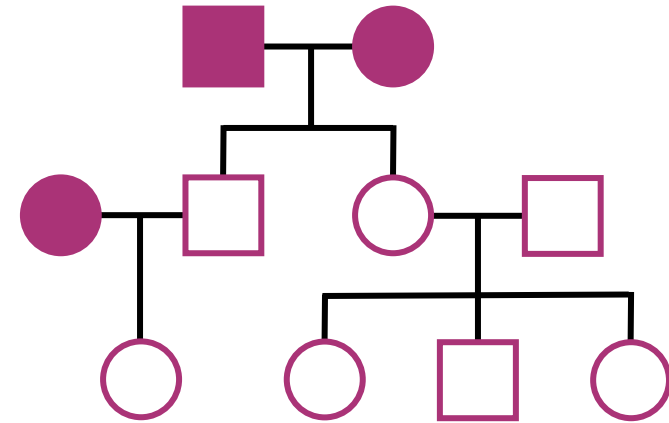
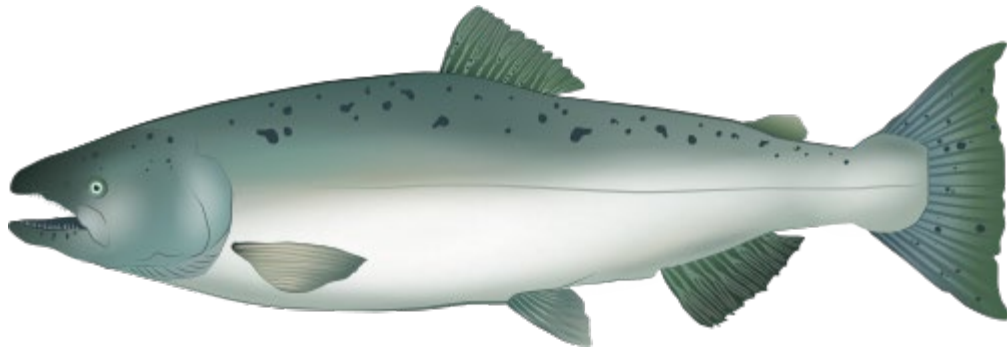


Evaluating Spring Chinook Salmon Releases above Cougar Dam, on the South Fork McKenzie River, Using Genetic Parentage Analysis



David I. Dayan¹, Cristín K. Fitzpatrick¹, Ryan Couture², Kathleen G. O'Malley¹

¹State Fisheries Genomics Lab, Coastal Oregon Marine Experiment Station, Department of Fisheries, Wildlife and Conservation Sciences, Oregon State University, Newport, Oregon

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Hatcheries and Dams

-123.000

-122.800

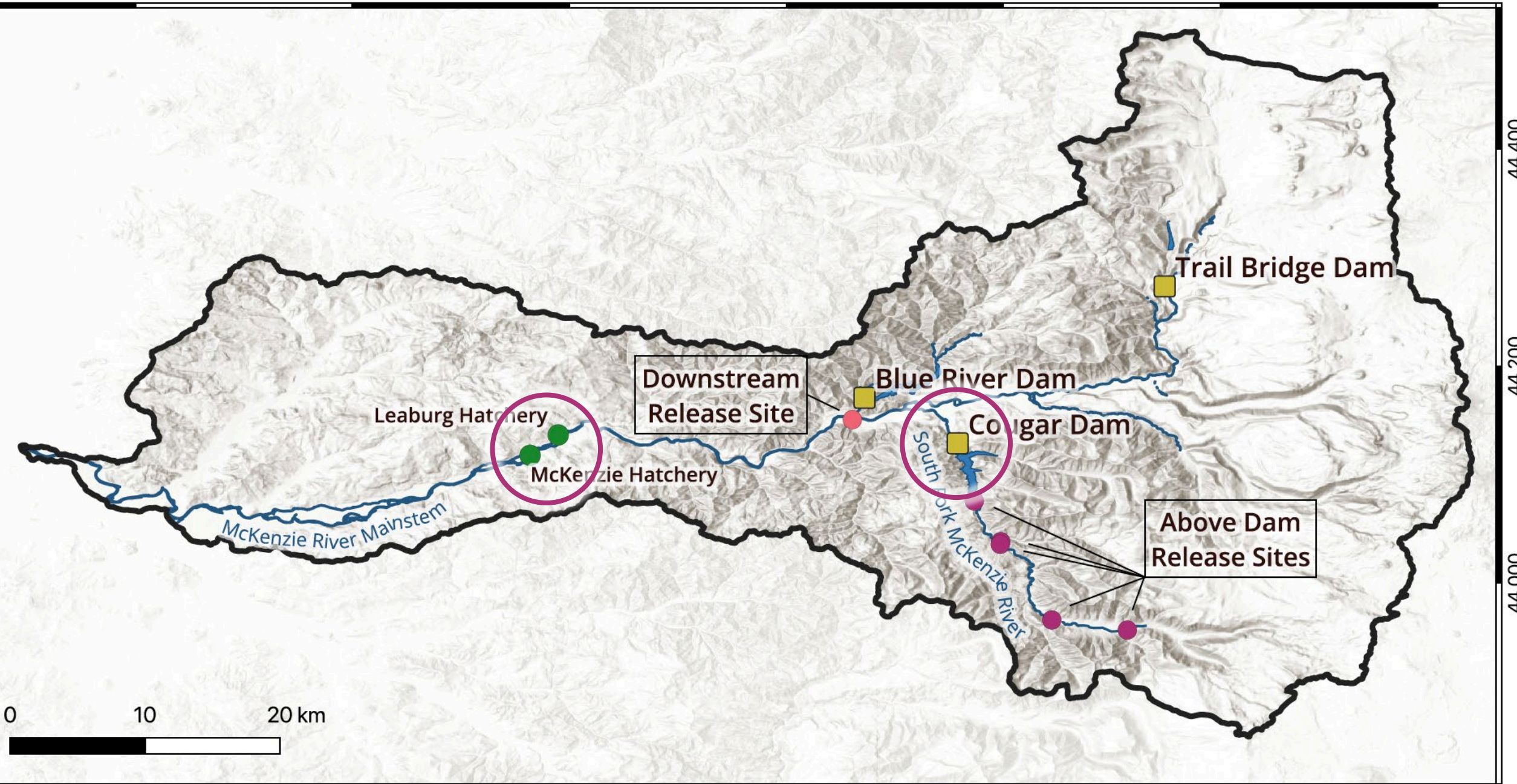
-122.600

-122.400

-122.200

-122.000

-121.800



44.400

44.200

44.000

0 10 20 km



Leaburg Hatchery

McKenzie Hatchery

Downstream
Release Site

Blue River Dam

Cougar Dam

Above Dam
Release Sites

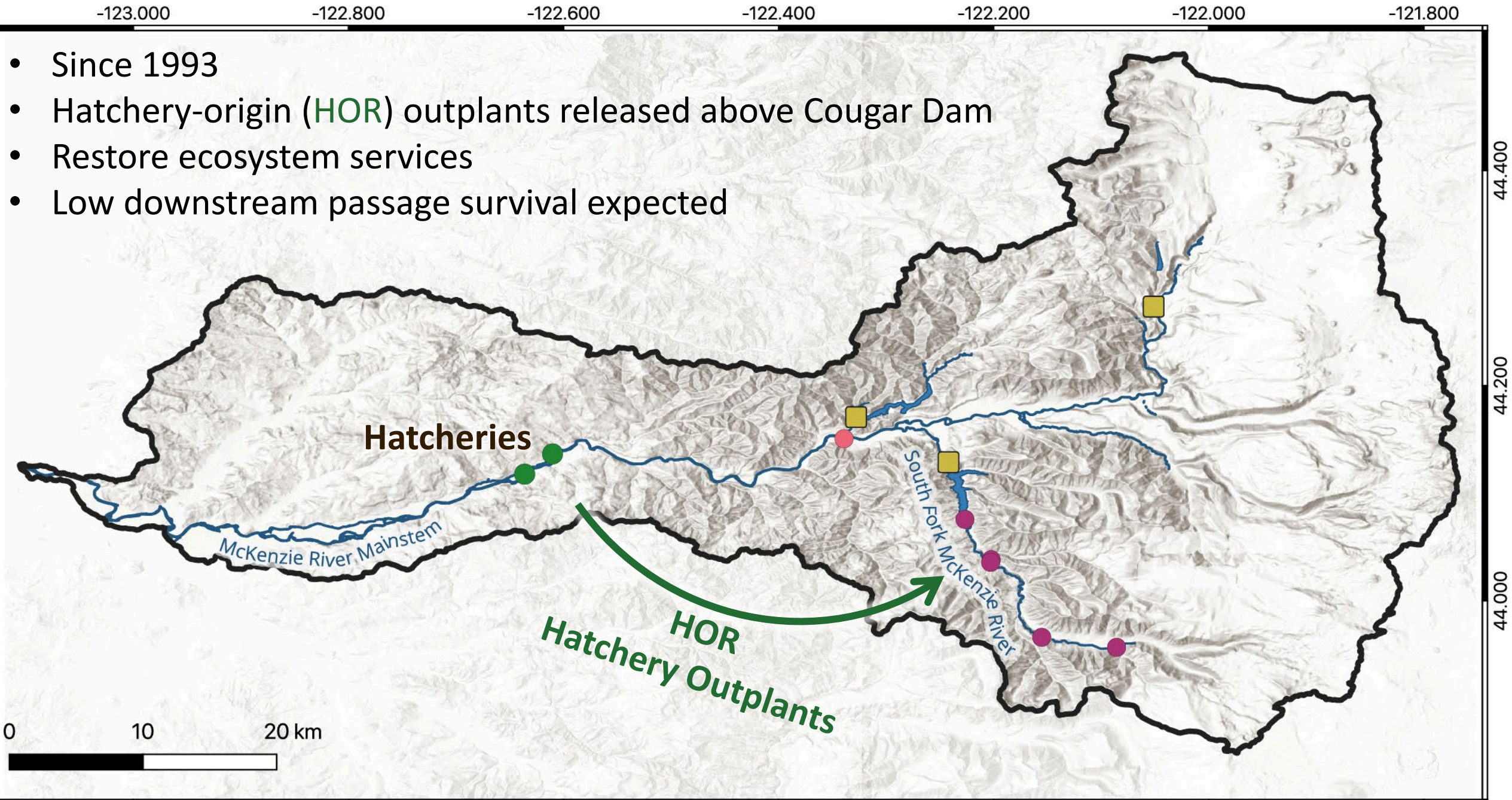
Trail Bridge Dam

McKenzie River Mainstem

South Fork
McKenzie River

Hatchery Outplants

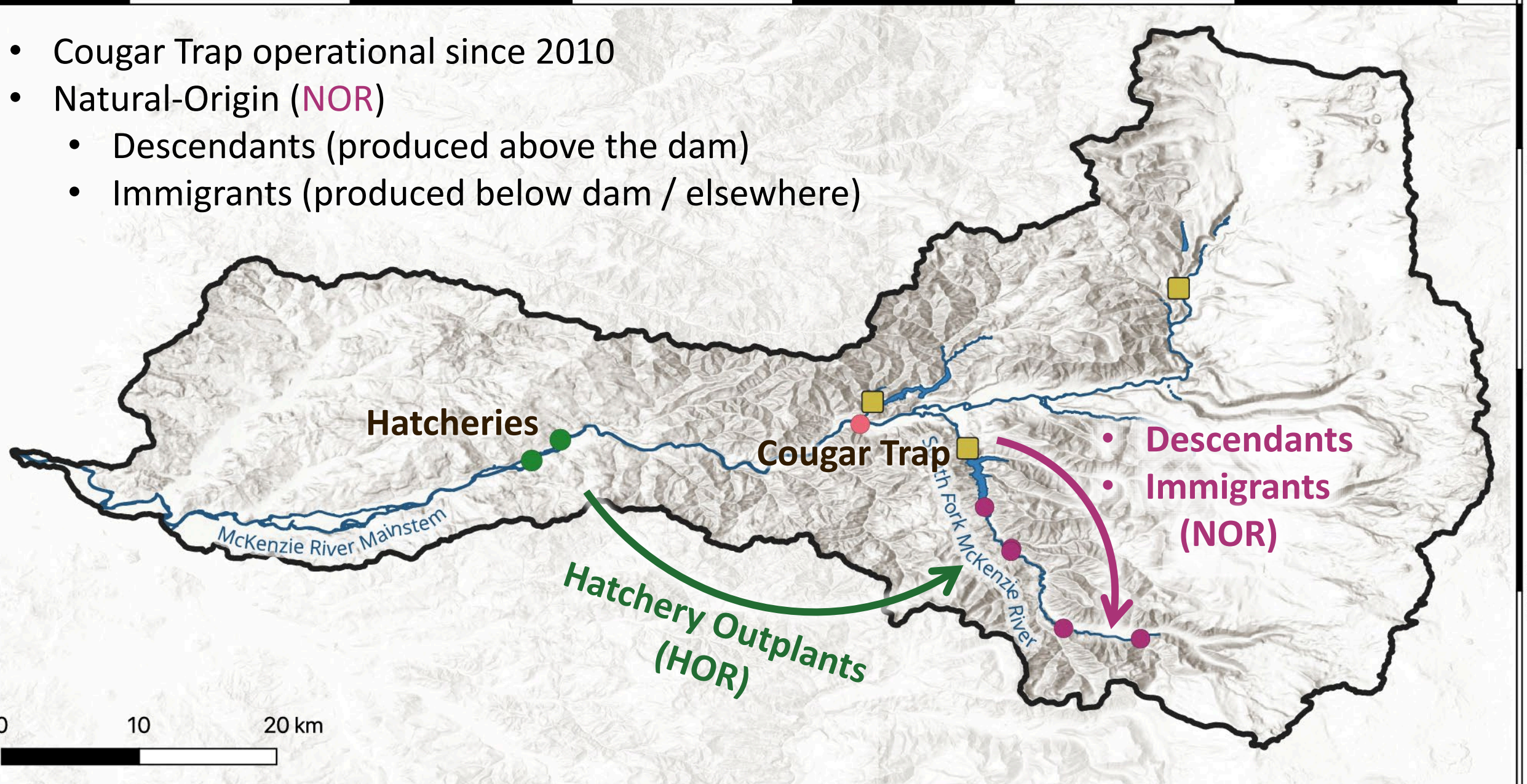
- Since 1993
- Hatchery-origin (**HOR**) outplants released above Cougar Dam
- Restore ecosystem services
- Low downstream passage survival expected



Cougar Trap NORs

-123.000 -122.800 -122.600 -122.400 -122.200 -122.000 -121.800

- Cougar Trap operational since 2010
- Natural-Origin (NOR)
 - Descendants (produced above the dam)
 - Immigrants (produced below dam / elsewhere)



Hatcheries

Cougar Trap

• Descendants
• Immigrants
(NOR)

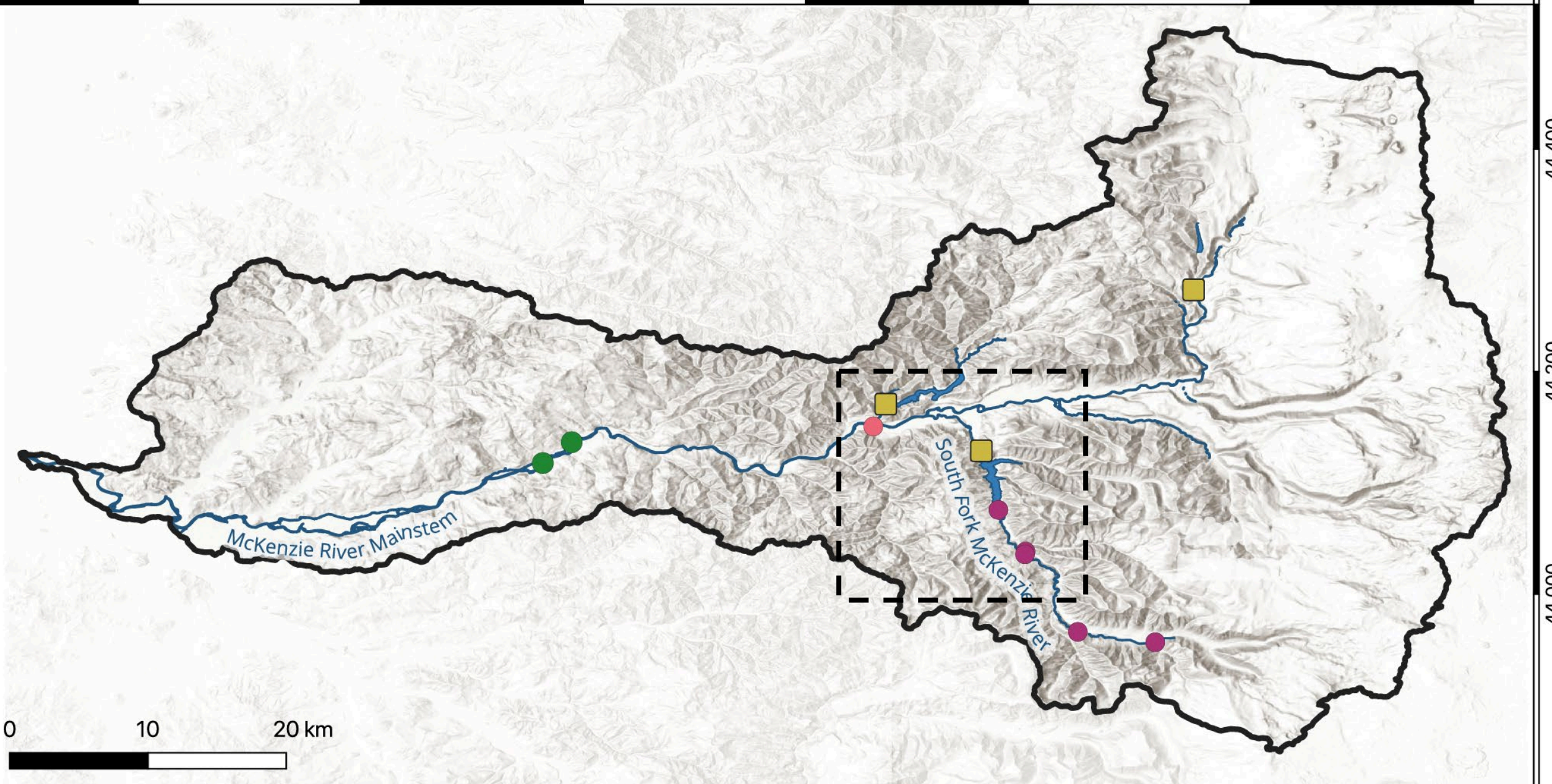
Hatchery Outplants
(HOR)

0 10 20 km

44.400
44.200
44.000

Cougar Trap NORs

-123.000 -122.800 -122.600 -122.400 -122.200 -122.000 -121.800



44.400

44.200

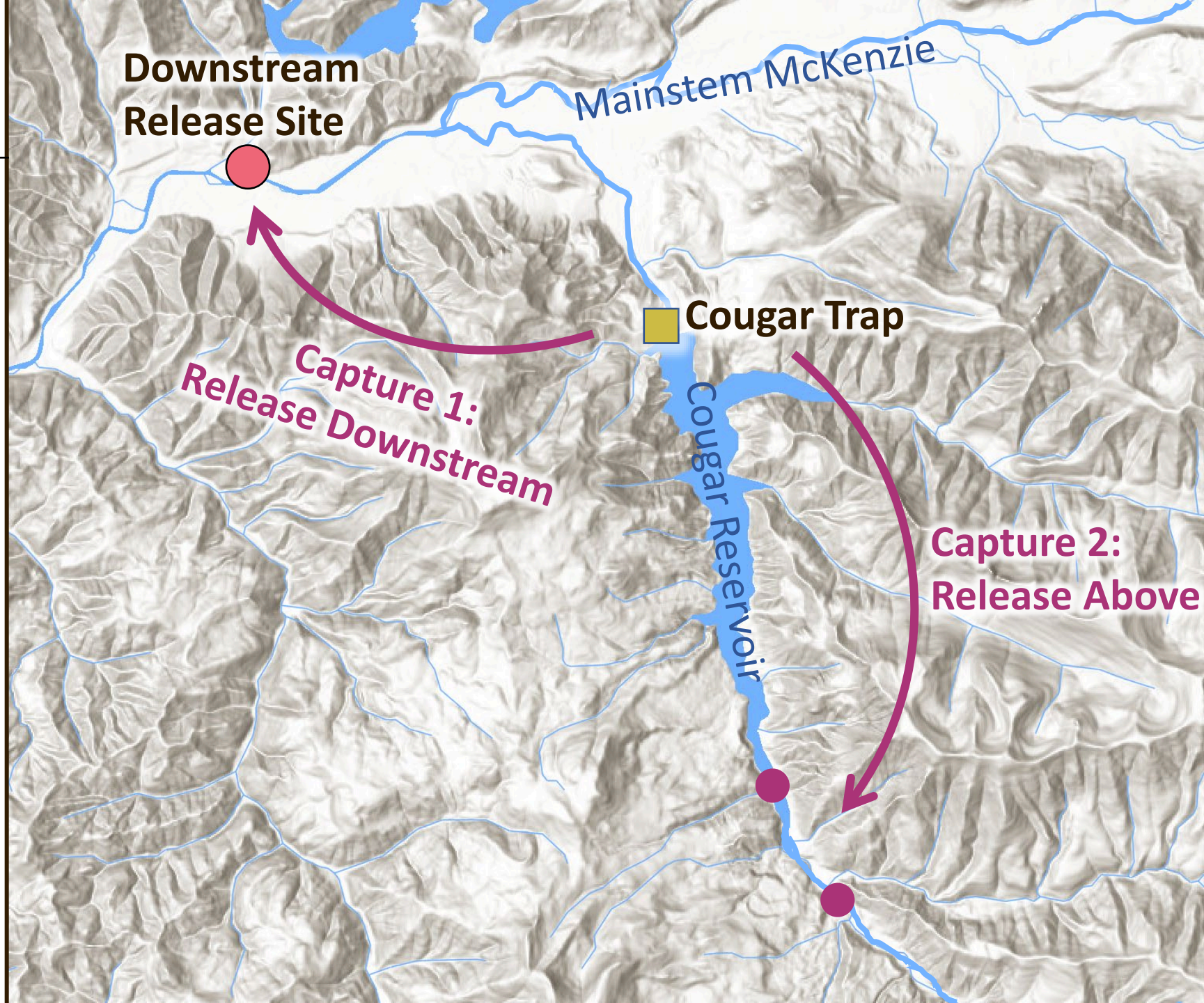
44.000

0 10 20 km

Introduction

Downstream Recycling

- Control where NORs collected at trap are eventually released (disposition)
- Downstream Recycling
 - All NORs recycled
 - 2015 – 2020
- Late Season Downstream Release (LSDR)
 - NORs collected after September 1 recycled
 - 2013 – 2014



Reintroduction Review

-123.000

-122.800

-122.600

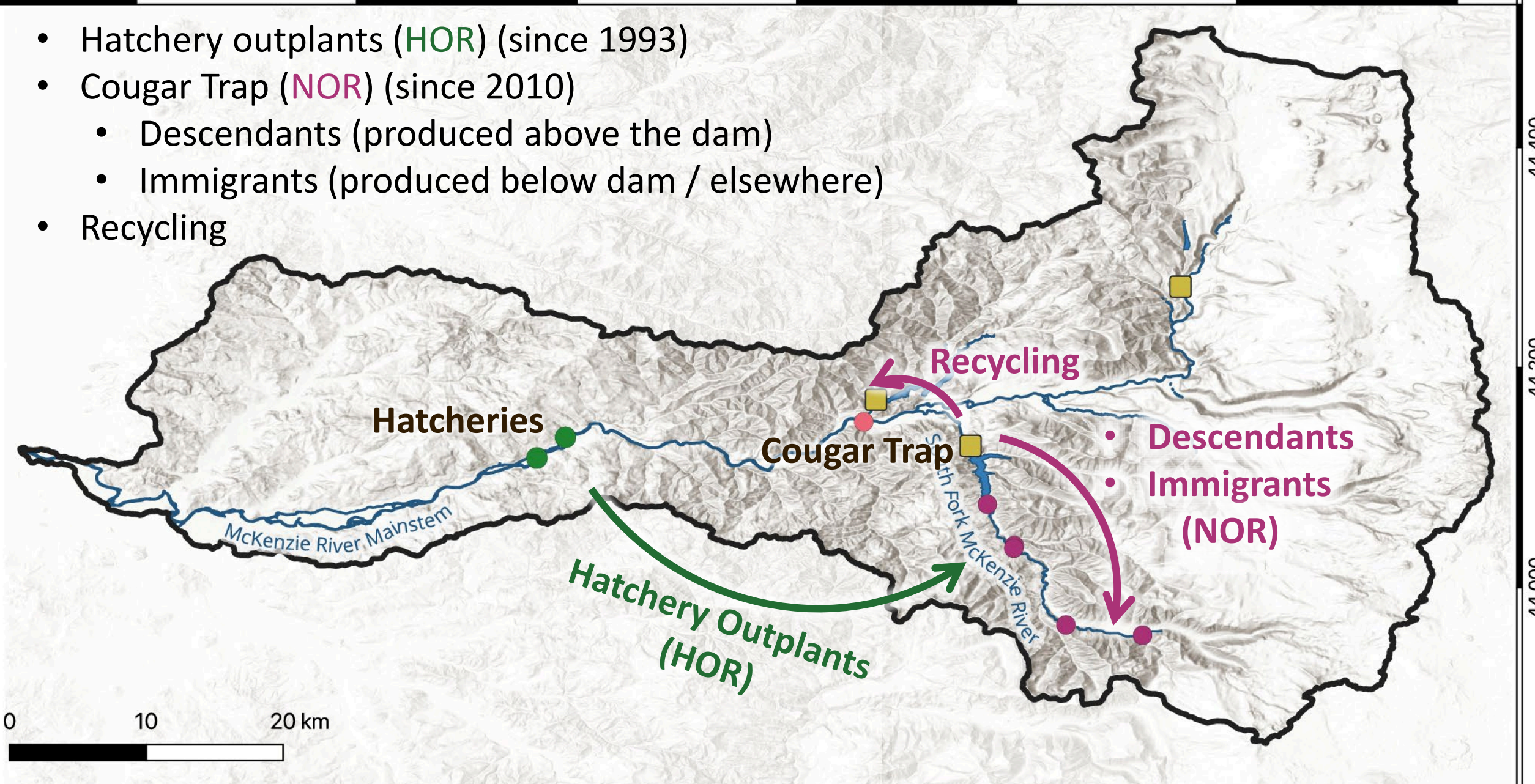
-122.400

-122.200

-122.000

-121.800

- Hatchery outplants (**HOR**) (since 1993)
- Cougar Trap (**NOR**) (since 2010)
 - Descendants (produced above the dam)
 - Immigrants (produced below dam / elsewhere)
- Recycling



44.400

44.200

44.000

0 10 20 km

Introduction

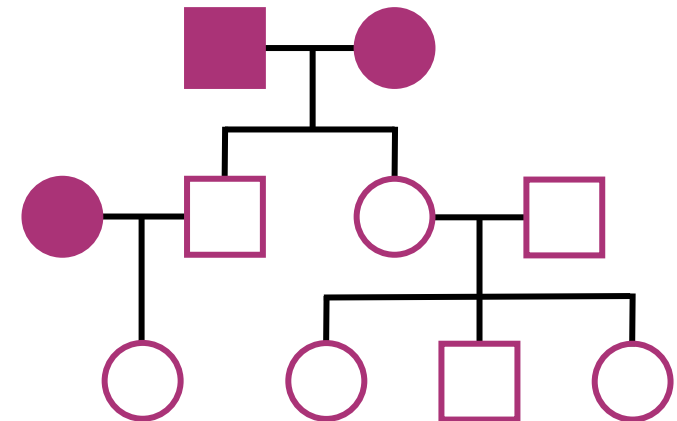
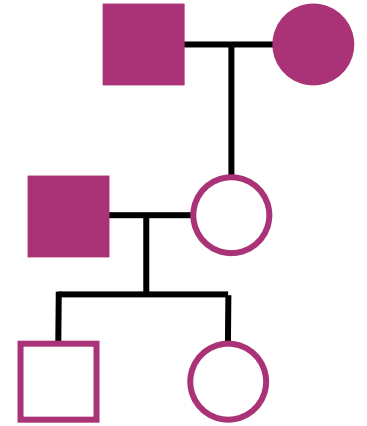
Methods and Objectives

Objectives

- Cohort Replacement Rate (CRR)
- Identify Predictors of Fitness (particular focus on origin)
- NOR salmon at Cougar Trap: Immigrants or Descendants?
- Recycling Effects on NORs

Pedigree

- All candidate parents (released above dam) 2007 – 2017
- All *potential* adult offspring (NORs collected at trap) 2010 – 2020



Cohort Replacement Rate

For each salmon put above the dam, how many adult offspring come back?

$$\text{CRR} = \frac{n_{\text{offspring}}}{n_{\text{parents}}}$$

CRR > 1 : Net Population Growth, Viability

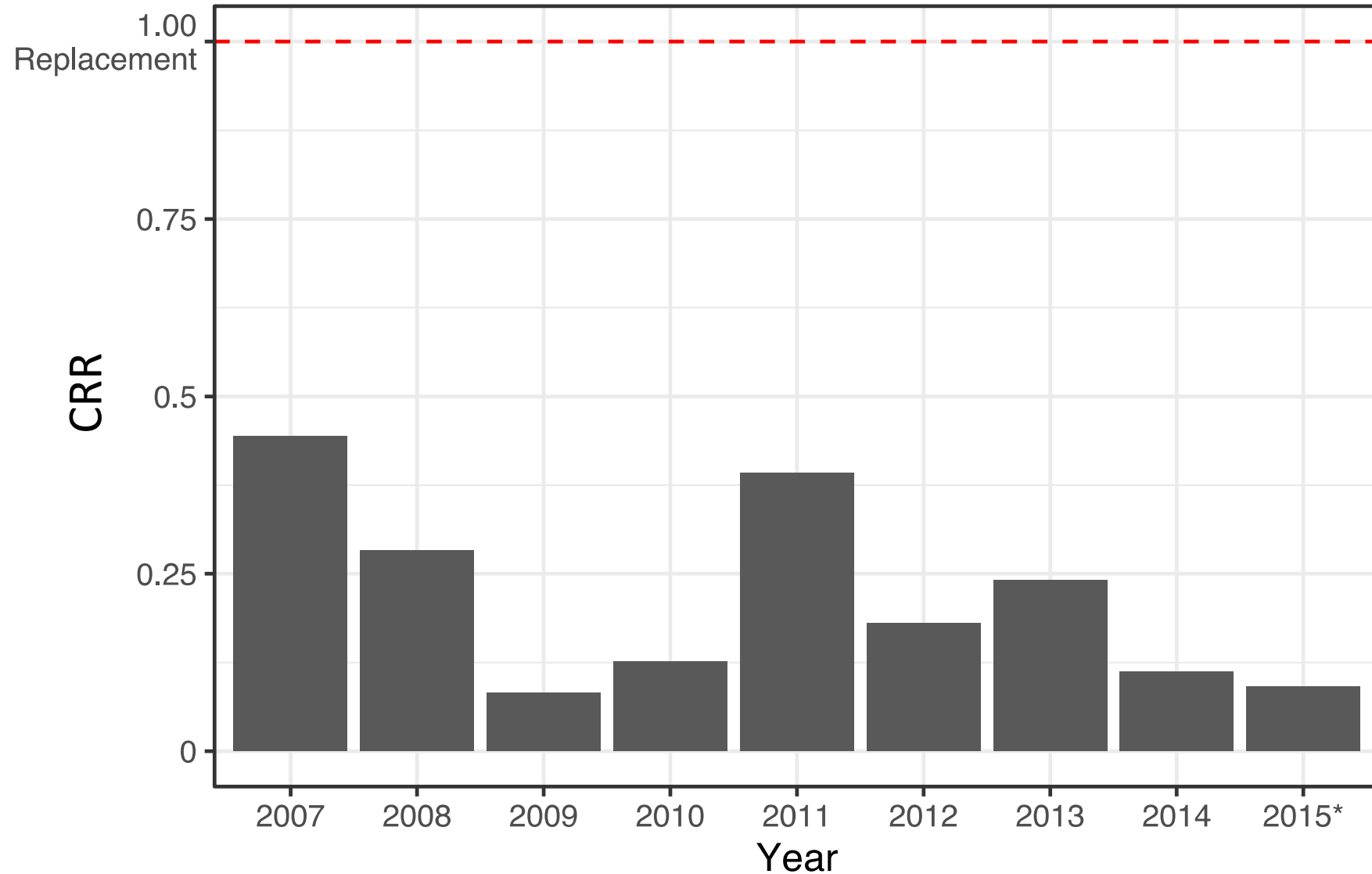
CRR < 1: Net Population Decline, Non-viable (without continued supplementation)

Cohort Replacement Rate

- $CRR = \frac{n_{offspring}}{n_{parents}}$

- CRR never approached one

- Population above the dam is not replacing itself



Predictors of Fitness

Question

What explains variation in productivity among parents?

Predictors of Fitness

Model Selection

Generalized Linear Mixed Model 9 years (2007 - 2015)

Response Variable

Total Lifetime Fitness (TLF):
Adult offspring per individual parent
 $n = 7,063$



Fixed Effects

- *sex*
- *origin (NOR vs HOR)*
- *release day*
- *release location*
- *release group density*
- *release group sex ratio*
- *annual sex ratio*
- *sex*release day*
- *sex*origin*
- *sex*annual sex ratio*

Random Effects

- *release group*
- *year*

Predictors of Fitness

Model Selection

Generalized Linear Mixed Model 9 years (2007 - 2015)

Fixed effects	β	s.e.	LRT p-value	Wald p-value
(Intercept)	-1.343	0.208		
<i>sex</i> [male]	-0.150	0.082		0.066
<i>origin</i> [NOR]	0.446	0.132		0.001
<i>Julian Day of release</i>	-0.004	0.001	0.004	0.003
<i>annual sex ratio</i>	1.042	0.501		0.038
<i>sex</i> [male] * <i>origin</i> [NOR]	0.293	0.142	0.039	0.039
<i>sex</i> [male] * <i>annual sex ratio</i>	-0.750	0.177	<0.001	<0.001
Random effects	σ^2	s.d.		
<i>year</i>	0.306	0.553		
<i>release group</i>	0.085	0.292		

Fixed Effects

- *sex*
- *origin (NOR vs HOR)*
- *release day*
- *release location*
- *release group density*
- *release group sex ratio*
- *annual sex ratio*
- *sex*release day*
- *sex*origin*
- *sex*annual sex ratio*

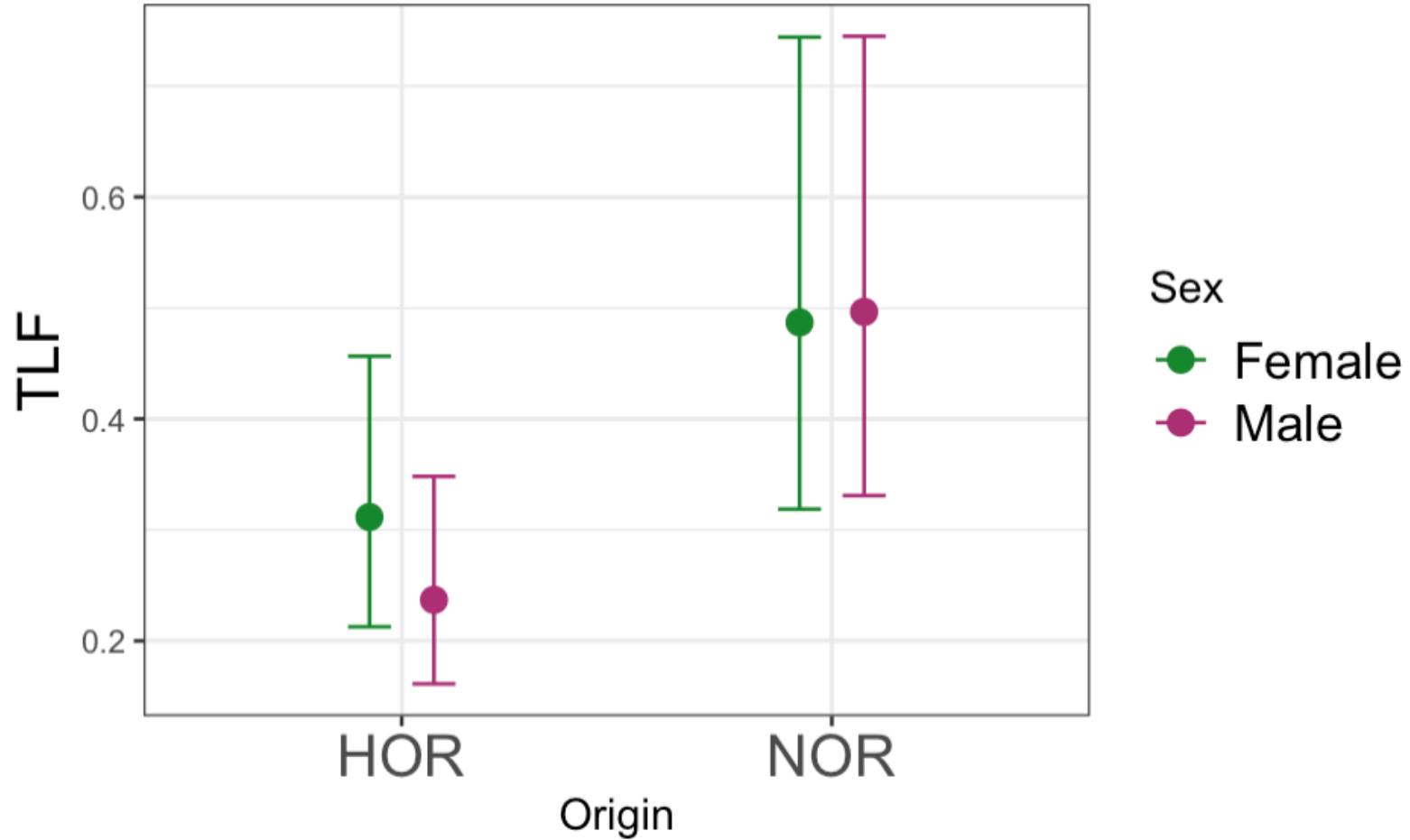
Random Effects

- *release group*
- *year*

Predictors of Fitness

Predicted Effects: Sex*Origin

- Males
 - NORs 2.1–fold more offspring than HORs
- Females
 - NORs 1.6–fold more offspring than HORs

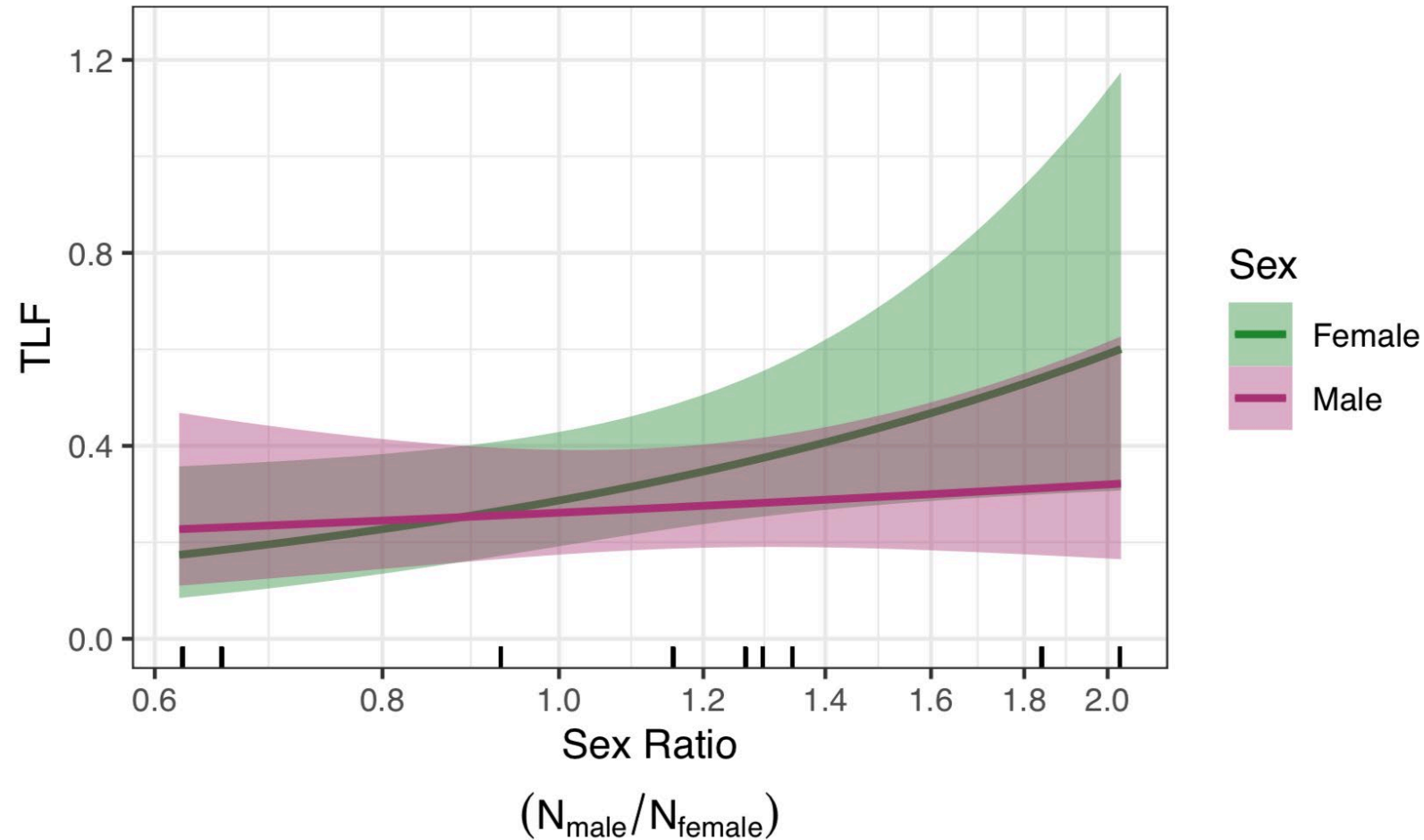


- Origin p-value = 0.001 (Wald test)
- Sex*Origin p-value = 0.039 (Wald Test)

Predictors of Fitness

Predicted Effects: Sex*Annual Sex Ratio

- Annual sex ratio: $N_{\text{males}} / N_{\text{females}}$
- Males
 - Little Effect
- Females
 - Fitness decrease under strong female biased sex ratio

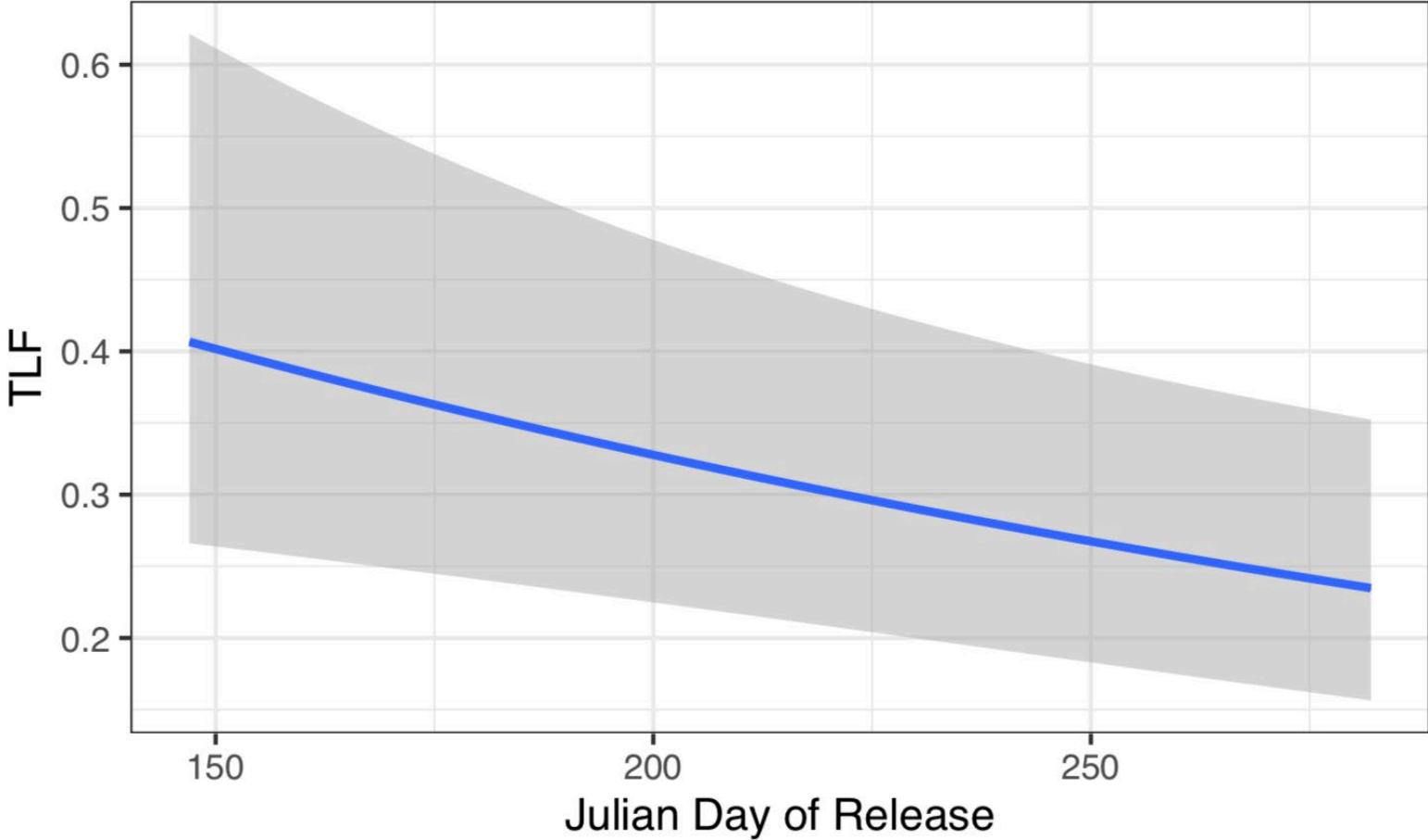


- Annual sex ratio p-value = 0.038 (Wald test)
- Sex*annual sex ratio p-value = <0.001 (Wald Test)

Predictors of Fitness

Predicted Effects: Release Day

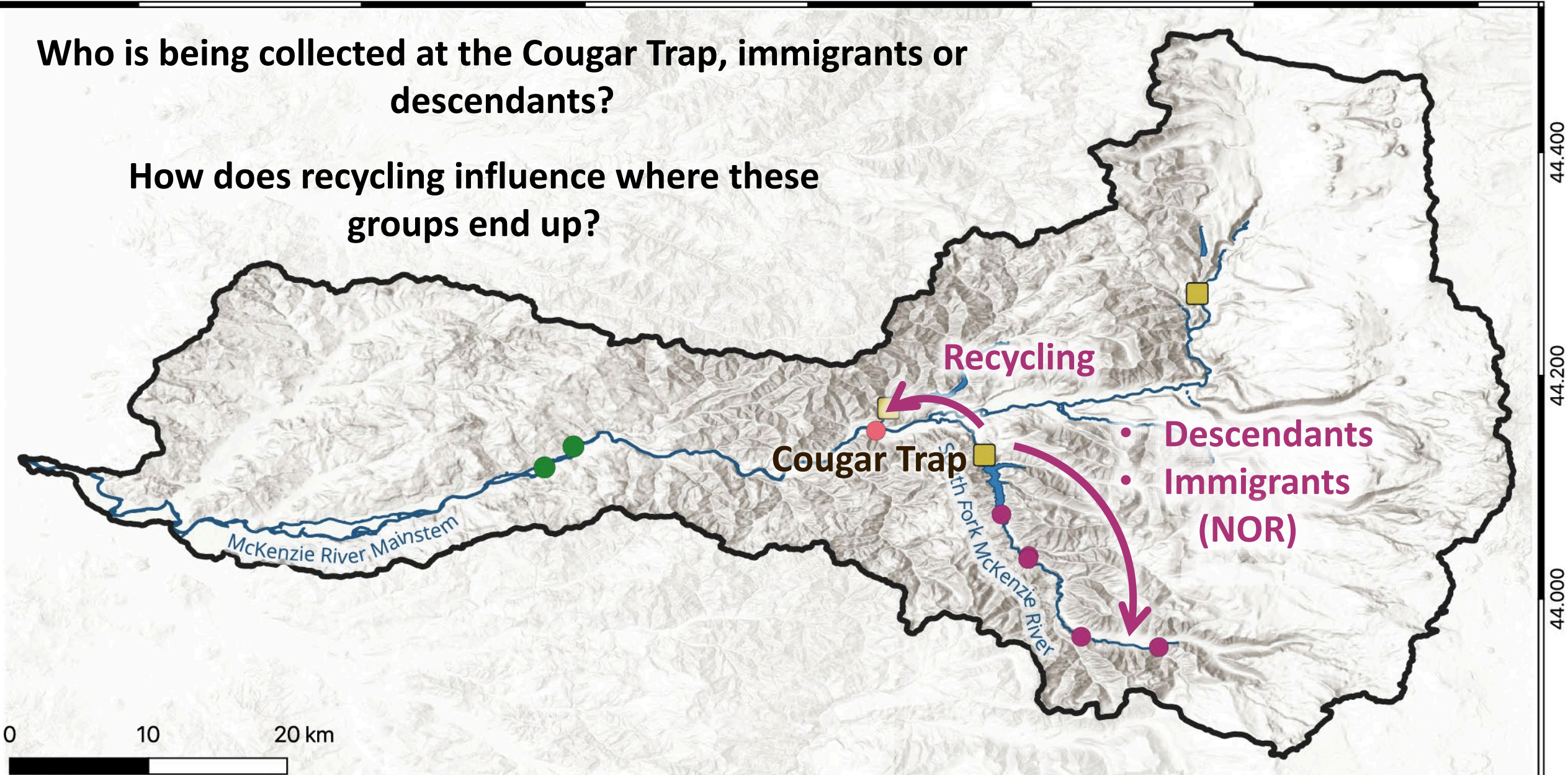
Earlier Release: More Offspring



Assignments

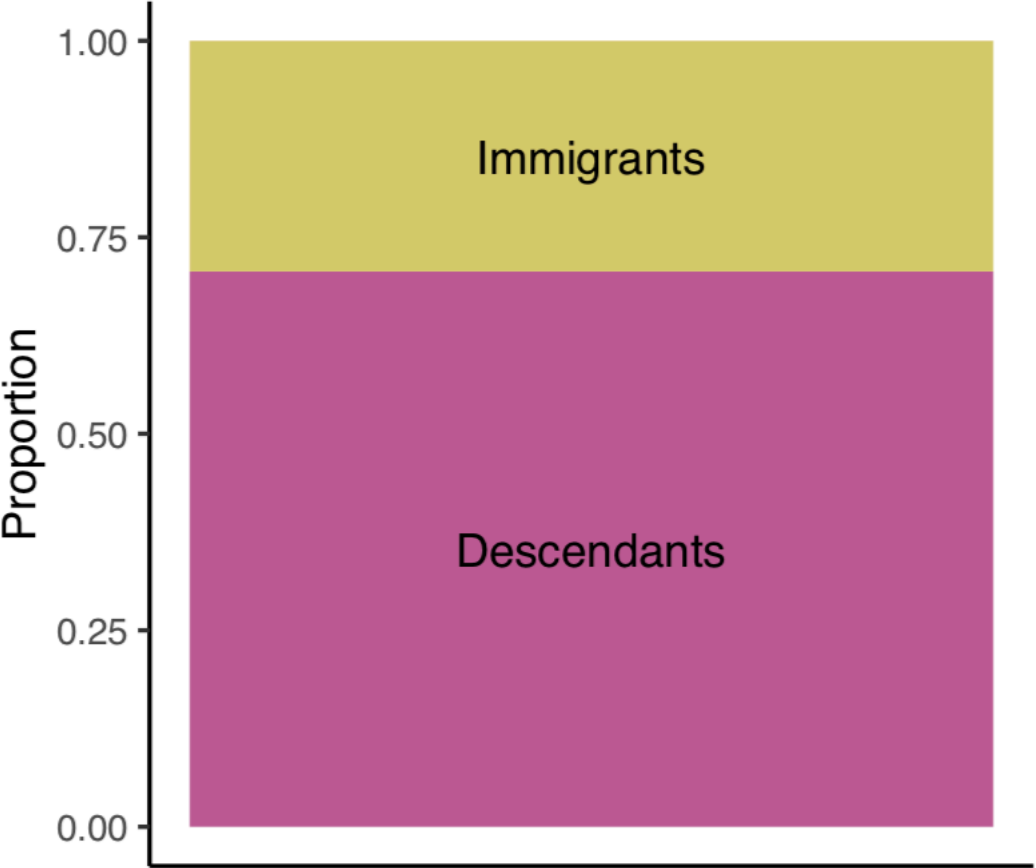
Who is being collected at the Cougar Trap, immigrants or descendants?

How does recycling influence where these groups end up?



Assignments

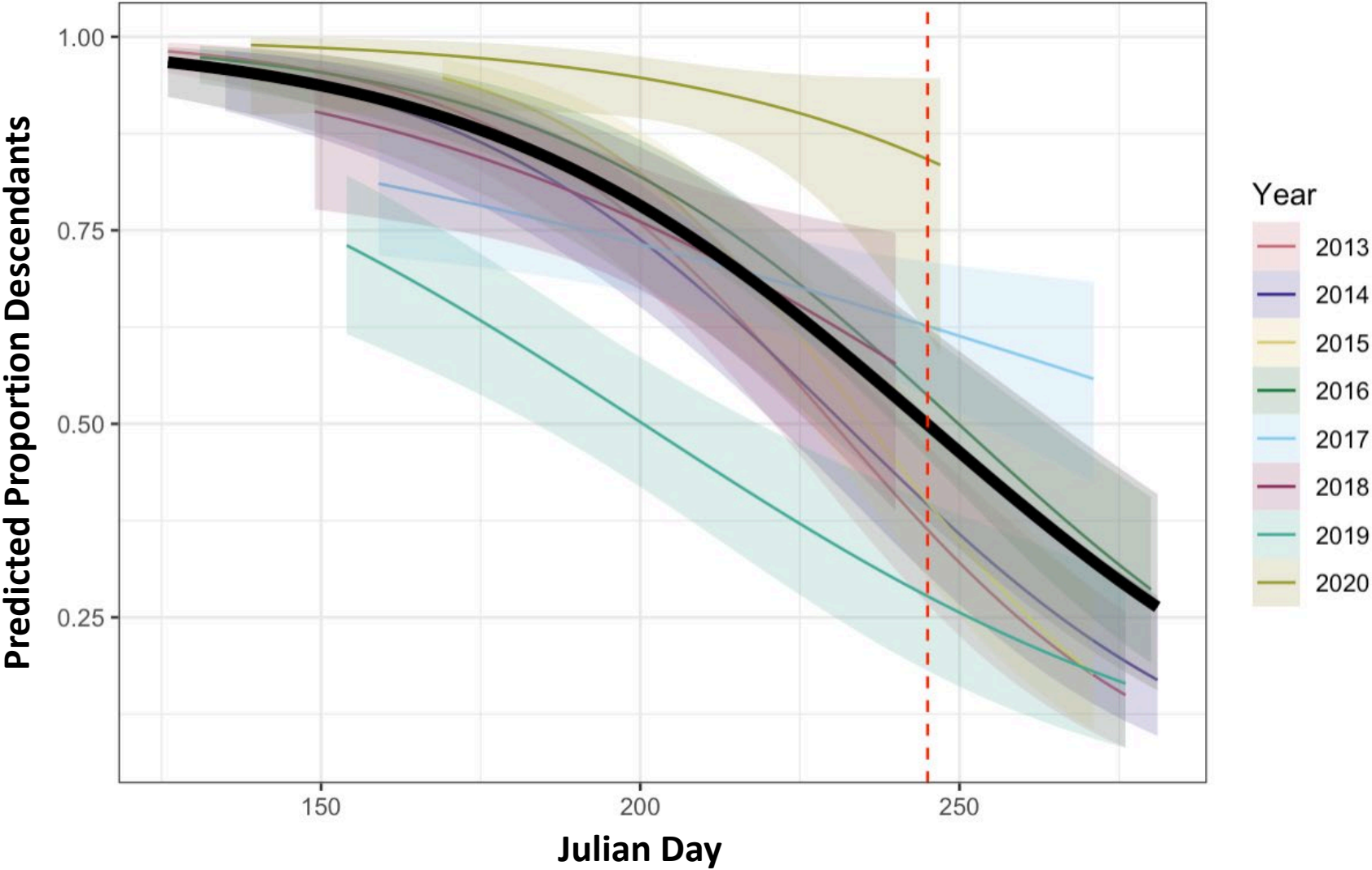
Immigrants and Descendants



71% of NOR salmon at Cougar Trap are descendants

Assignments

Immigrants and Descendants



- 95% descendants early in the season
- ~50% by September 1st

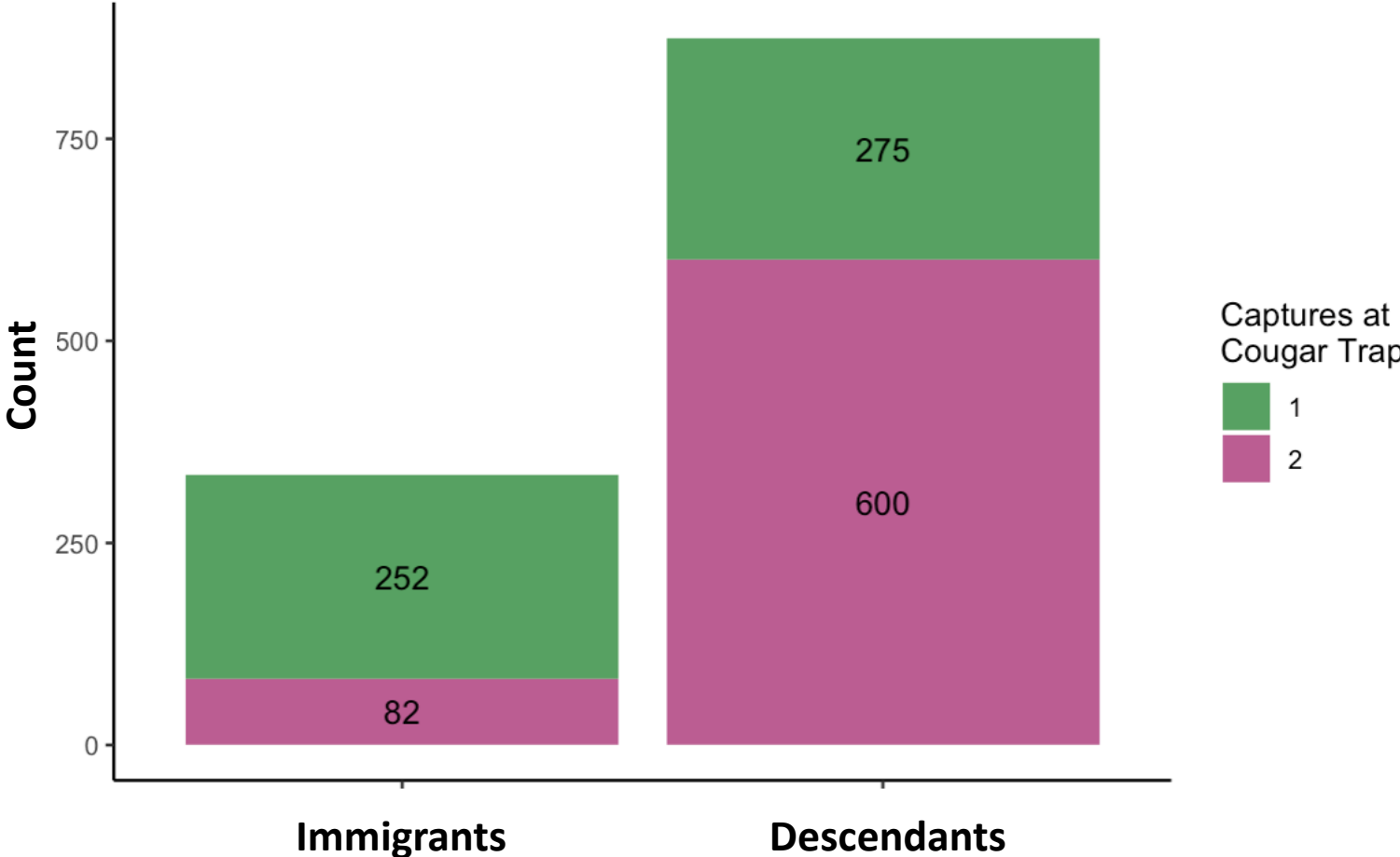
Assignments

Evaluating Recycling Program

Downstream Recycling

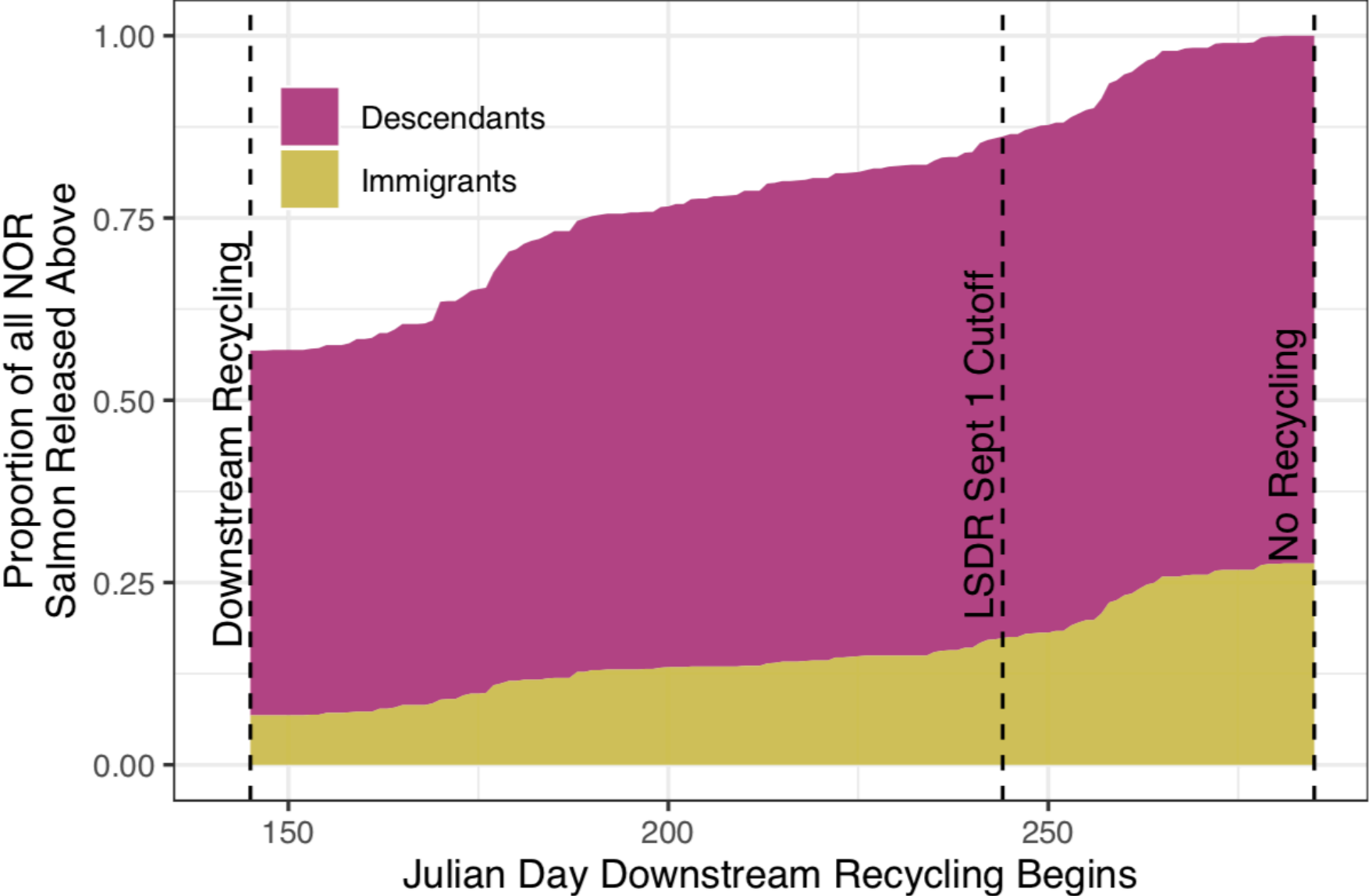
(all NORs recycled, regardless of date)

- Migration delayed by 31 days
 - 12% Reduction in TLF
- Descendants were 6.8 times more likely to return a second time than immigrants



Assignments

Evaluating Recycling Program



Downstream Recycling

- 56% NORs overall
- 12% of which are immigrants

No Recycling

- 100% NORs overall
- 28% of which are immigrants

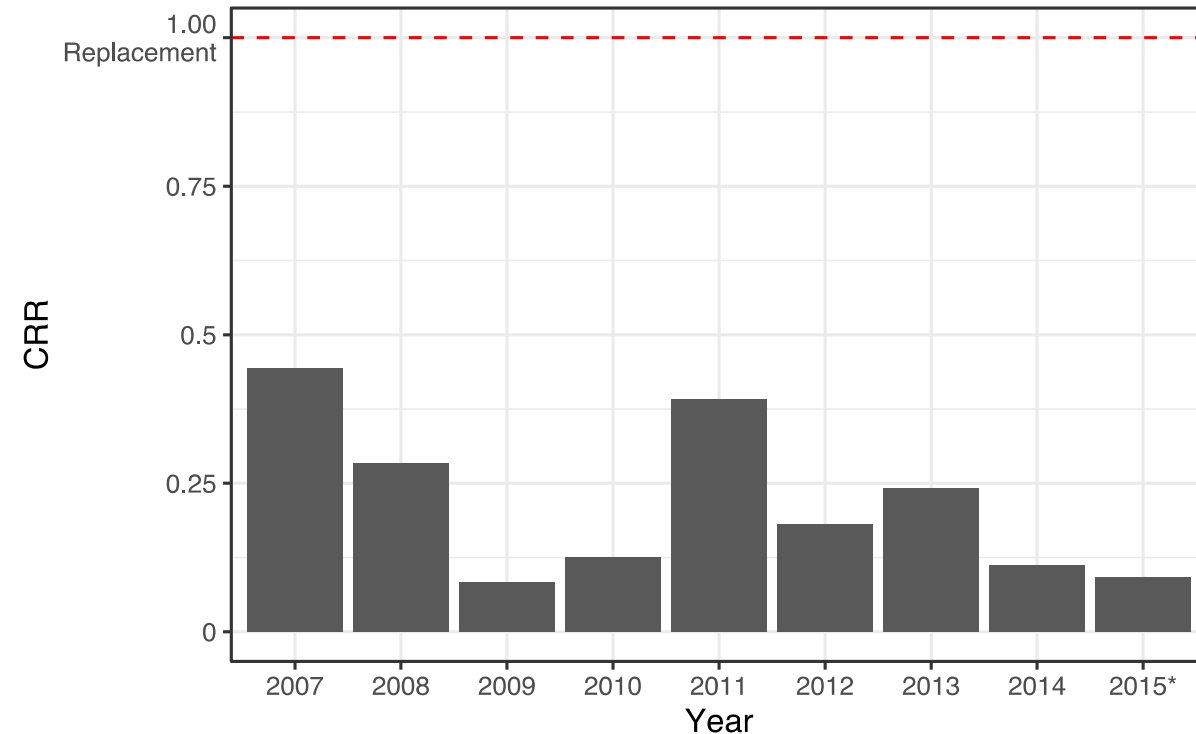
Later cutoff date to start recycling downstream

- More NORs overall
- Greater proportion immigrants

Discussion

Review

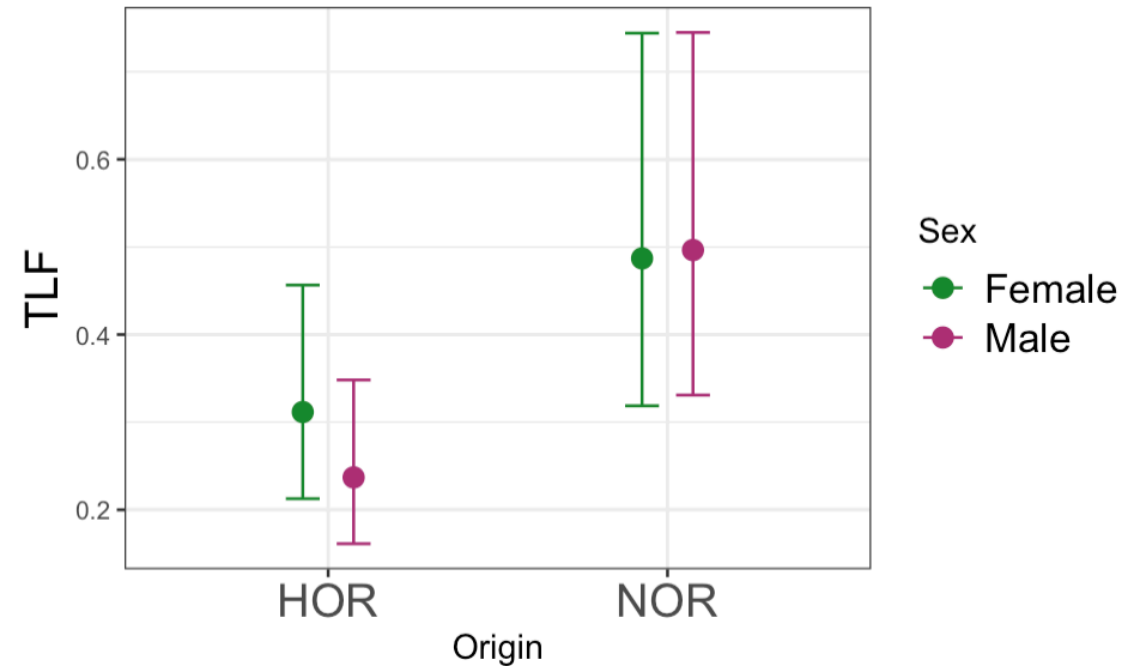
- **CRR \ll 1 above Cougar Dam**
- **NOR fitness \sim 2-fold greater than HOR fitness**
- **Descendants vs Immigrants and Recycling**
 - 71% of Cougar Trap NORs are descendants
 - Descendants
 - Arrive earlier
 - More likely to return after downstream recycling
 - Release of NORs above dam can be controlled by altering the LSDR cutoff date



Discussion

Review

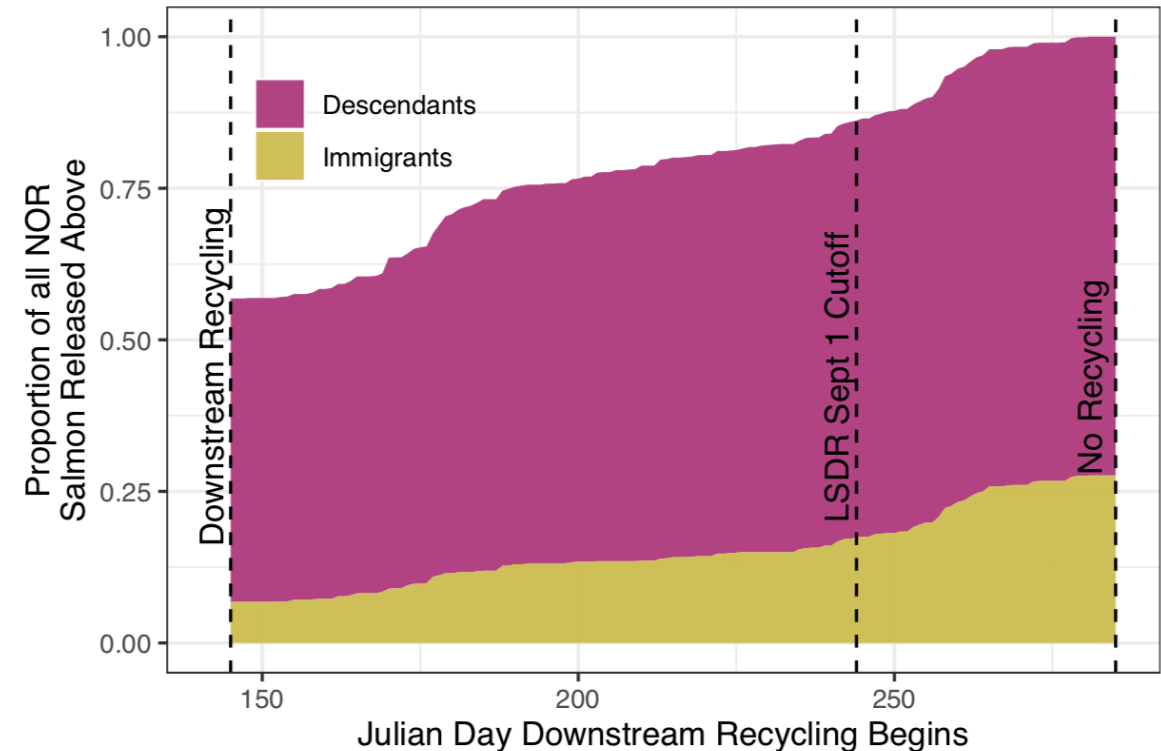
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Discussion

Review

- **CRR \ll 1 above Cougar Dam**
- **NOR fitness \sim 2-fold greater than HOR fitness**
- **Descendants vs Immigrants and Recycling**
 - 71% of Cougar Trap NORs are descendants
 - Descendants
 - Arrive earlier
 - More likely to return after downstream recycling
 - Release of NORs above dam can be controlled by altering the LSDR cutoff date



Discussion

Balancing Risks and Benefits

Effects of increased NOR above dam on natural production (implementing later cutoff date)

Broader Metapopulation: Natural production McKenzie River

South Fork McKenzie Above Dam (Sink: $CRR \ll 1$)

- Direct demographic benefits
- Local adaptation
 - Successive generations of selection (descendants)
 - Standing genetic variation (immigrants)
- NOR fitness $>$ HOR fitness
- Delayed release



South Fork McKenzie Below Dam



Mainstem McKenzie



Other Tributaries

Discussion

Balancing Risks and Benefits

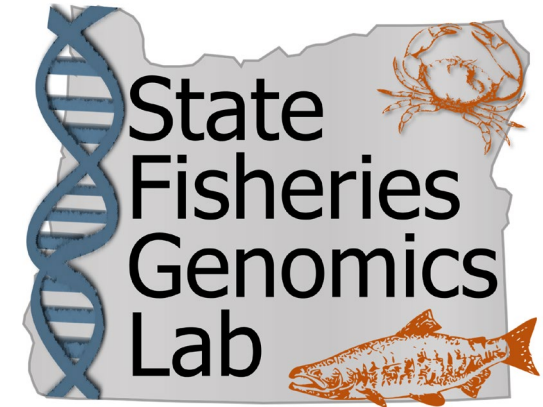
More NORs above the dam:

- Any potential benefits must be weighed against the costs of releasing NOR salmon into a strong demographic sink ($CRR \ll 1$)
- **Likely reduces natural production sub-basin wide (McKenzie River)**

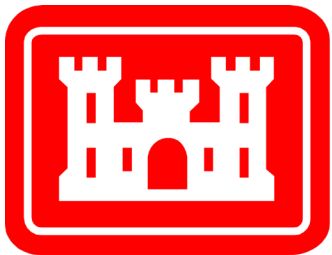
Acknowledgments



Oregon State University
**Coastal Oregon Marine
Experiment Station**



Funding

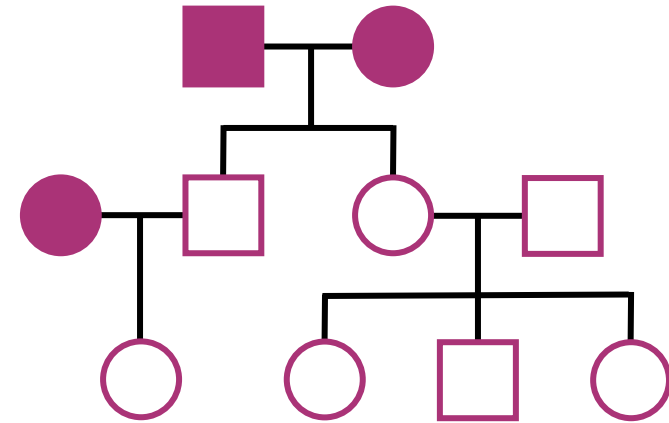
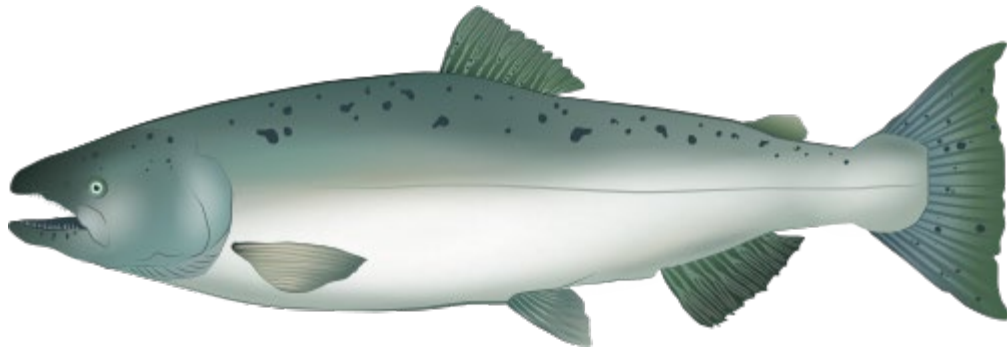


**US Army Corps
of Engineers®**

Authors of Previous Evaluations

- Nicholas M Sard, *SUNY Oswego*
- Melissa L Evans
- Michael A Banks, *Oregon State University*
- Dave P Jacobson, *Oregon State University*
- Michael Hogansen, *Oregon Department of Fish and Wildlife*
- Marc A Johnson, *Oregon Department of Fish and Wildlife*

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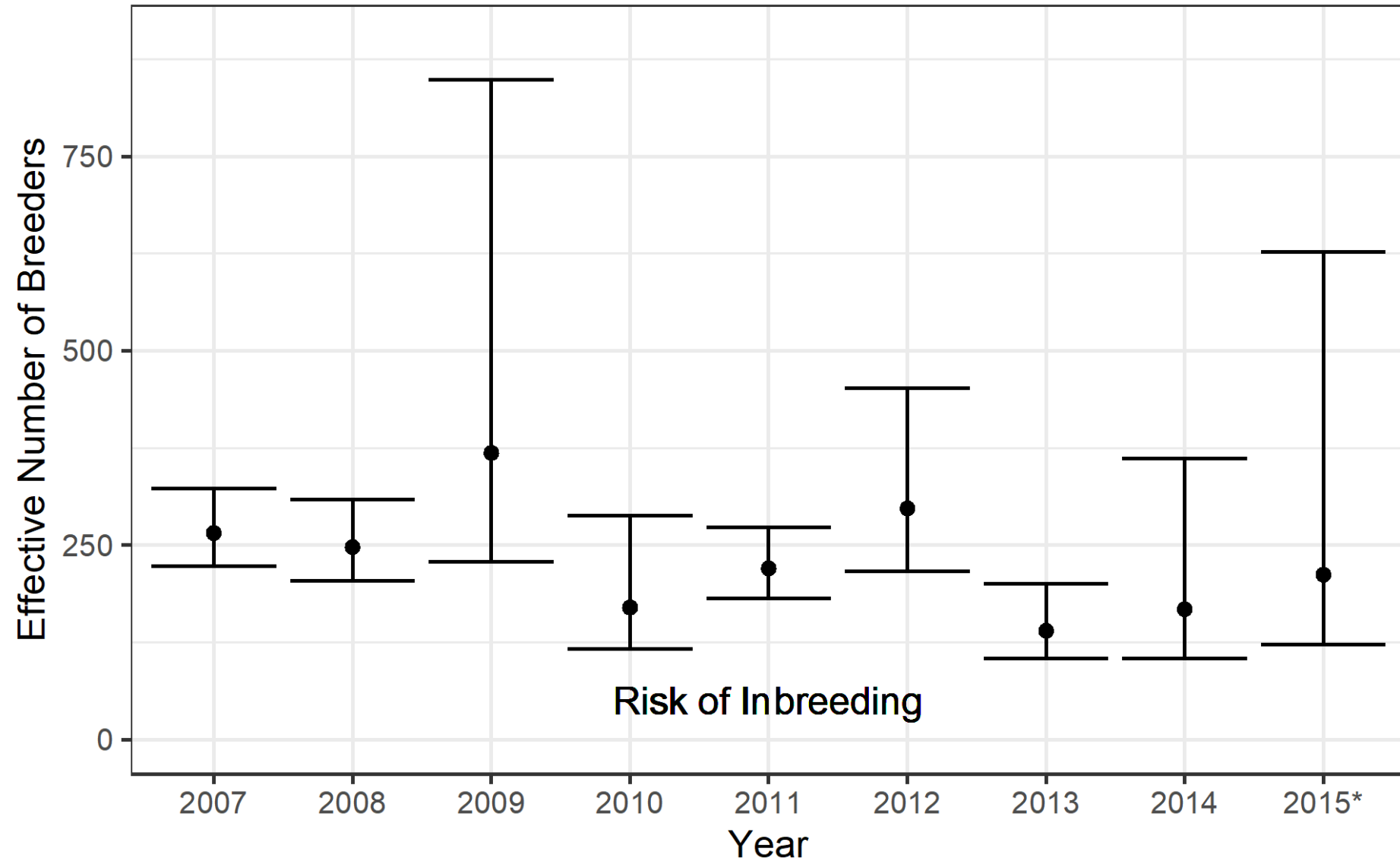
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Demography

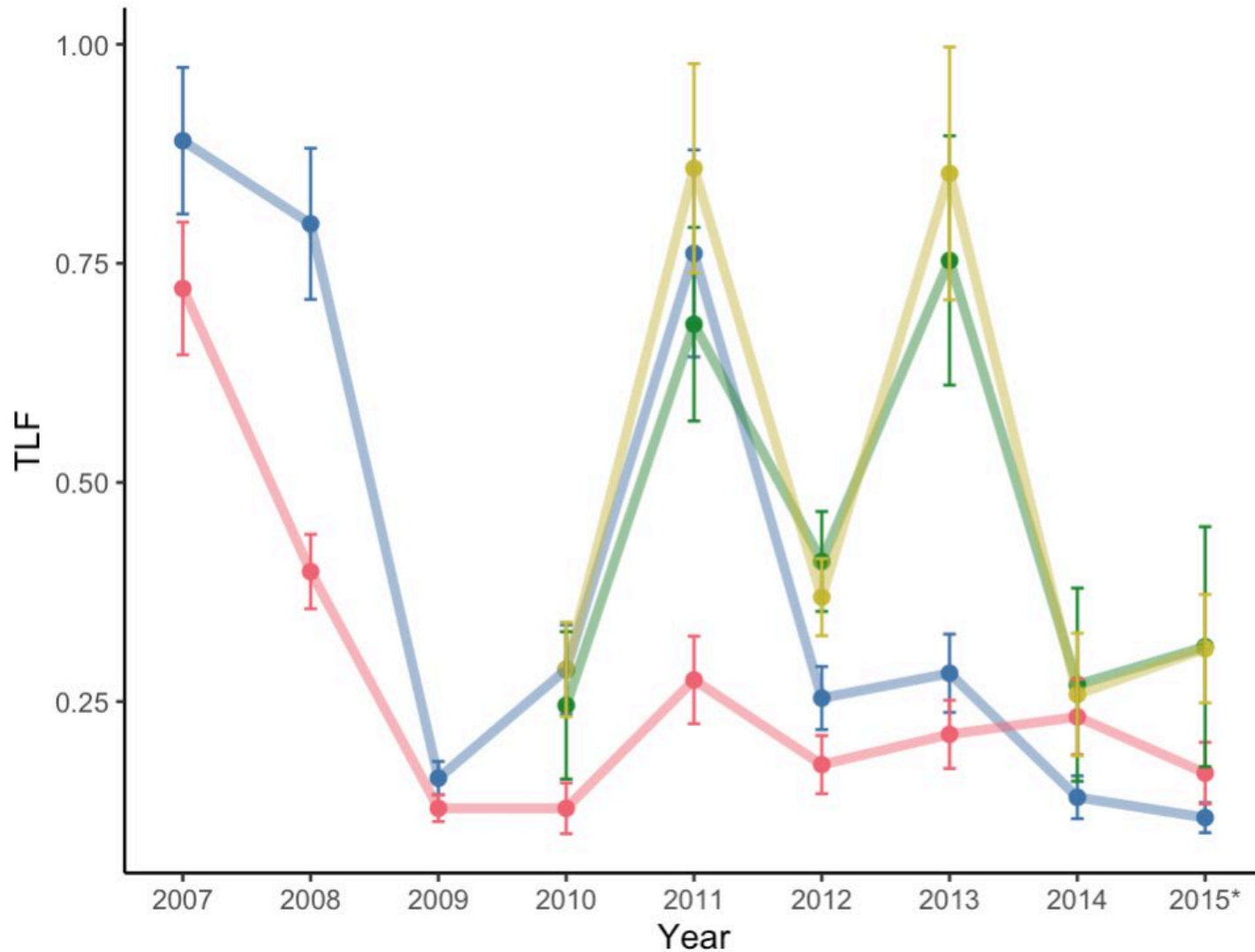
Effective Number of Breeders



- Likely sufficient genetic diversity within a parental cohort to avoid inbreeding depression.

Demography

Total Lifetime Fitness



Origin, Sex

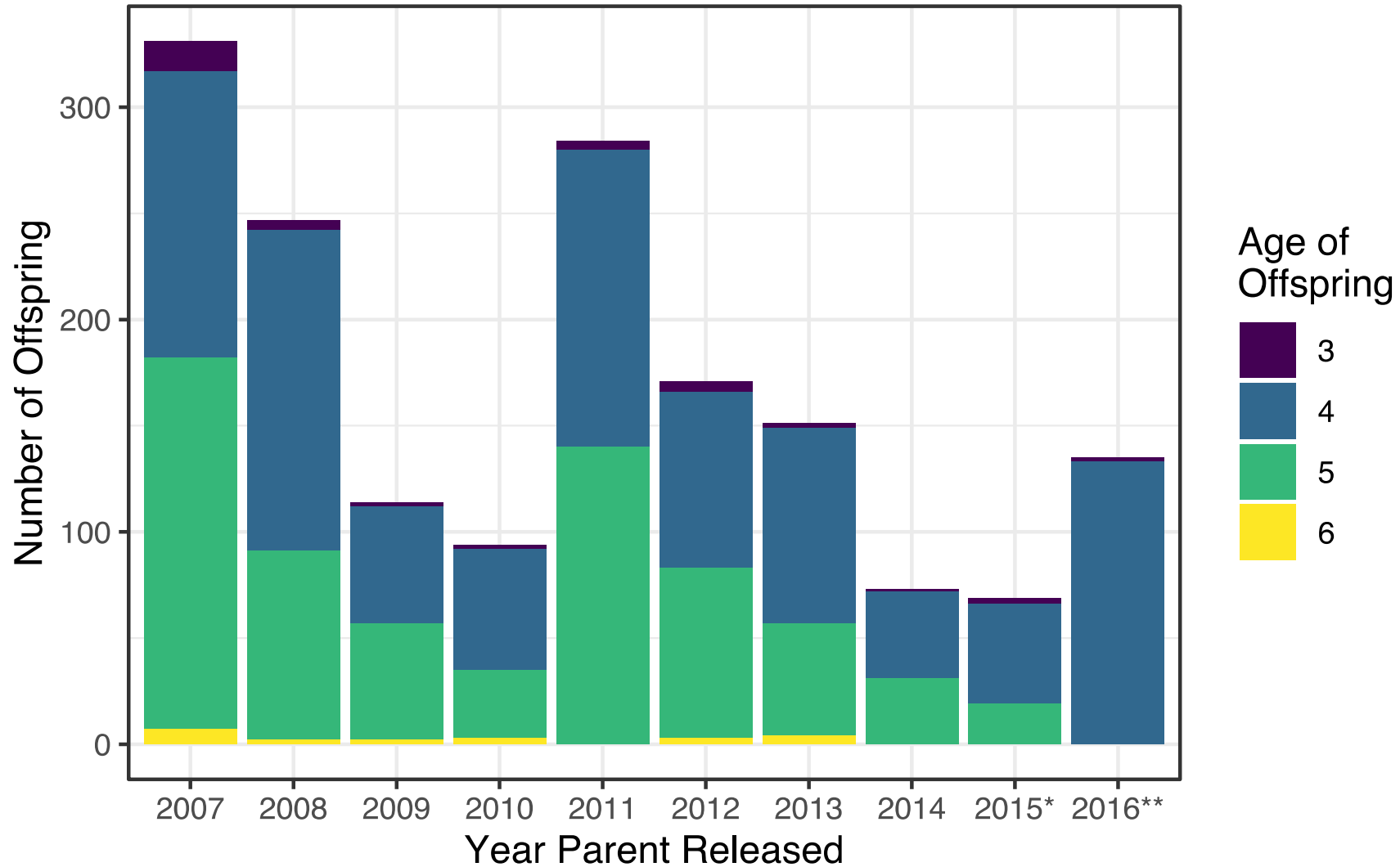
- HOR Female
- HOR Male
- NOR Female
- NOR Male

- Total Lifetime Fitness (TLF)
 - number of adult offspring that return after 3 – 6 years
- Mean TLF was 0.36.
- Varied a lot between years.
- NOR > HOR
- Females > Males
 - For HORs

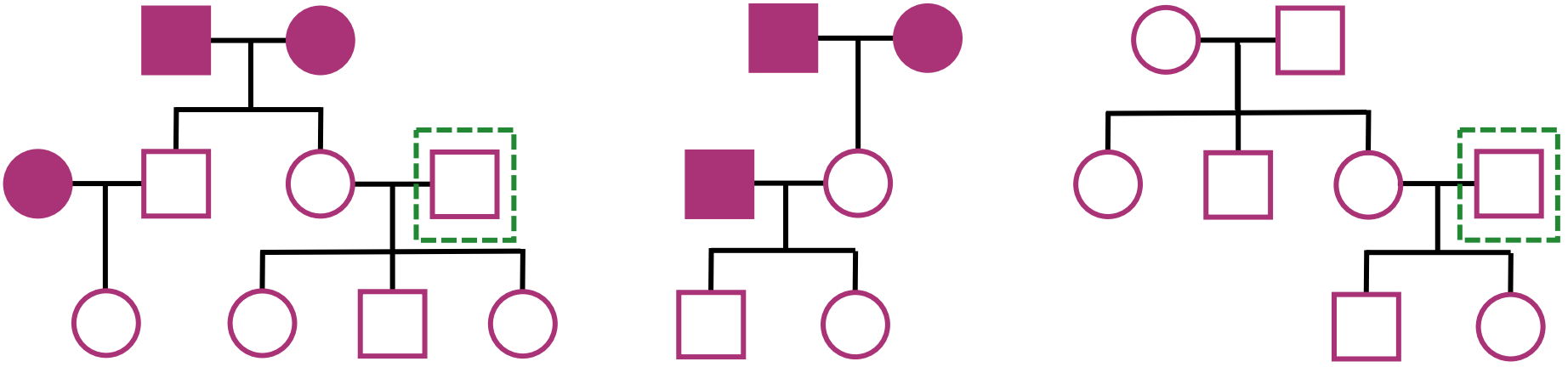
Demography

Age at Maturity

- Most offspring are either age-4 or age-5
- Few (<2%) are either age-3 or age-6
- Consistent across all years



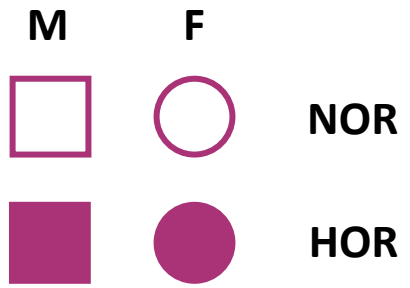
NOR Immigrant



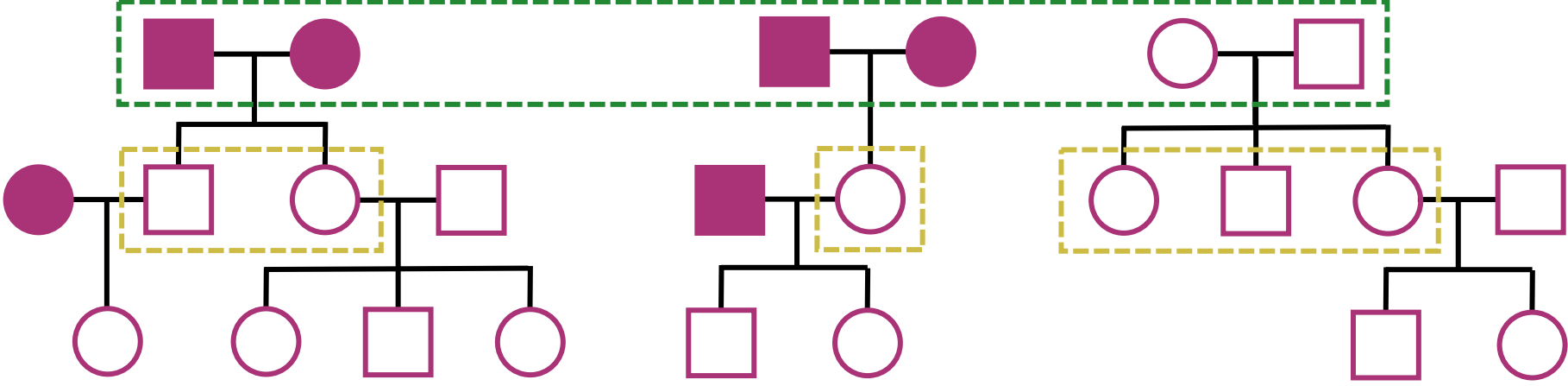
Parents Released in 2011

Adult Offspring Collected in 2014 - 2017

NOR Immigrant = NOR salmon with no parent in the pedigree, presumed produced elsewhere



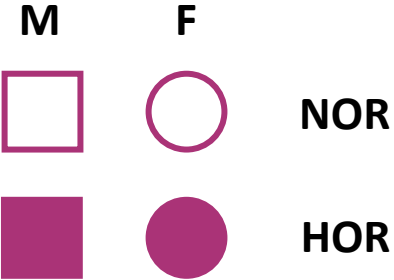
Cohort Replacement Rate



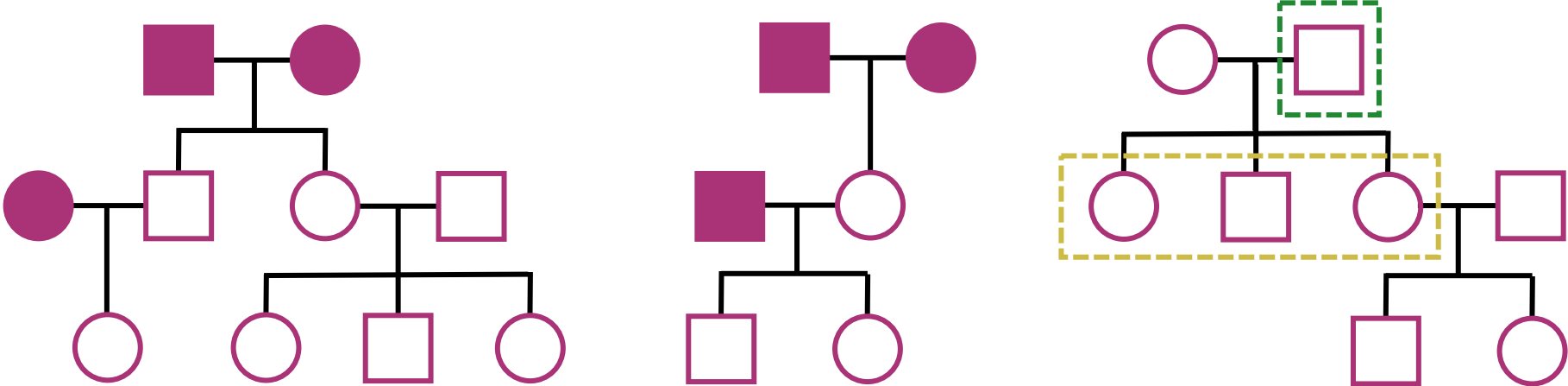
Parents Released in 2011

Adult Offspring Collected in 2014 - 2017

$CRR = \text{Number of Offspring Produced by a Cohort of Parents} / \text{Number of Parents} = 6 / 6 = 1.0$



Total Lifetime Fitness



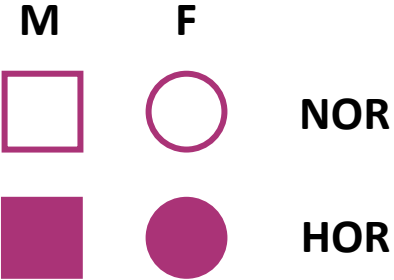
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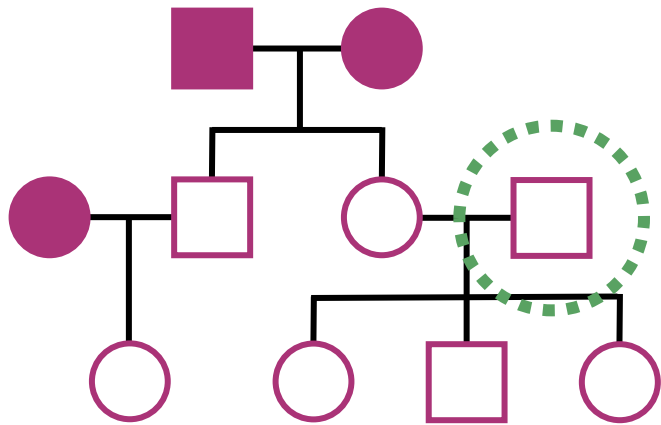
NOR Immigrant = NOR salmon with no parent, presumed produced elsewhere

$\text{Total Lifetime Fitness} = \text{Number of adult offspring, per individual parent} = 3$



Definitions

Total Lifetime Fitness



This NOR male produced 3 offspring that returned in later years
It's TLF = 3

