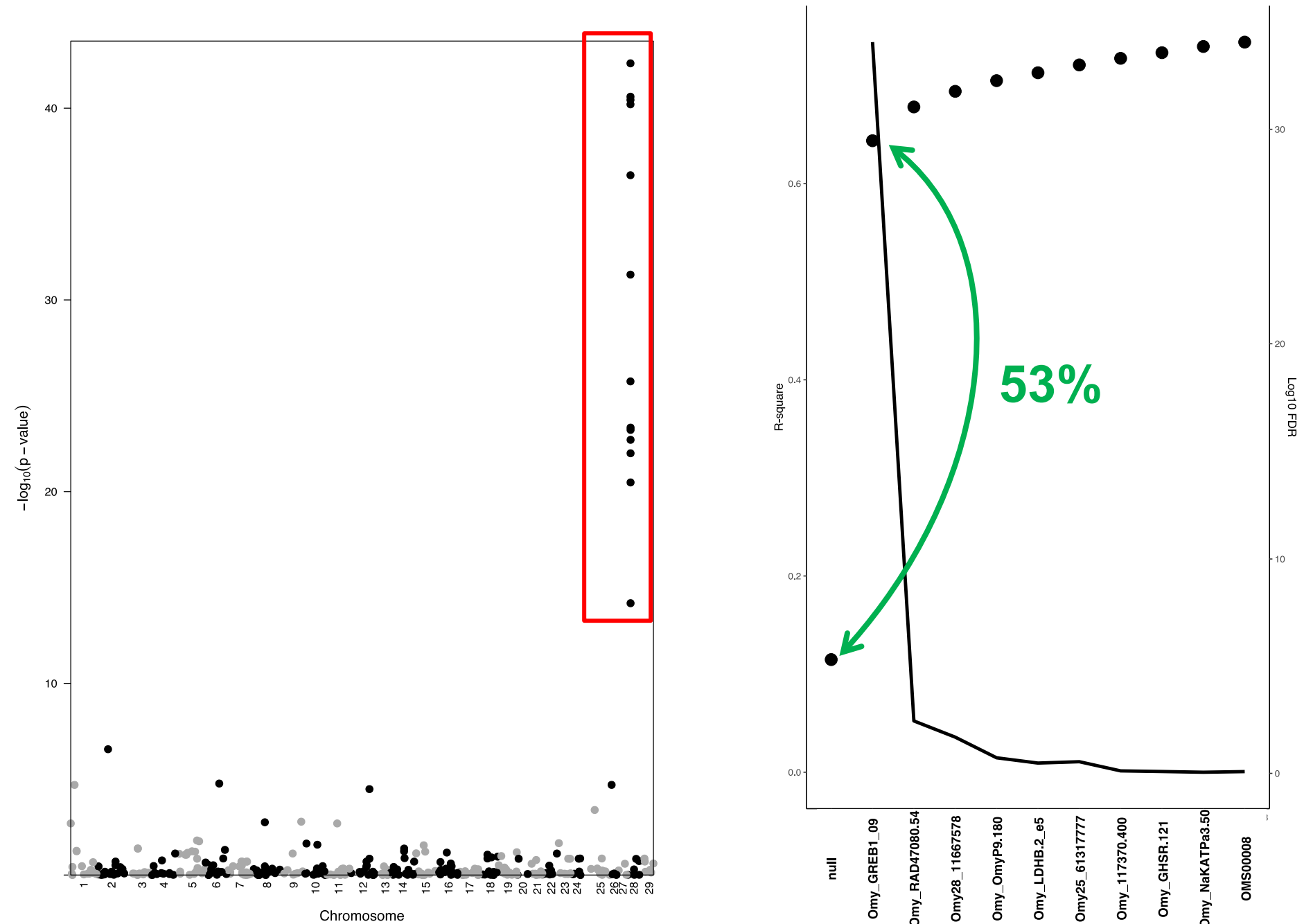
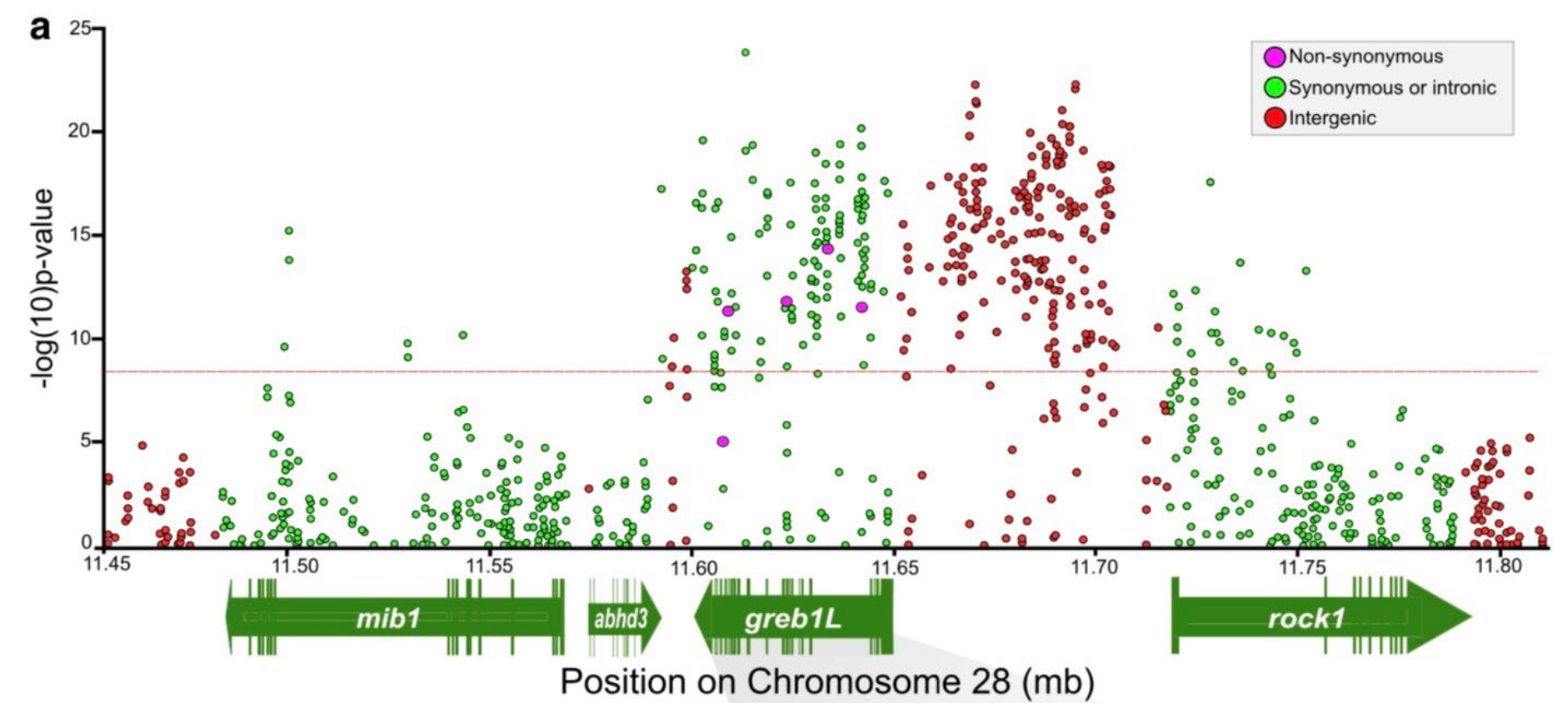
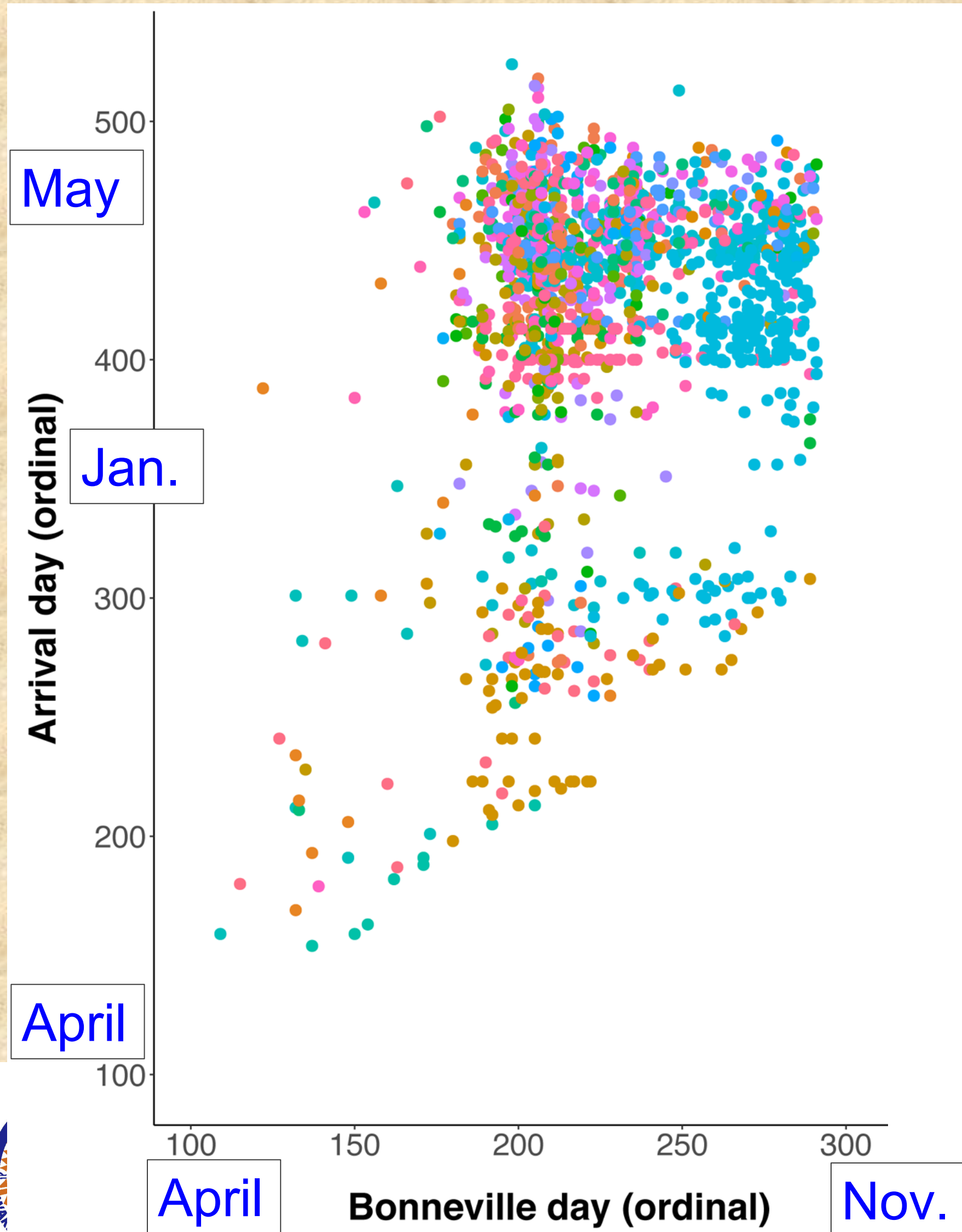


Basin-wide variation in steelhead



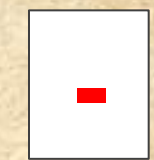
Steelhead natural history: *one size does not fit all*

Run Timing



Large effect genes: applications

NAME	SEX	migration markers	%WINTER
OmyHOOD-2020-13353	Female	[Bar chart]	50%
OmyHOOD-2020-13476	Female	[Bar chart]	50%
OmyHOOD-2020-13226	Male	[Bar chart]	59%
OmyHOOD-2020-13183	Female	[Bar chart]	64%
OmyHOOD-2020-13202	Male	[Bar chart]	86%
OmyHOOD-2020-13527	Male	[Bar chart]	86%
OmyHOOD-2020-13275	Female	[Bar chart]	86%
OmyHOOD-2020-13345	Female	[Bar chart]	86%
OmyHOOD-2020-13382	Female	[Bar chart]	86%
OmyHOOD-2020-13355	Male	[Bar chart]	91%
OmyHOOD-2020-13372	Male	[Bar chart]	91%
OmyHOOD-2020-13387	Female	[Bar chart]	91%
OmyHOOD-2020-13410	Female	[Bar chart]	91%
OmyHOOD-2020-13459	Female	[Bar chart]	91%
OmyHOOD-2020-13262	Male	[Bar chart]	82%
OmyHOOD-2020-13323	Male	[Bar chart]	77%
OmyHOOD-2020-13189	Male	[Bar chart]	100%
OmyHOOD-2020-13190	Female	[Bar chart]	100%
OmyHOOD-2020-13193	Female	[Bar chart]	100%
OmyHOOD-2020-13211	Male	[Bar chart]	100%
OmyHOOD-2020-13212	Female	[Bar chart]	100%
OmyHOOD-2020-13220	Male	[Bar chart]	100%
OmyHOOD-2020-13224	Female	[Bar chart]	100%
OmyHOOD-2020-13245	Male	[Bar chart]	100%
OmyHOOD-2020-13248	Male	[Bar chart]	100%
OmyHOOD-2020-13260	Female	[Bar chart]	100%
OmyHOOD-2020-13277	Male	[Bar chart]	100%
OmyHOOD-2020-13314	Male	[Bar chart]	100%
OmyHOOD-2020-13316	Female	[Bar chart]	100%
OmyHOOD-2020-13340	Female	[Bar chart]	100%
OmyHOOD-2020-13342	Female	[Bar chart]	100%
OmyHOOD-2020-13350	Female	[Bar chart]	100%
OmyHOOD-2020-13375	Male	[Bar chart]	100%
OmyHOOD-2020-13394	Female	[Bar chart]	100%



Warm Springs Fisheries:

East Fork Hood winter-run stock:

- Fish caught at weir can be rapidly genotyped to predict stock and migration-phenotype
- Allows identification and avoidance of stray or introgressed summer-run fish in broodstock

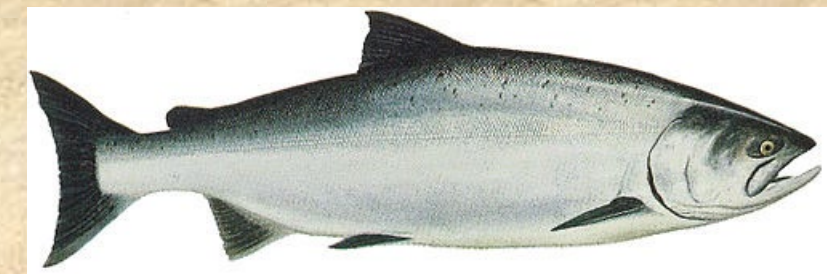
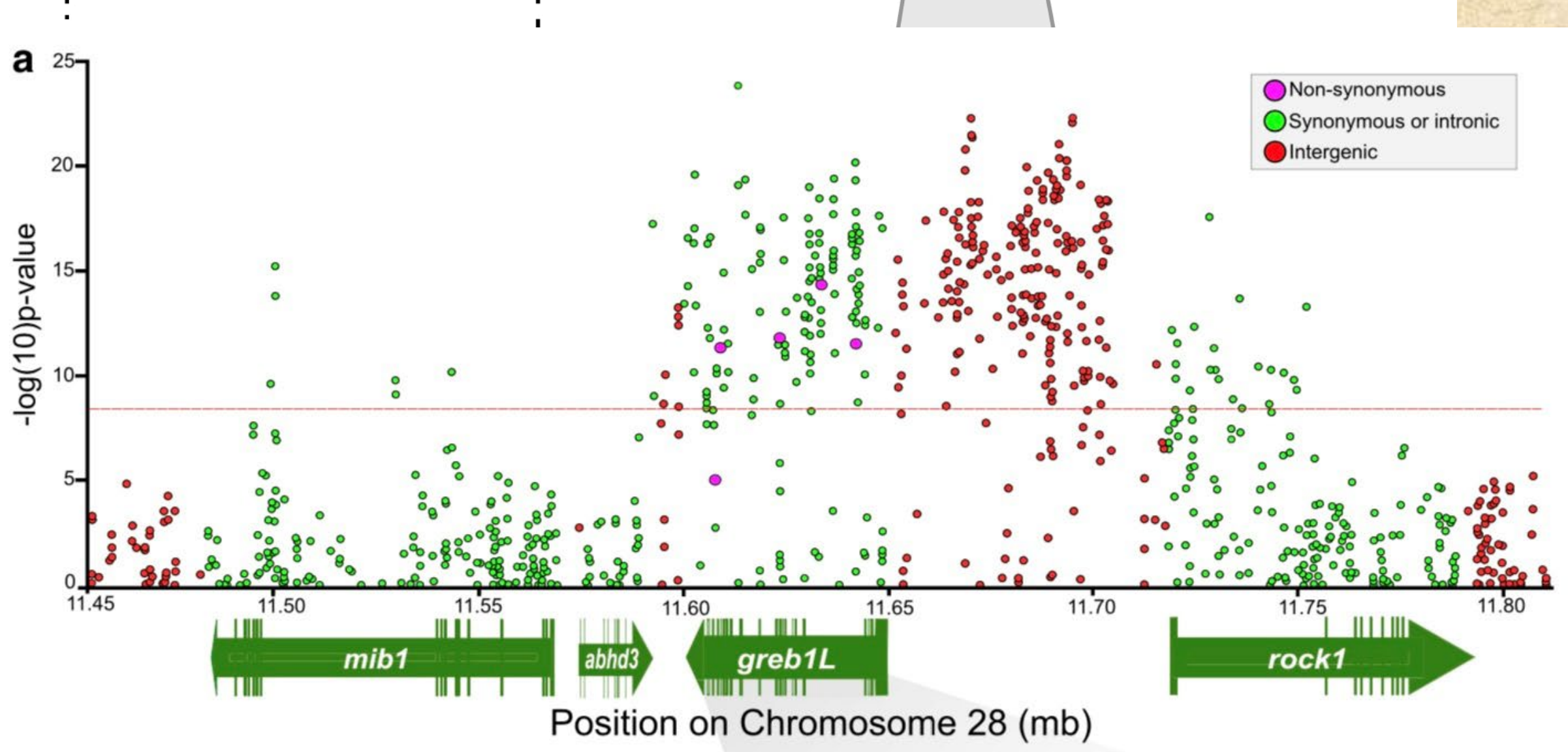
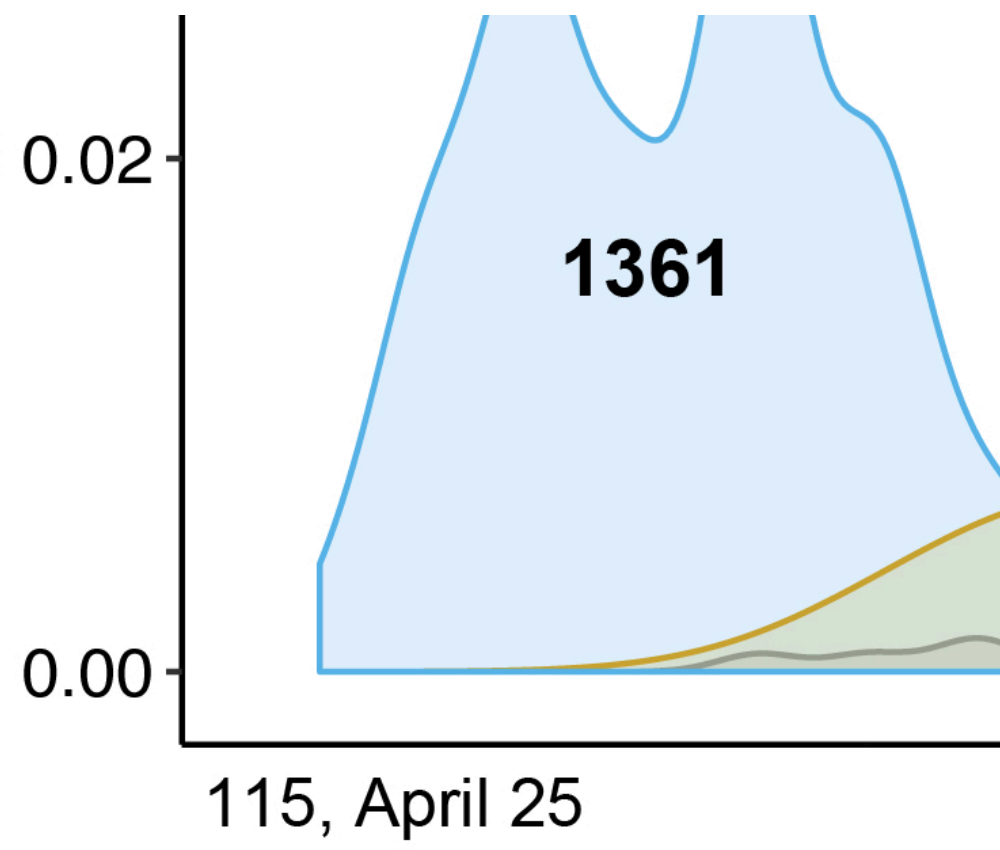
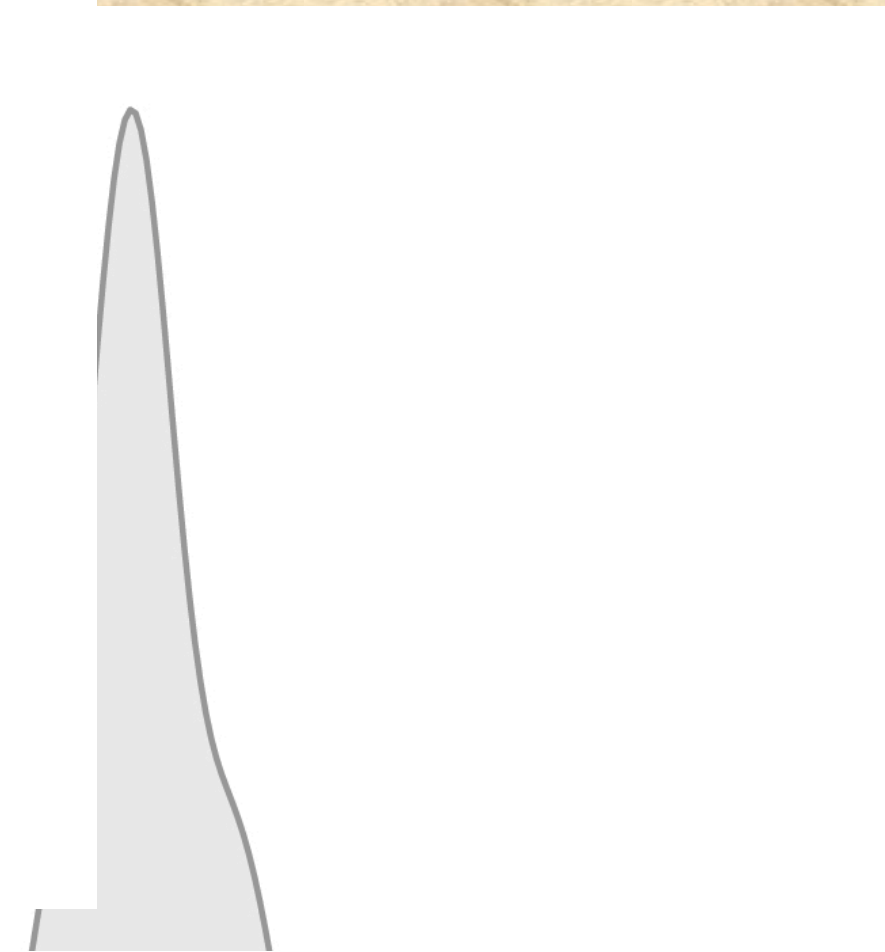
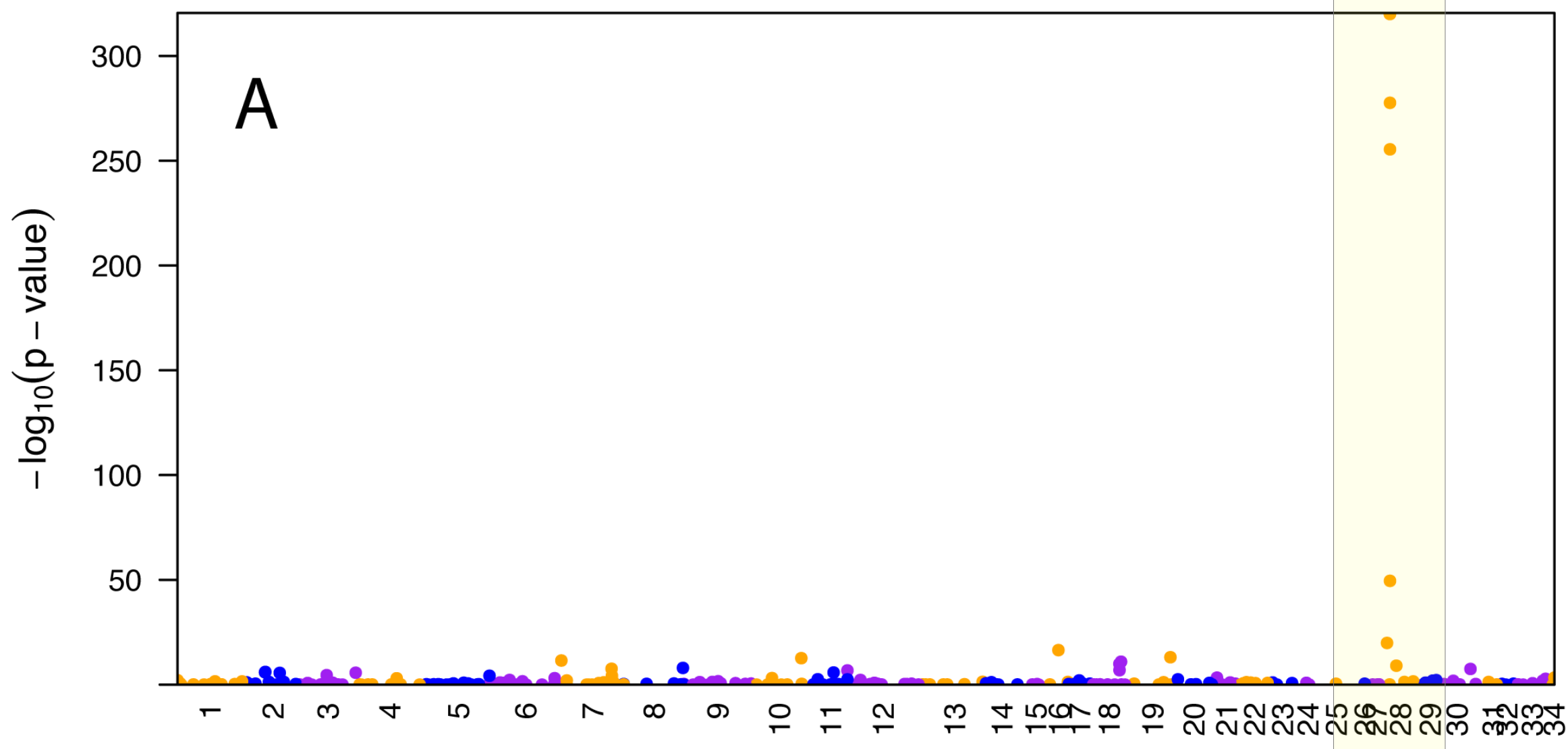


Hood River data courtesy of Jeff Stephenson

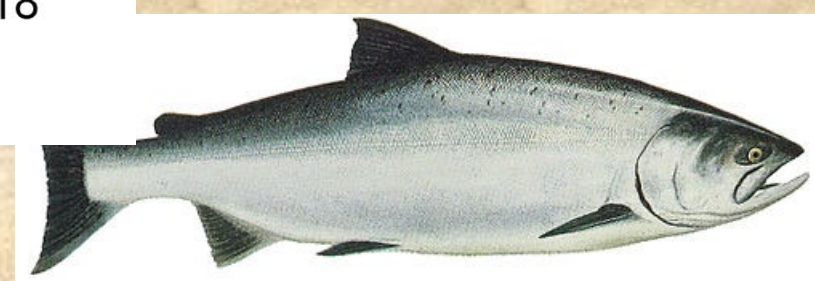
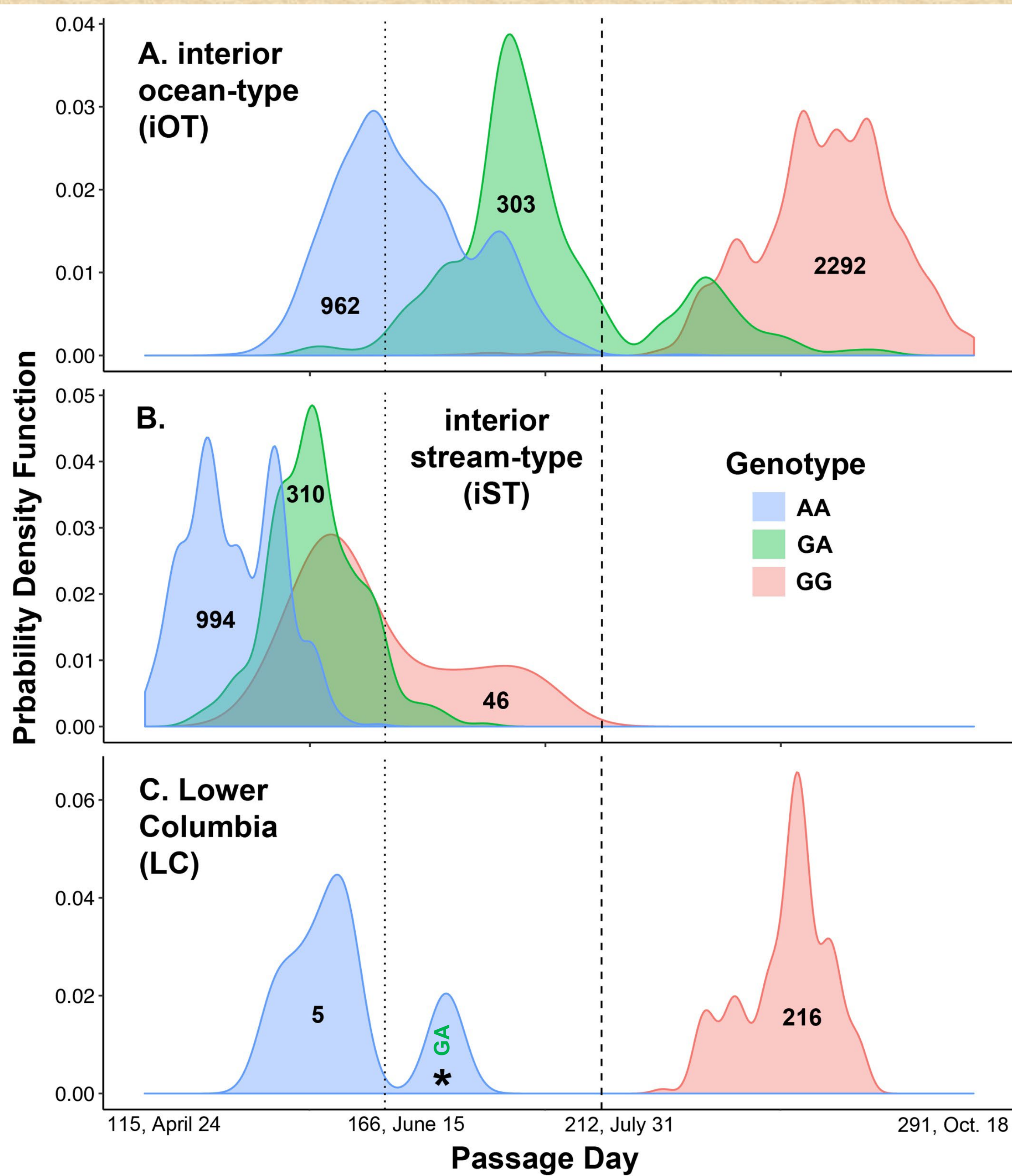
Ru

-ROCK1

Probability Density Function



Results



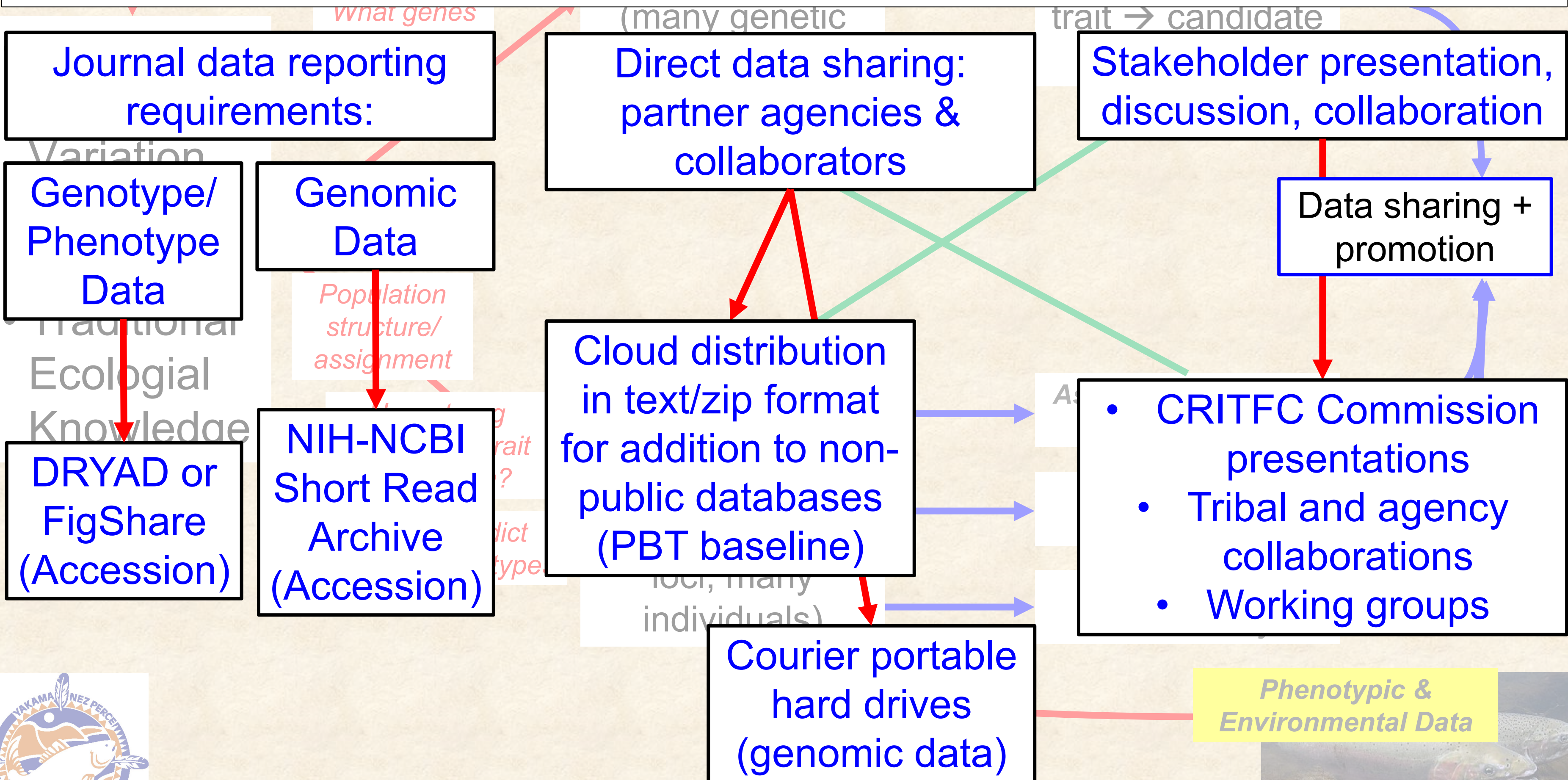
Steelhead (*Oncorhynchus mykiss*) lineages and sexes show variable patterns of association of adult migration-timing and age-at-maturity traits with two genomic regions

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¹ Hagerman Genetics Laboratory, Columbia River Inter-Tribal Fish Commission, Hagerman, ID, USA

² Fishery Science Department, Columbia River Inter-Tribal Fish Commission, Portland, OR, USA

³ Branch of Natural Resources – Fisheries, Confederated Tribes of Warm Springs, Portland, OR, USA



Questions



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- Labmates at the Hagerman Genetics Lab
- Funding from Bonneville Power Administration

ORIGINAL ARTICLE |  OPEN ACCESS  

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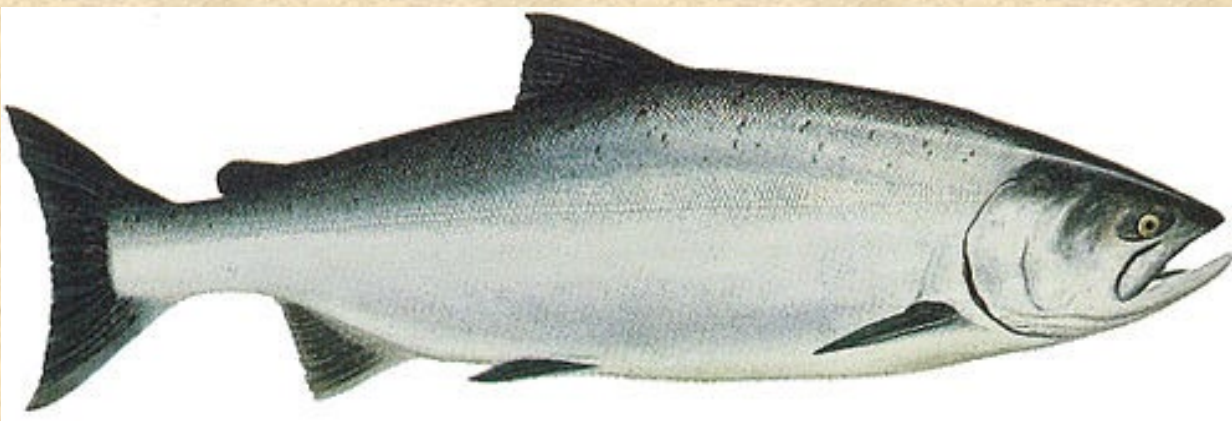
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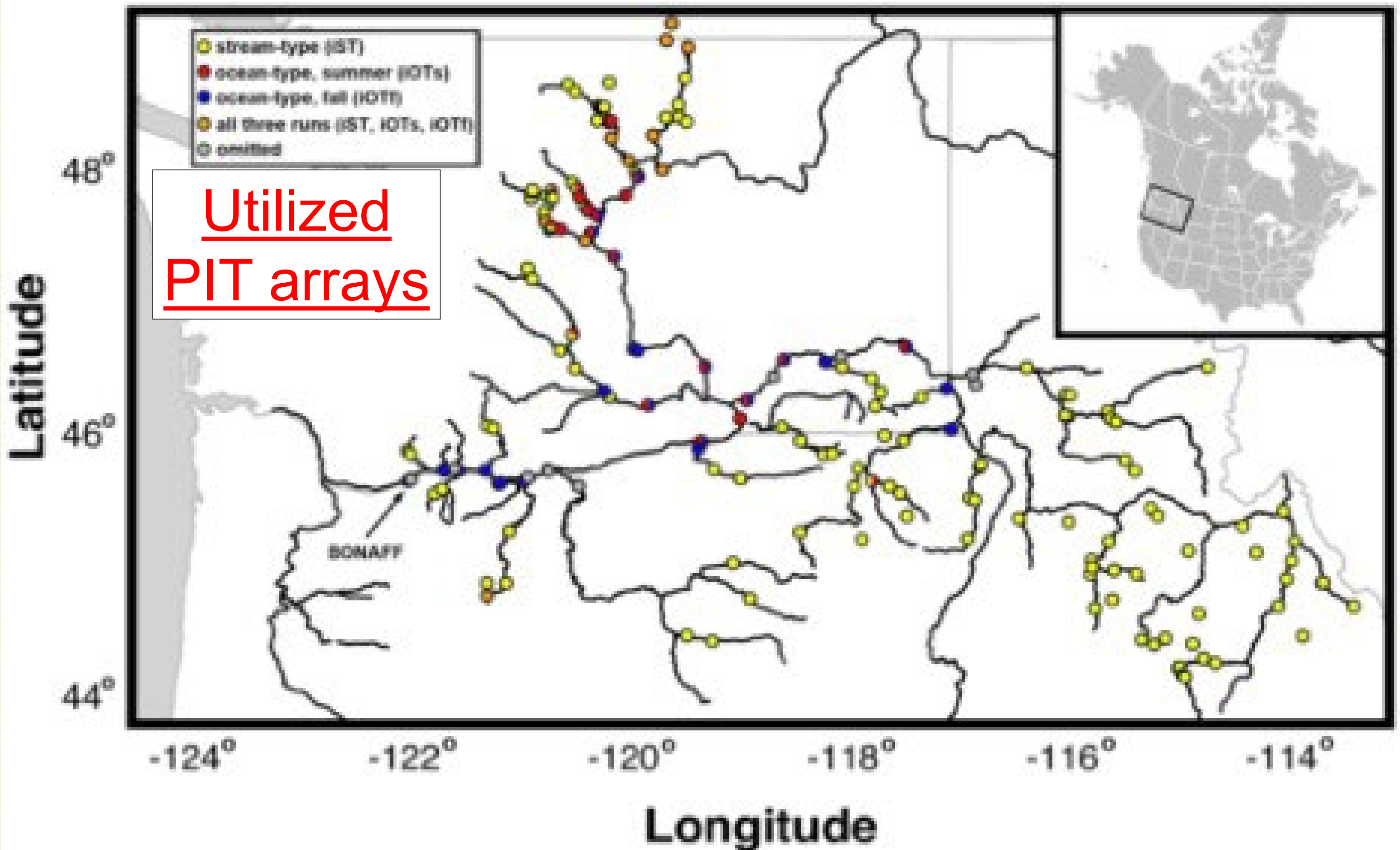
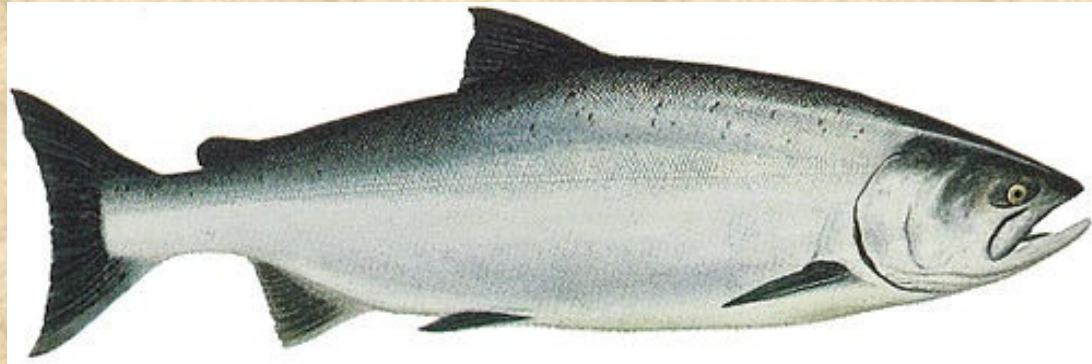
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Evol. Appl. 13 (10) 2836-2856



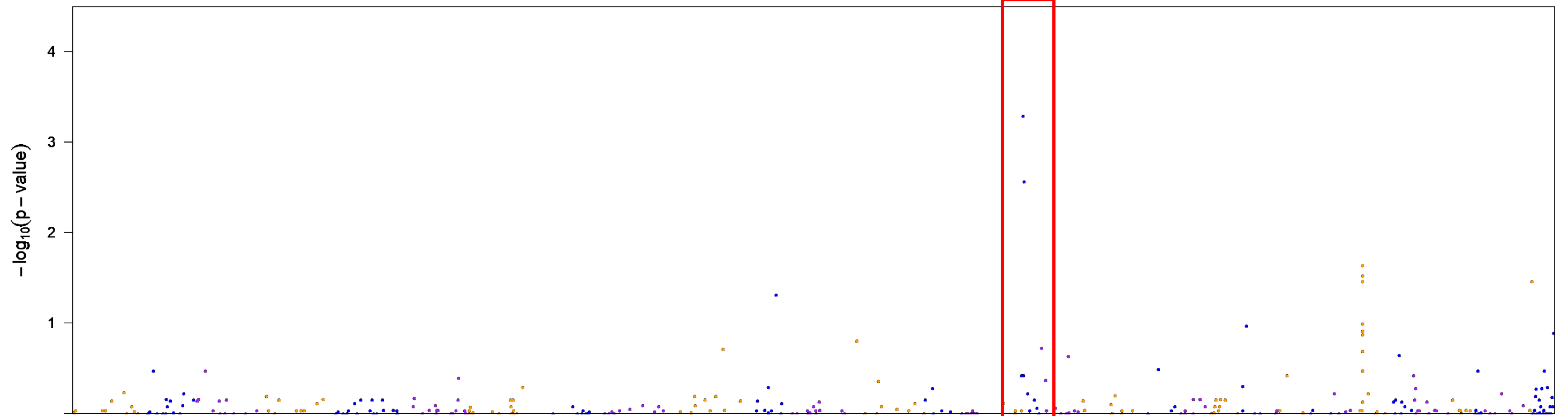
Genetic Markers for AAM

Chinook

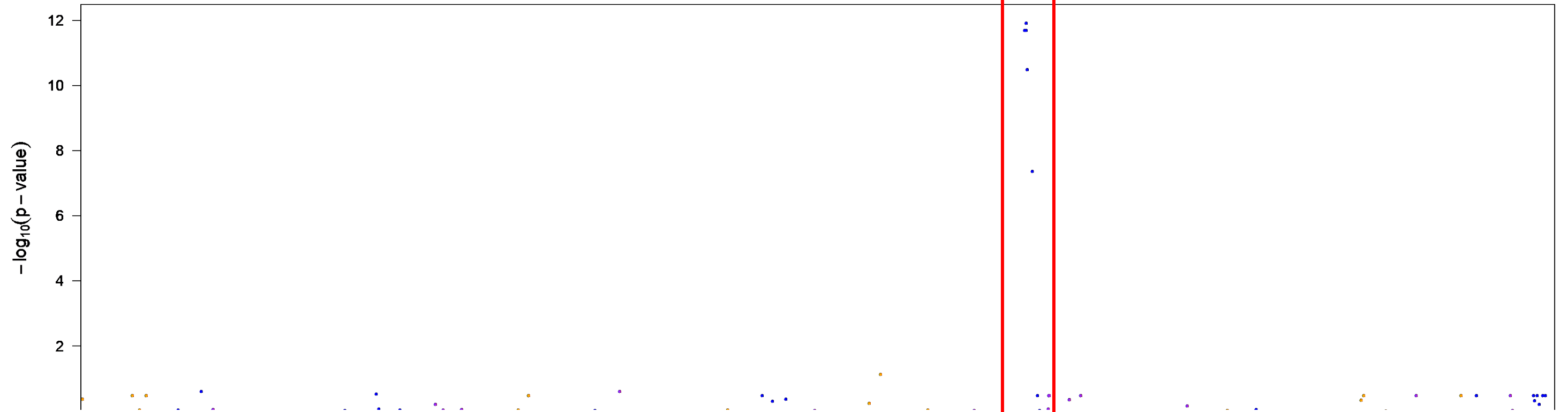


males

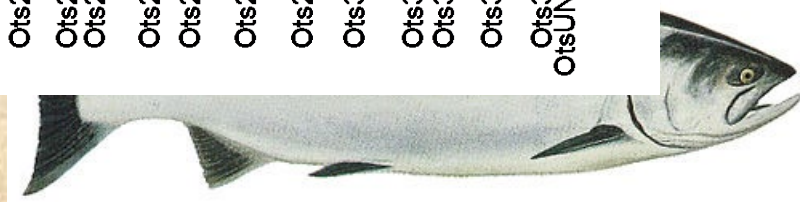
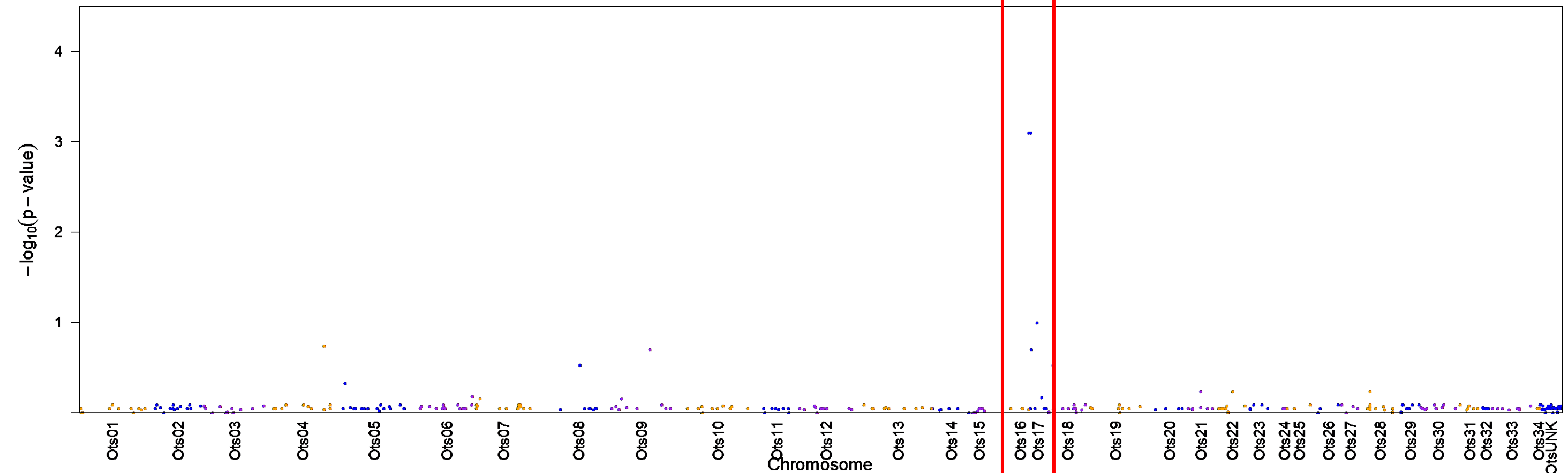
stream-
type



ocean-
type
FALL

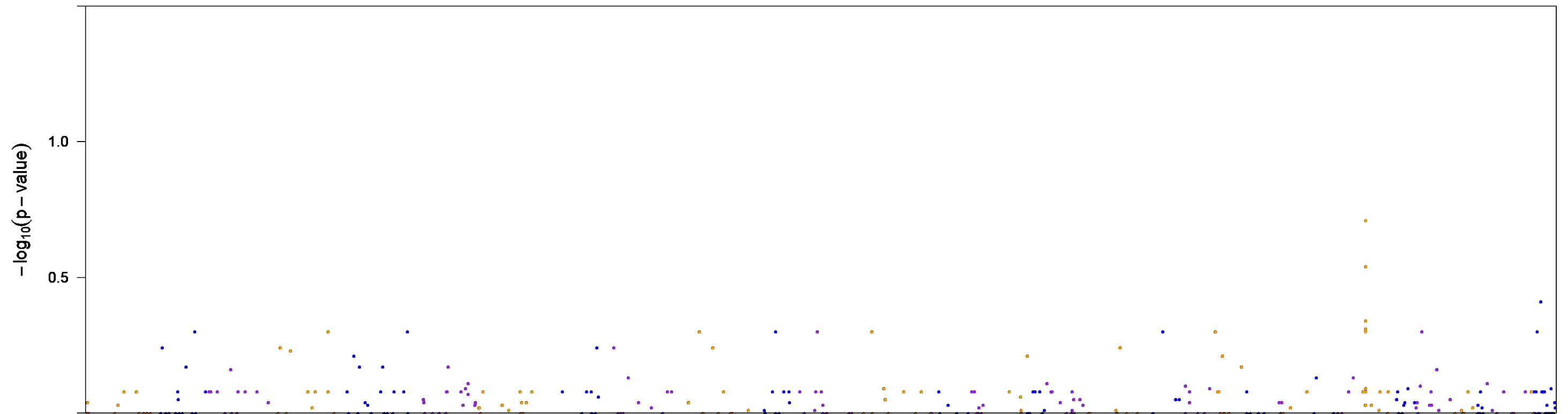


ocean-
type
SUMMER

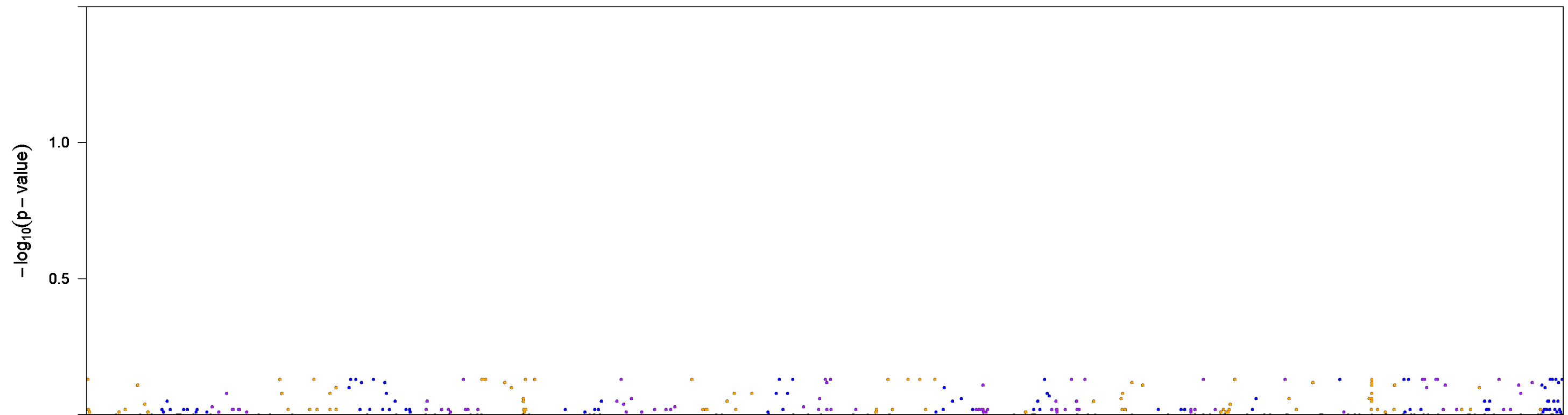


females

stream-
type



ocean-
type
FALL



ocean-
type
SUMMER

