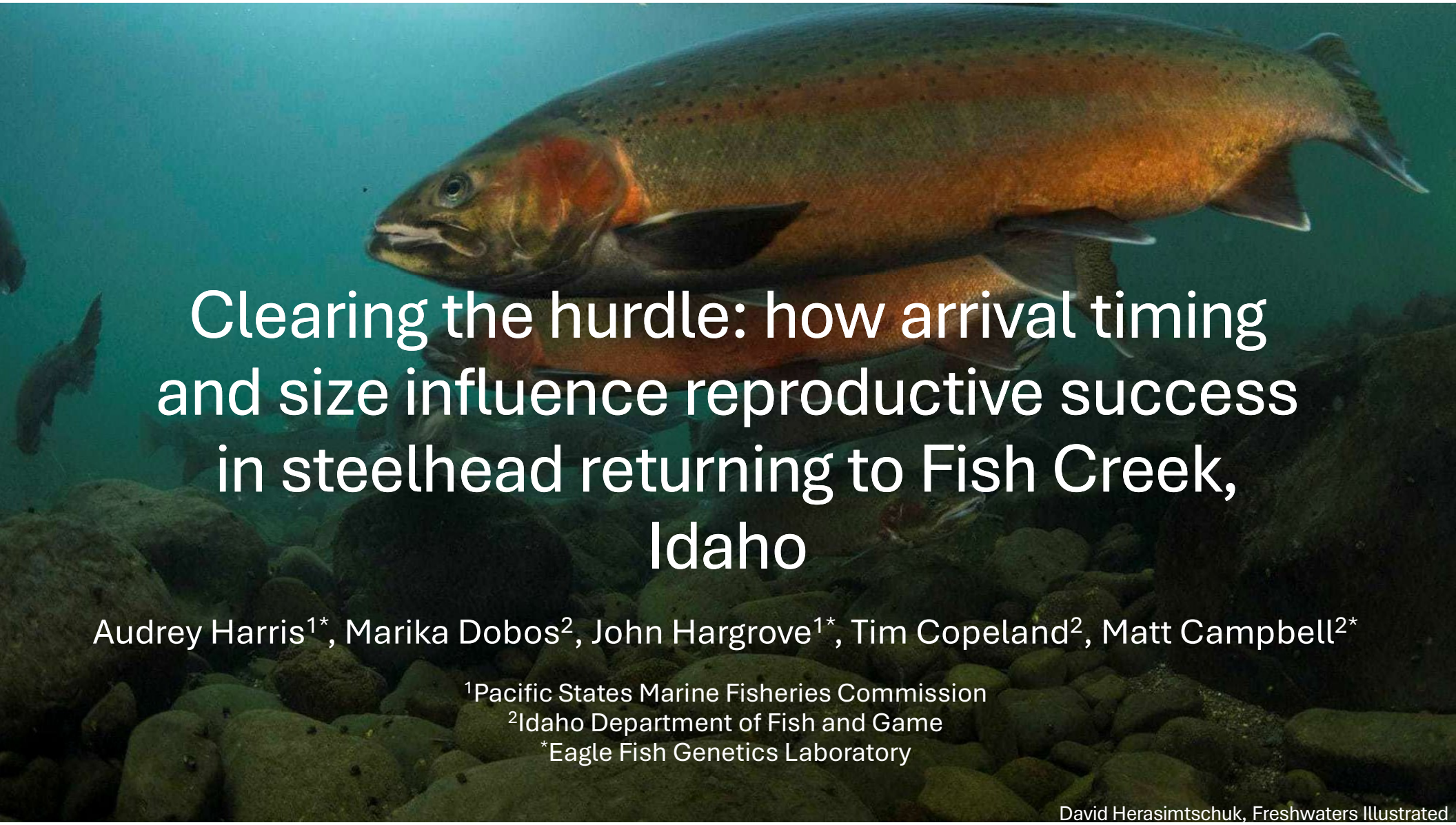


Clearing the hurdle: how arrival timing and size influence reproductive success in steelhead returning to Fish Creek, Idaho

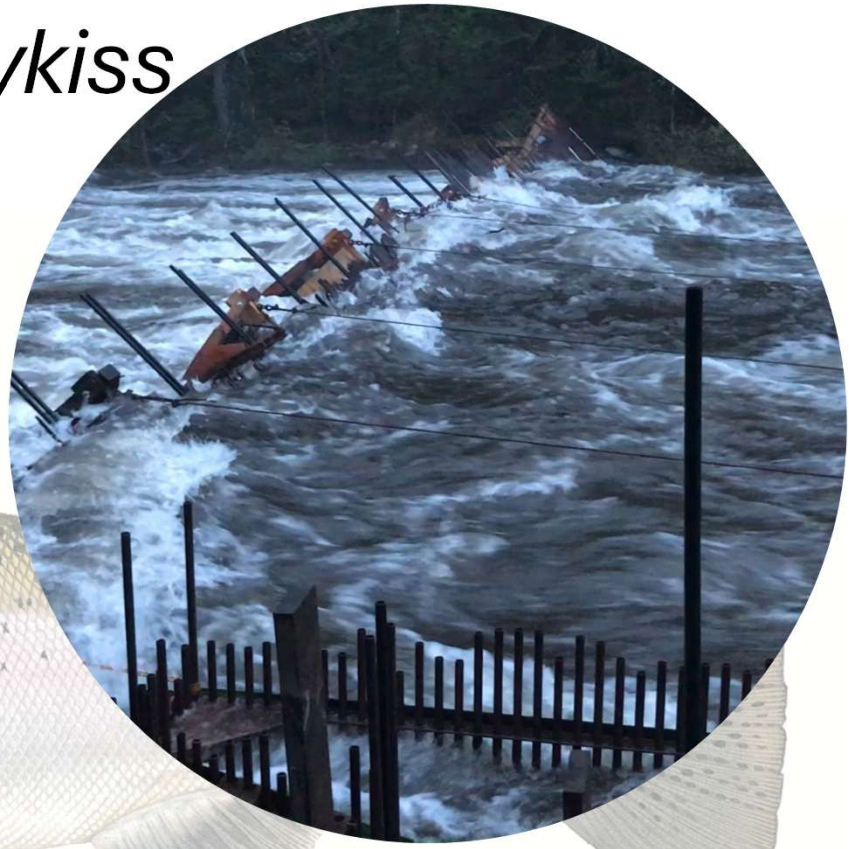
Audrey Harris[1*], Marika Dobos[2], John Hargrove[1*], Tim Copeland[2], Matt Campbell[2*]

[1]Pacific States Marine Fisheries Commission
[2]Idaho Department of Fish and Game
[*]Eagle Fish Genetics Laboratory

David Herasimtschuk, Freshwaters Illustrated

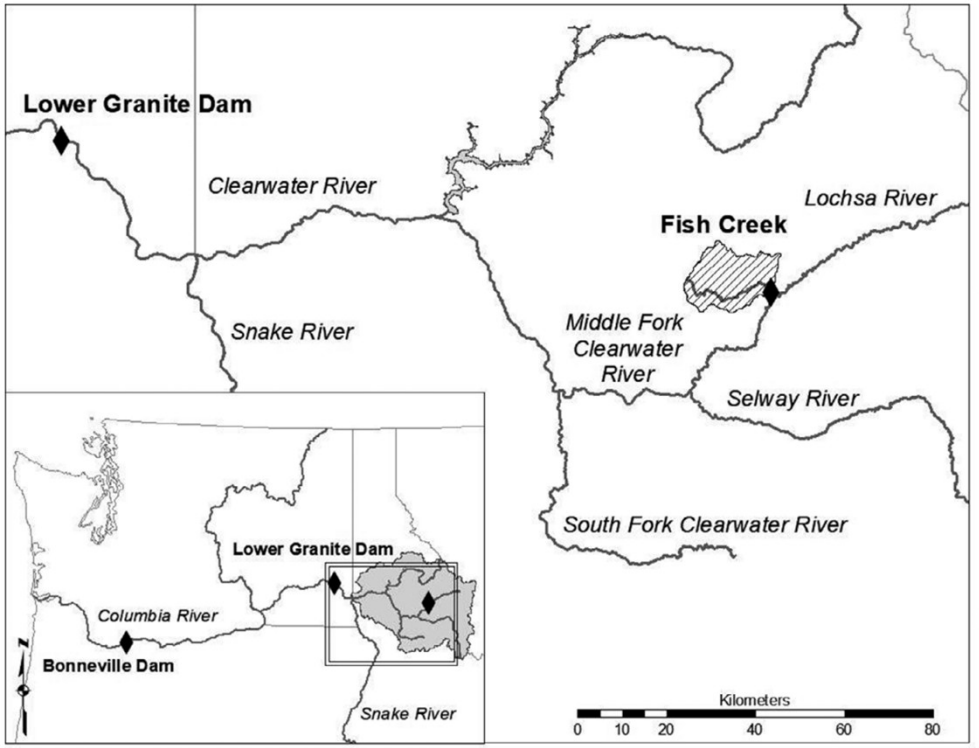
Steelhead *Oncorhynchus mykiss*

- Anadromous rainbow trout
- Life history diversity
- Spring spawners in snowmelt-driven watersheds
  - Knowledge gaps about abundance, migration timing, mating systems
- Snake River DPS
  - Listed in 1997
  - Recent declines



Fish Creek steelhead

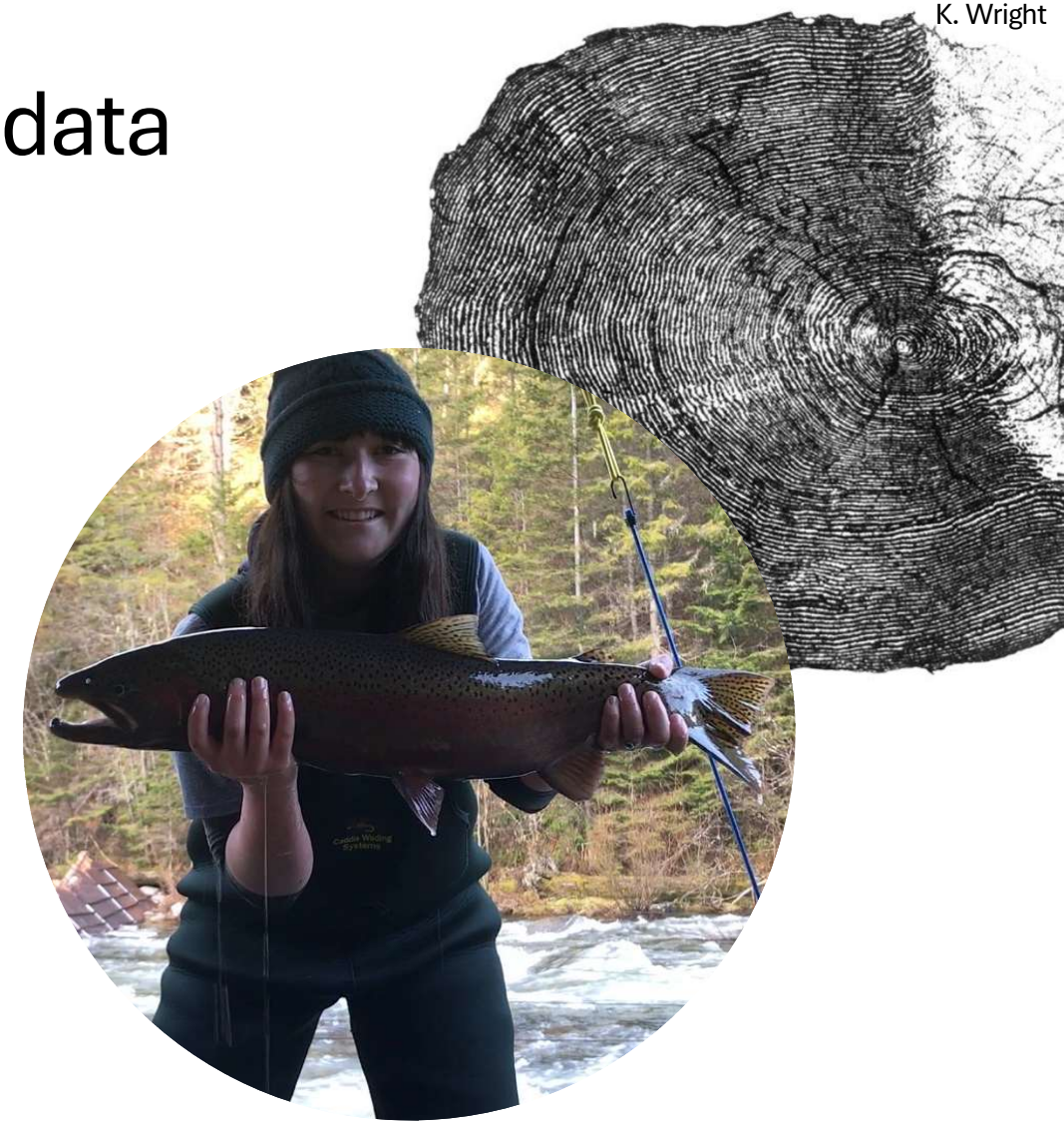
- Tributary to the Lochsa River with long-term monitoring program
- Modified picket weir and rotary screw trap since 1994
- Mark-recapture starting in 1996
- Genetic samples starting in 1997



Dobos et al. 2020

Genetic and biological data

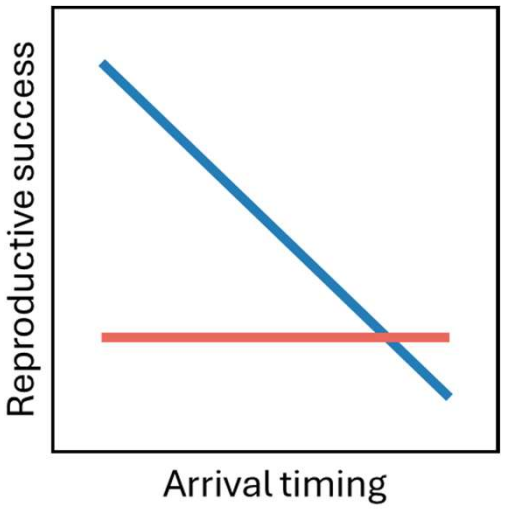
- Genotyped 3,265 samples collected in 1997-2022
  - Genetic sex marker
- Genetic data paired with biological data
  - Scale age
  - Length
  - Arrival date

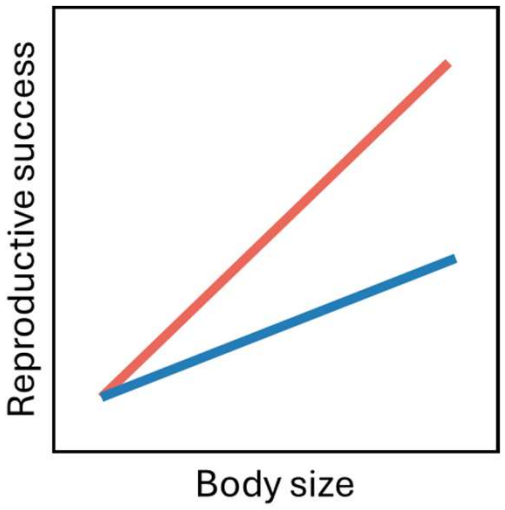


K. Wright

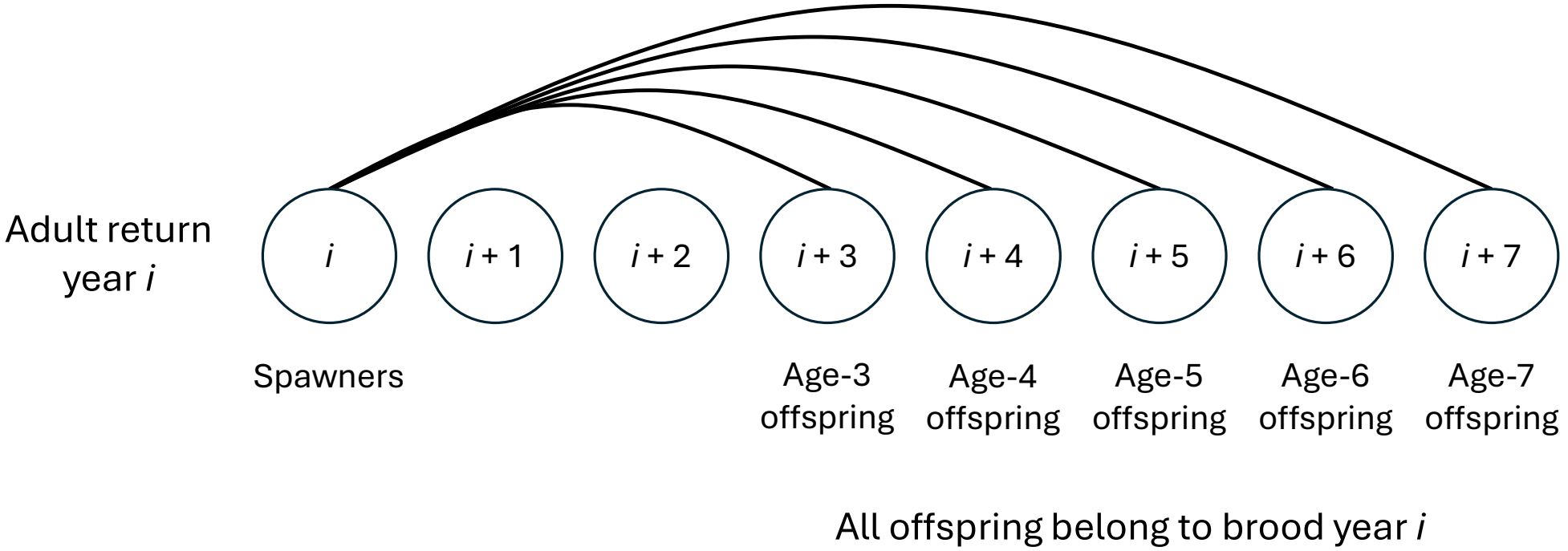
Objectives

- Describe genetic mating system using pedigree reconstruction
  - Life history diversity
  - Influence of sex, arrival timing, and body size



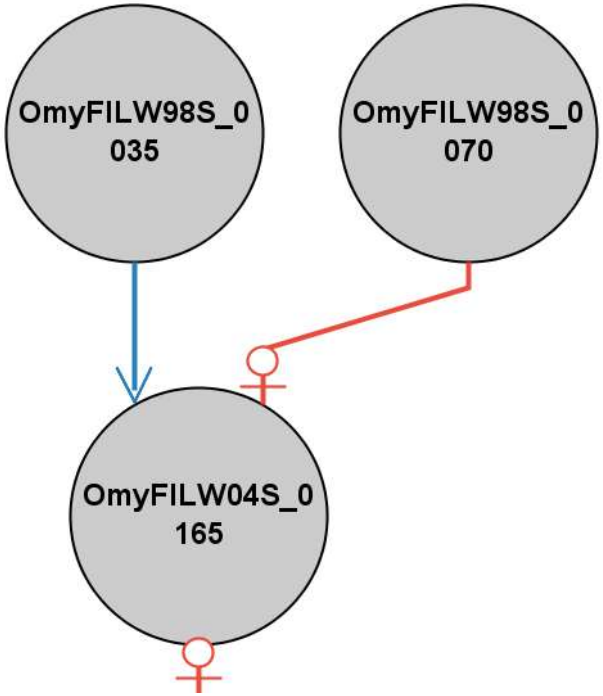


Pedigree reconstruction – adult-to-adult

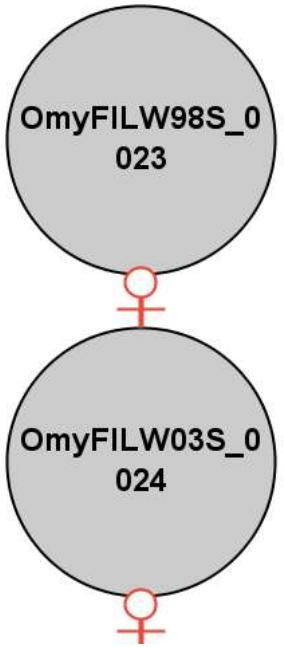


All offspring belong to brood year *i*

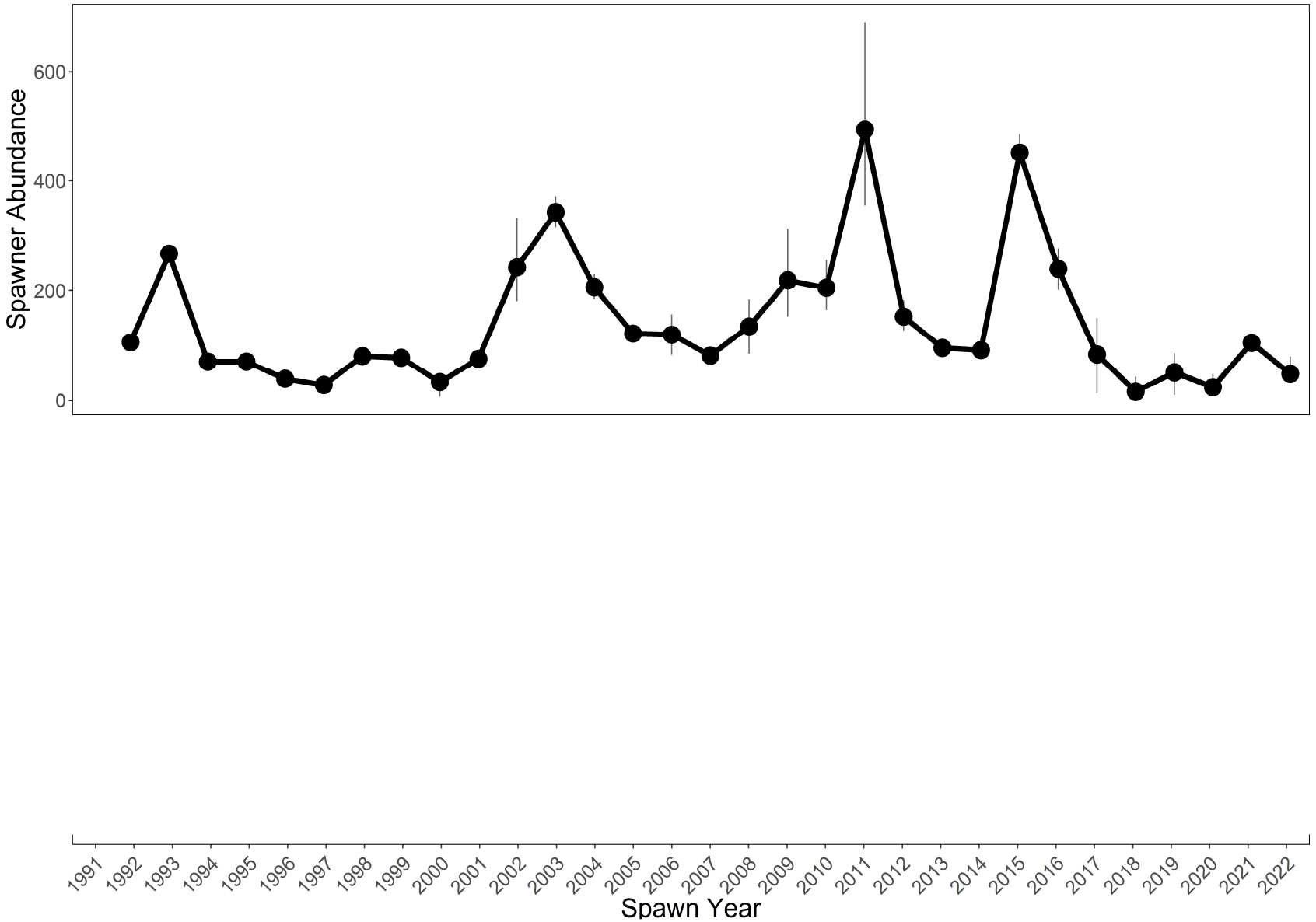
Types of parentage assignments

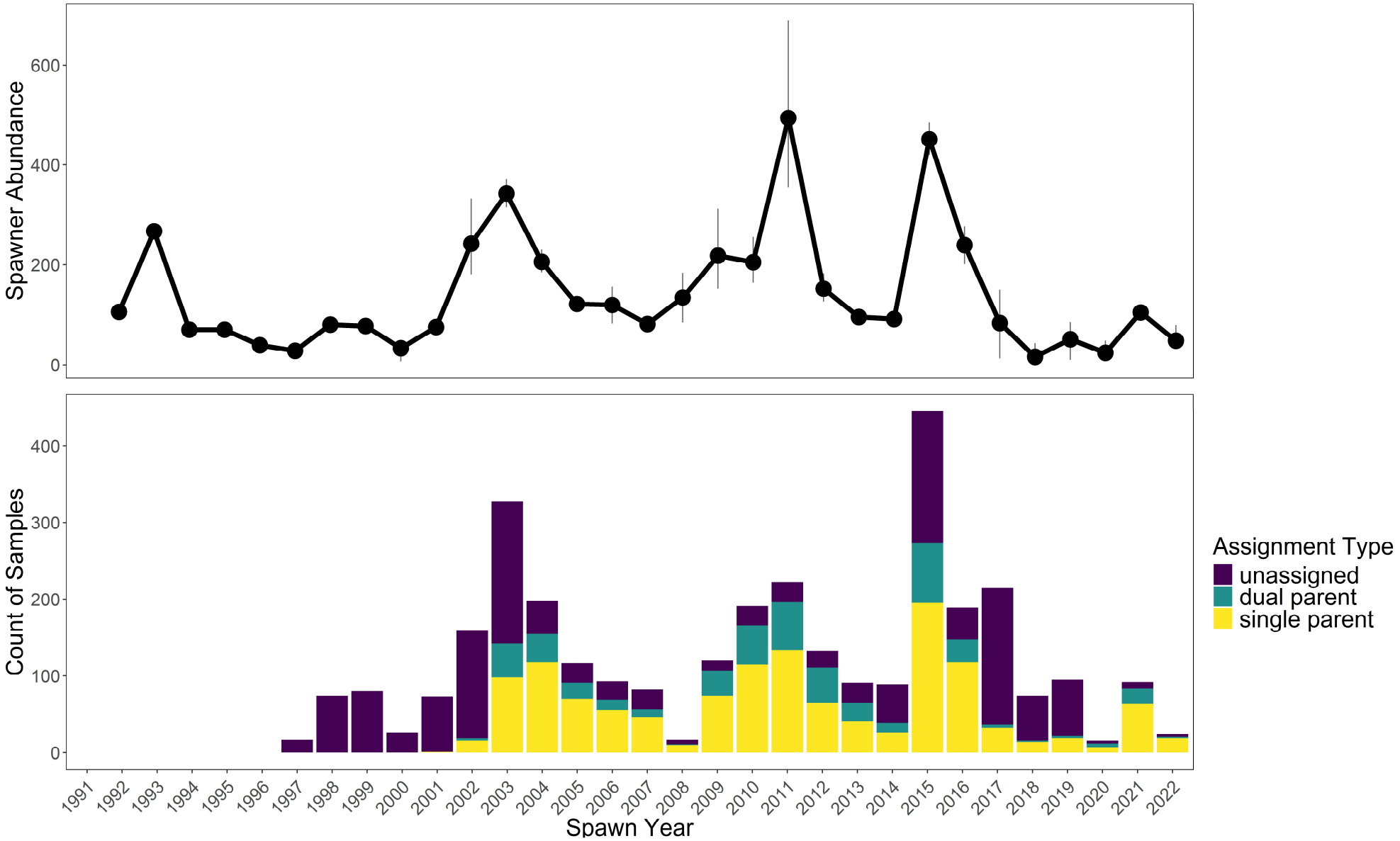


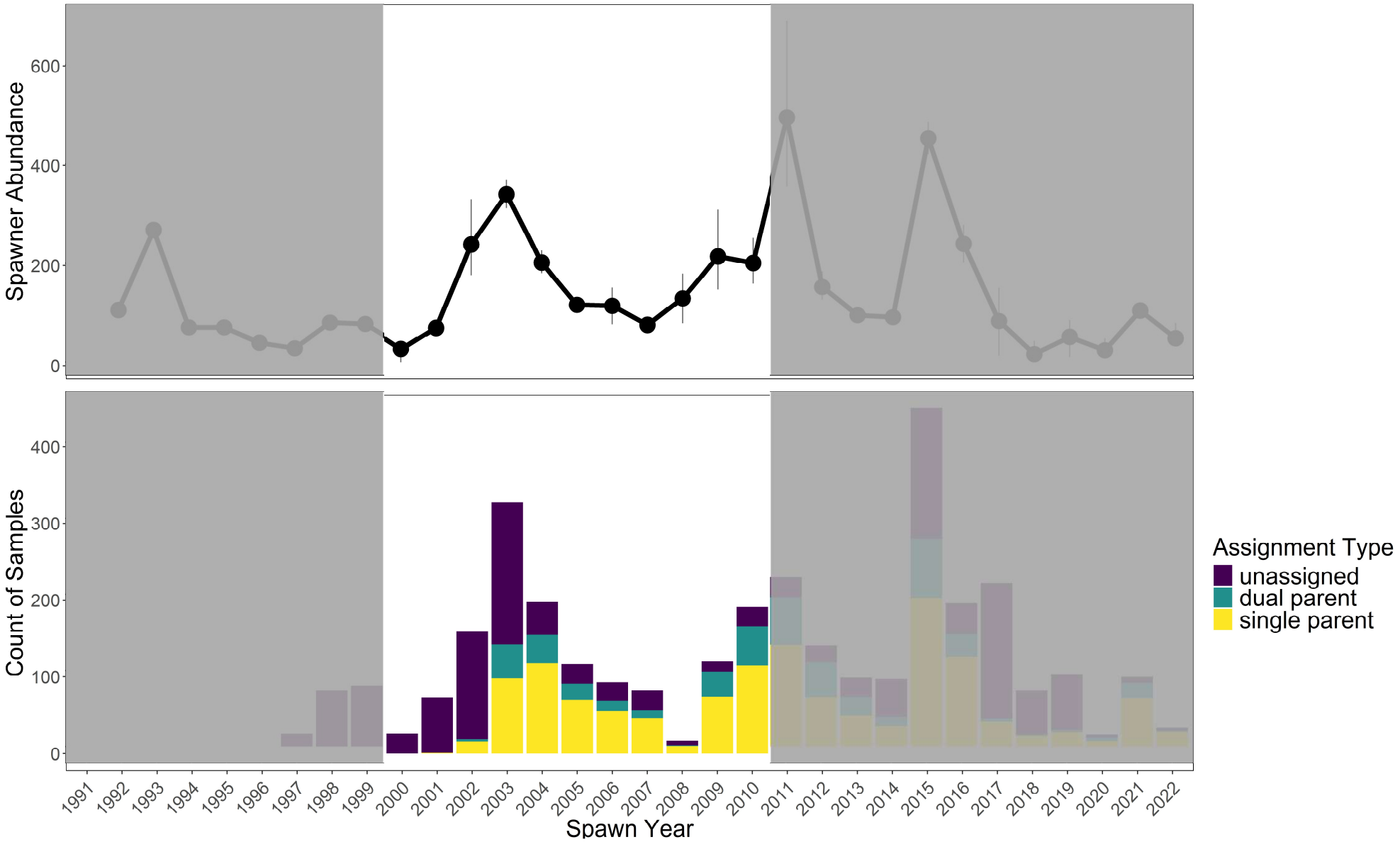
Dual parent assignment



Single parent assignment


Spawner Abundance
600
400
200
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Spawn Year


Spawner Abundance
0
200
400
600
Count of Samples
0
100
200
300
400
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
Spawn Year
Assignment Type
unassigned
dual parent
single parent


Spawner Abundance
600
400
200
0
Count of Samples
400
300
200
100
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
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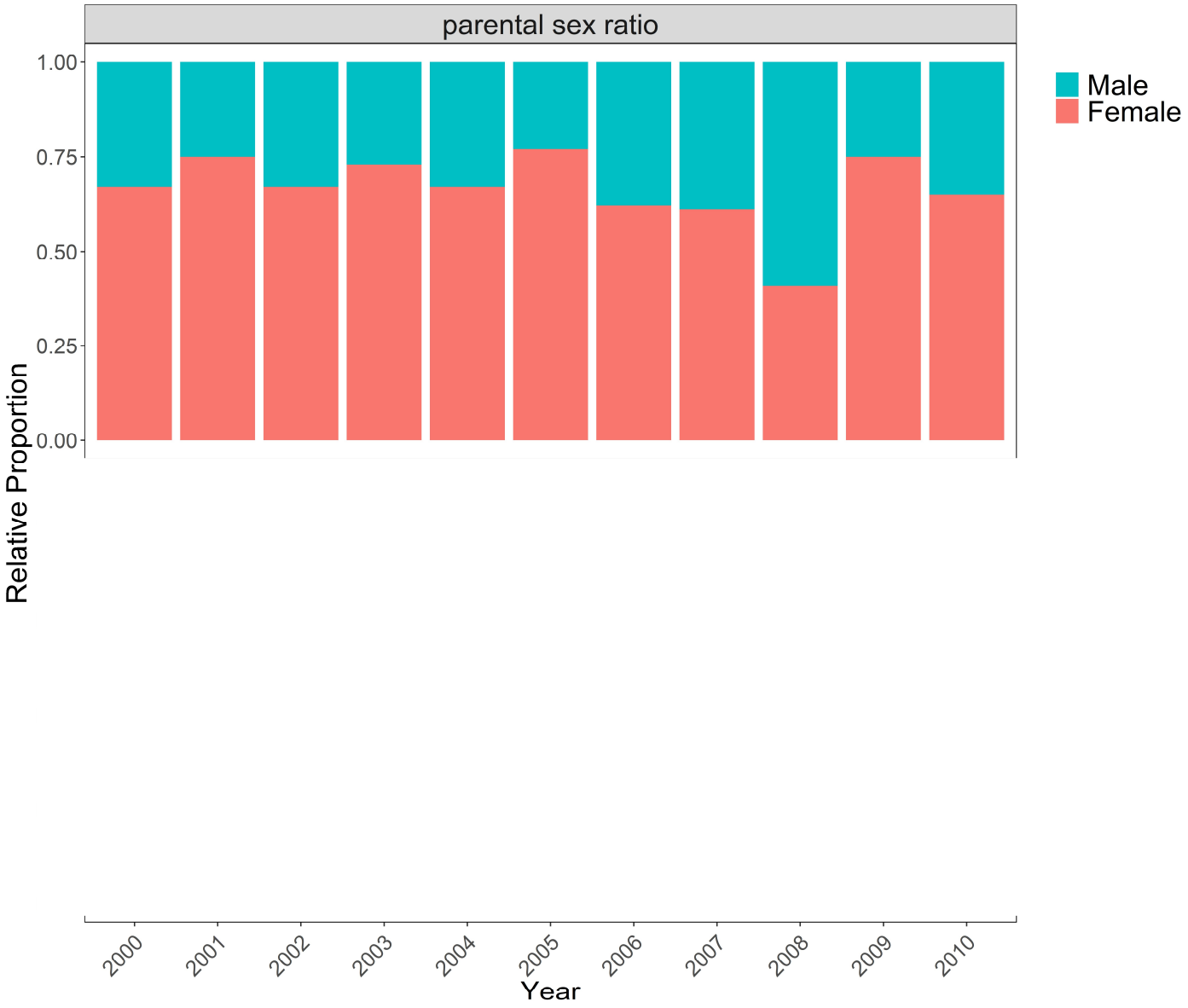
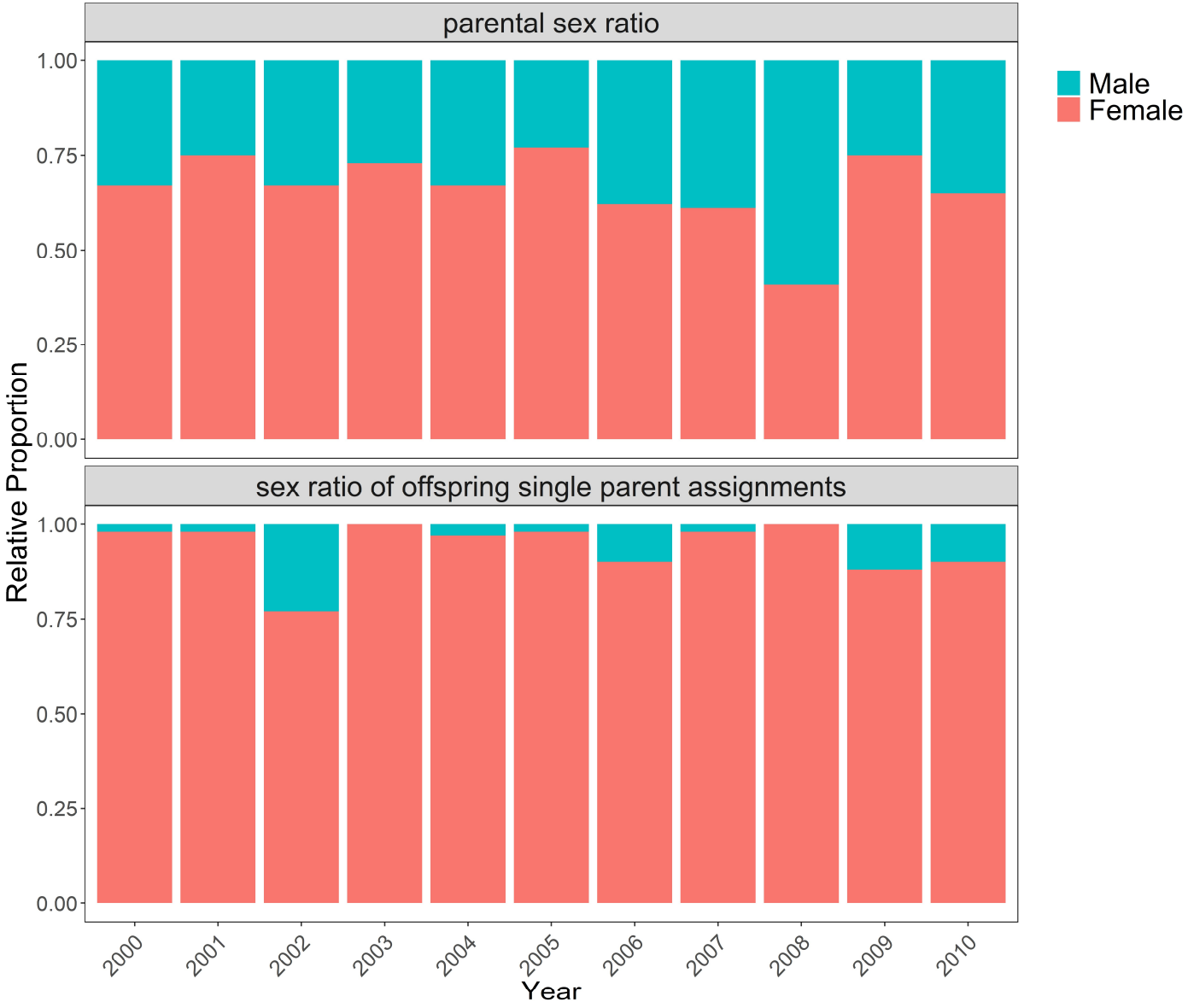
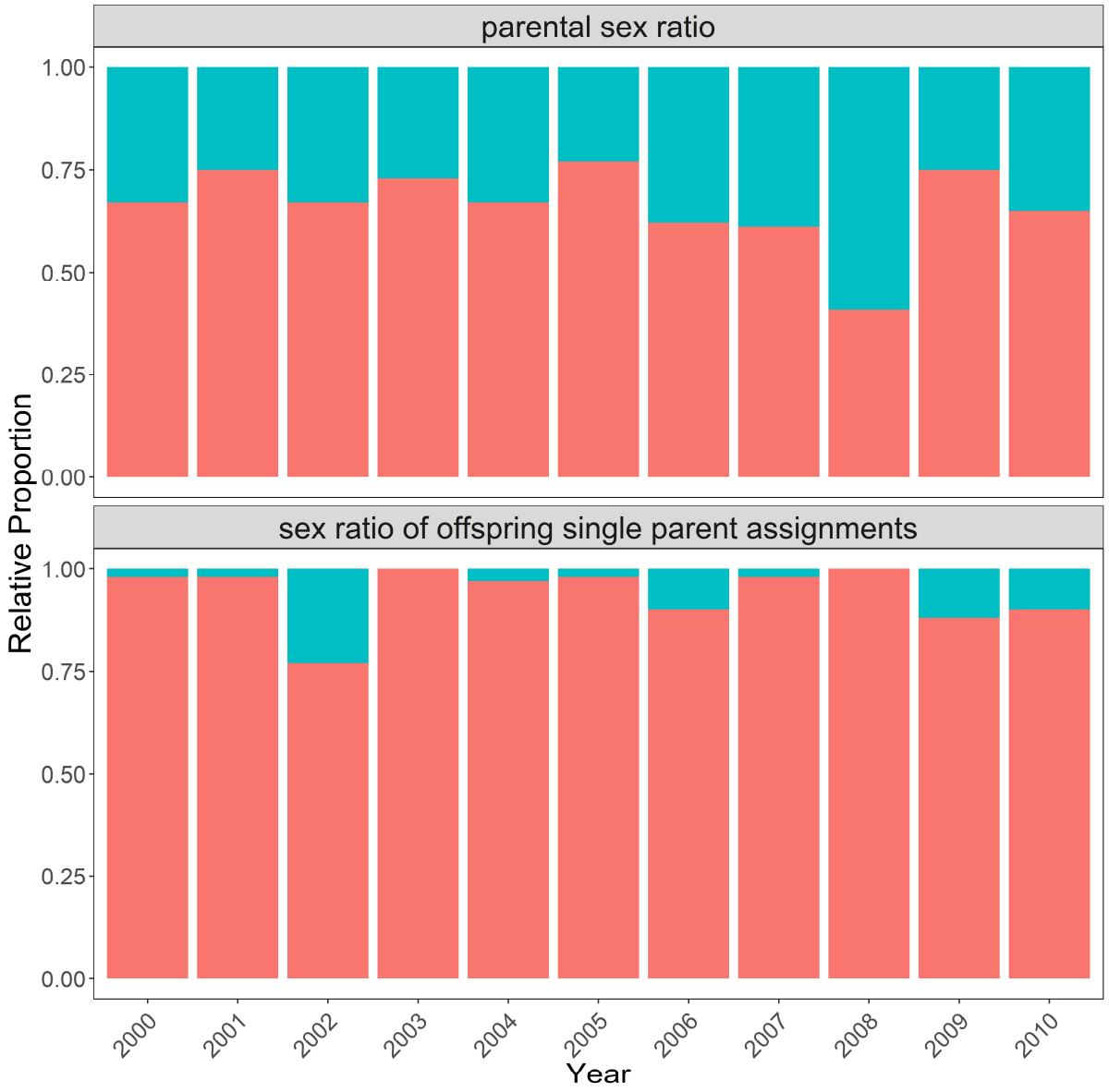
2019
2020
2021
2022
Spawn Year
Assignment Type
unassigned
dual parent
single parent


parental sex ratio
1.00
0.75
0.50
0.25
0.00
Relative Proportion
Male
Female
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year


parental sex ratio
sex ratio of offspring single parent assignments
Relative Proportion
1.00
0.75
0.50
0.25
0.00
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
Male
Female



Imbalance between the population-level sex ratio and sex ratio of single parent assignments indicates presence and significant reproductive contribution of resident males.

How successful are resident males?

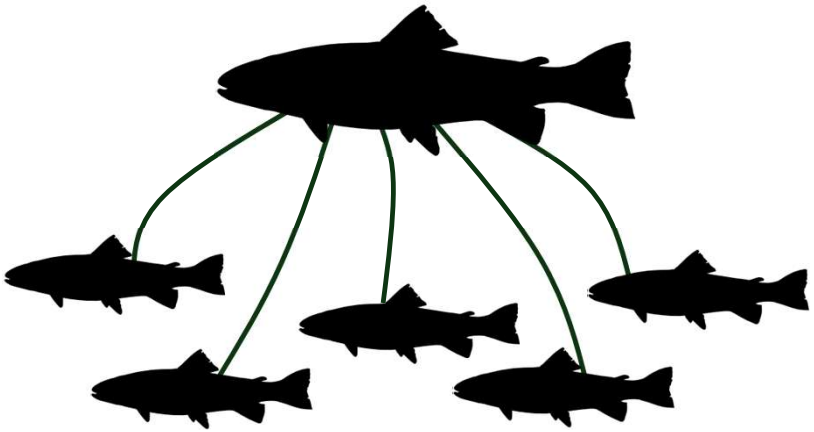
- Indirectly estimated the number of successful resident males, reproductive success, and overall reproductive contribution using:
  - Sampled anadromous males
    - Genotyping success
    - Probability of reproductive success
    - Mean reproductive success
  - Weir efficiency
  - Total number of unsampled reproductively successful males
    - Estimated from single parent assignments to females

How successful are resident males?

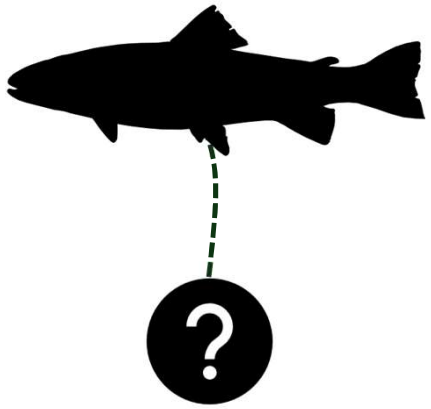
In most years, the majority of successful males were unsampled residents. These resident males produced ≈46% of anadromous offspring from brood years 2000-2010.

How to model reproductive success?

- Excessive zeros with biological meaning (*zero-inflation*)



Successful spawner
≥ 1 offspring assigned

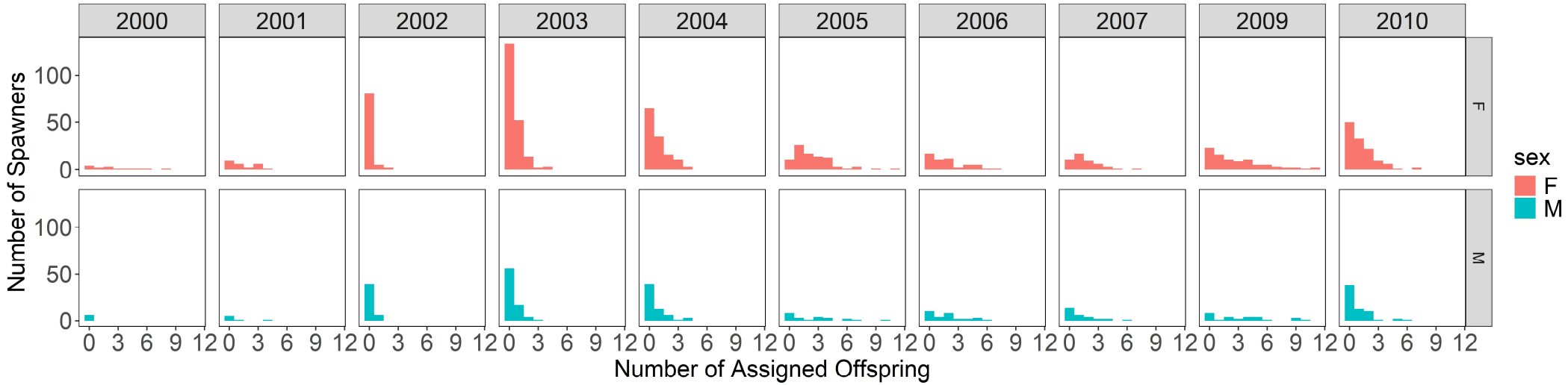


Unsuccessful spawner
0 offspring assigned

~62% of all spawners

How to model reproductive success?

- Excessive zeros with biological meaning (*zero-inflation*)
- High variability in numbers of offspring (*overdispersion*)

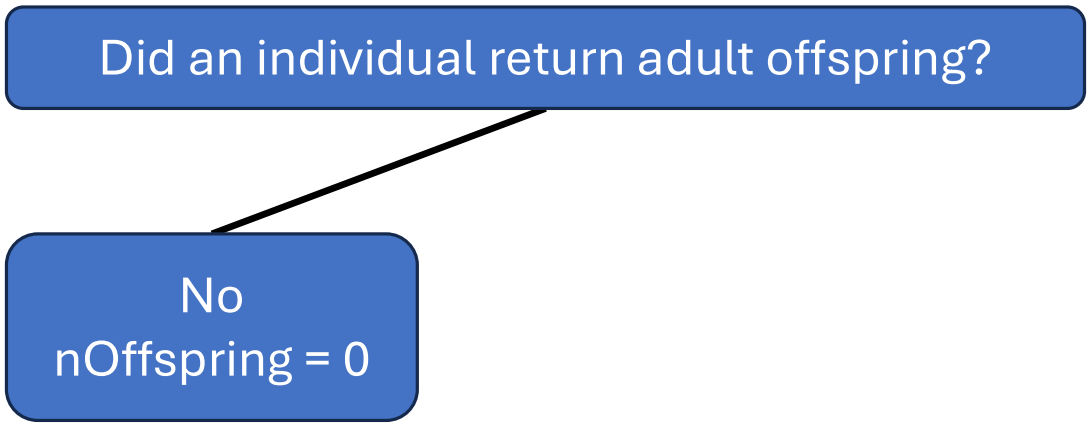


Negative binomial hurdle model

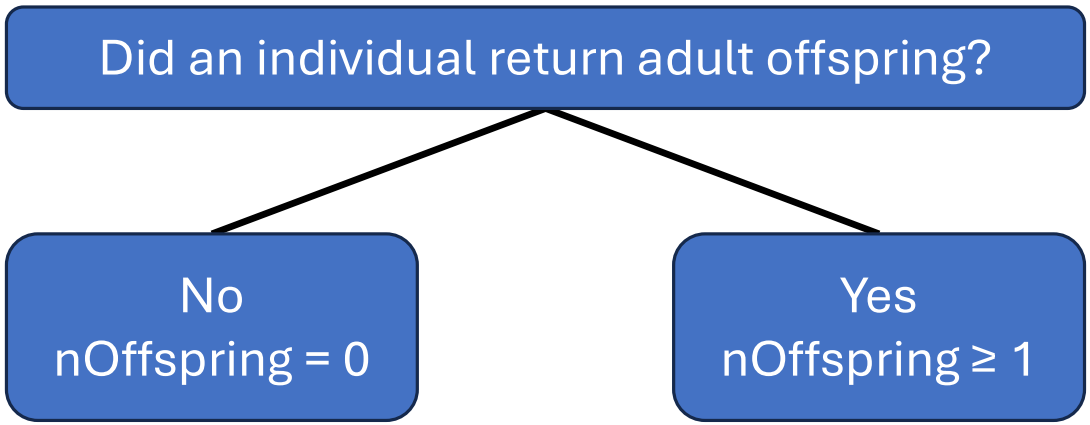
Negative binomial hurdle model

Did an individual return adult offspring?

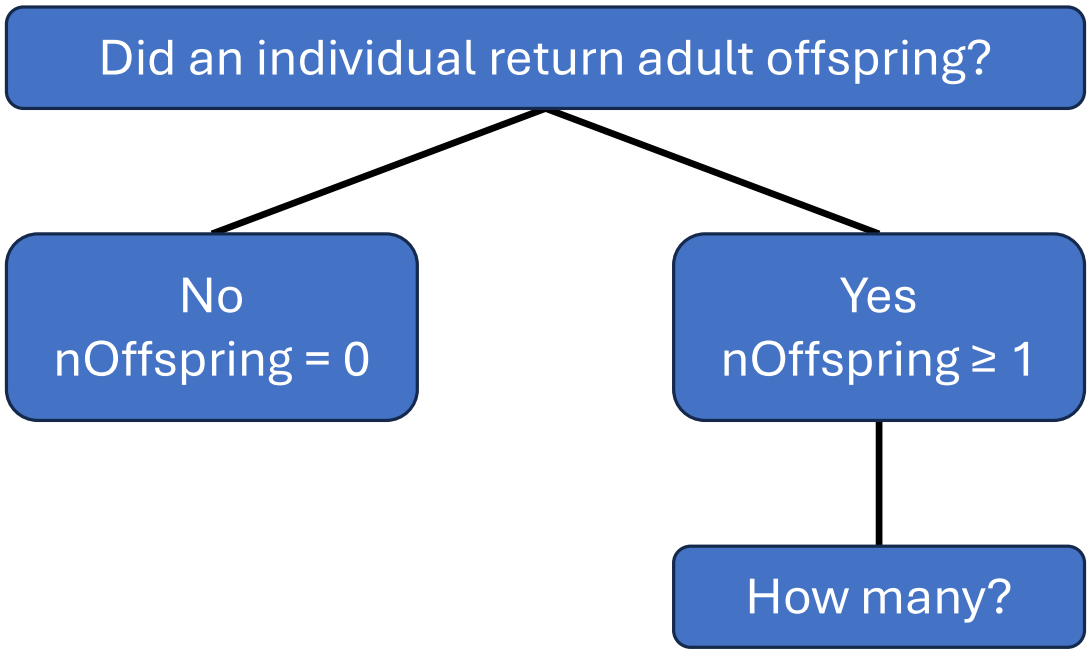
Negative binomial hurdle model



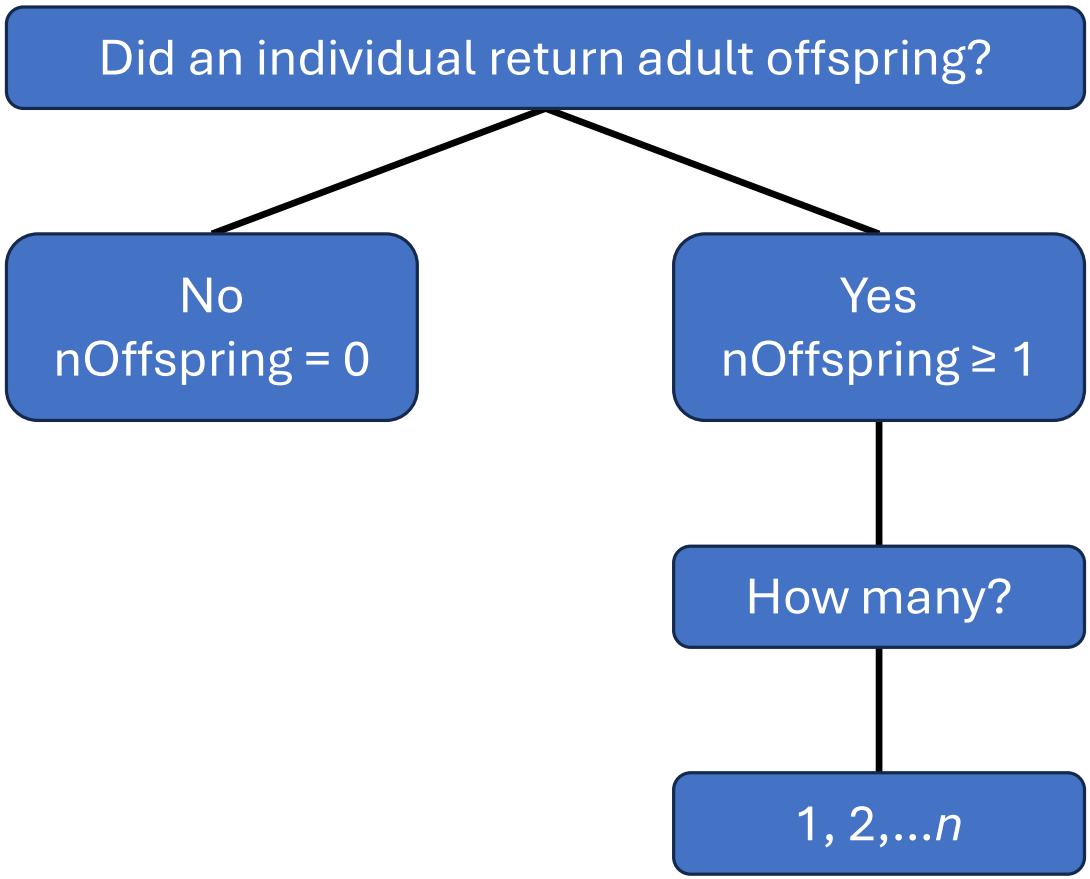
Negative binomial hurdle model



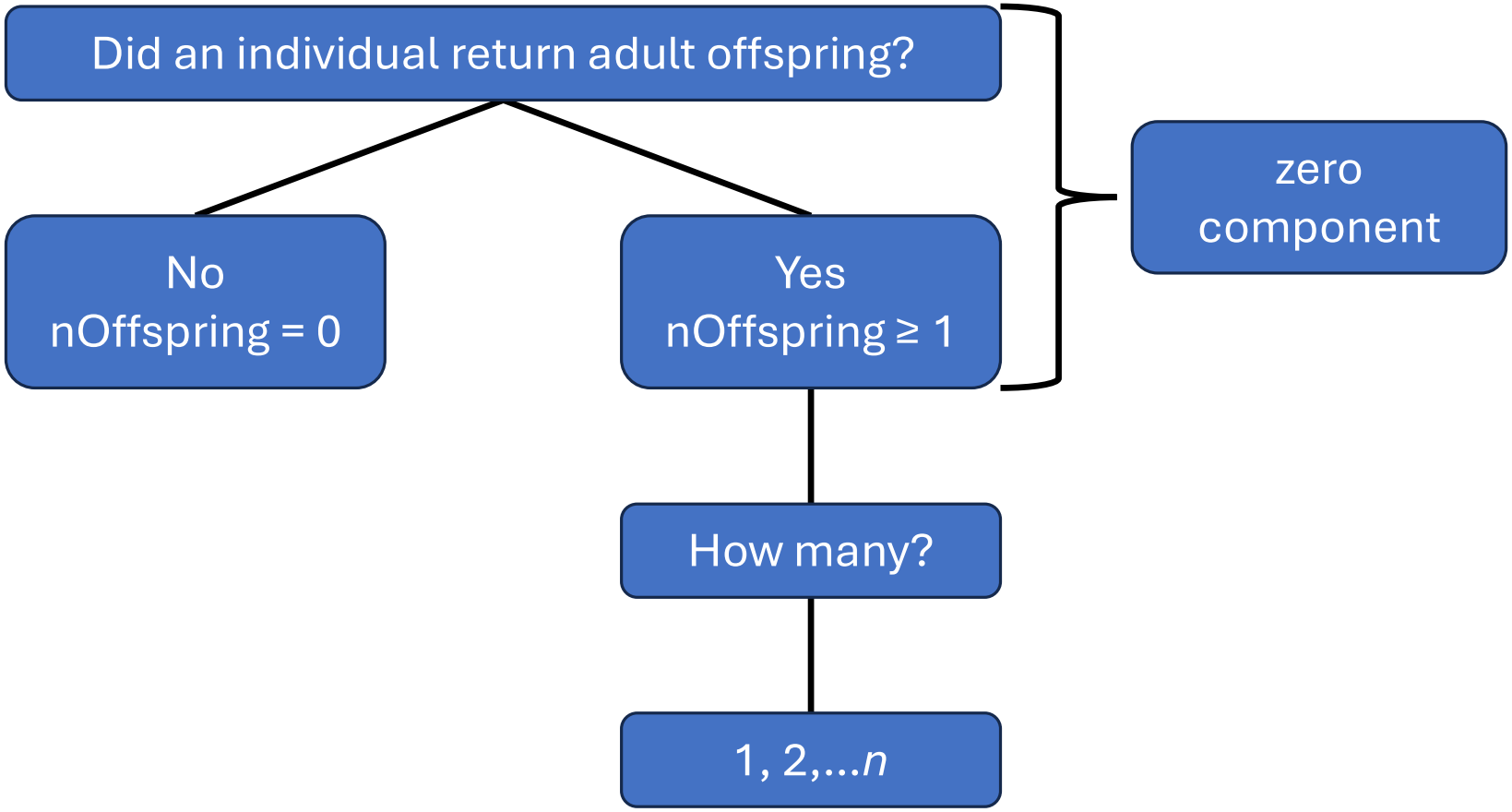
Negative binomial hurdle model



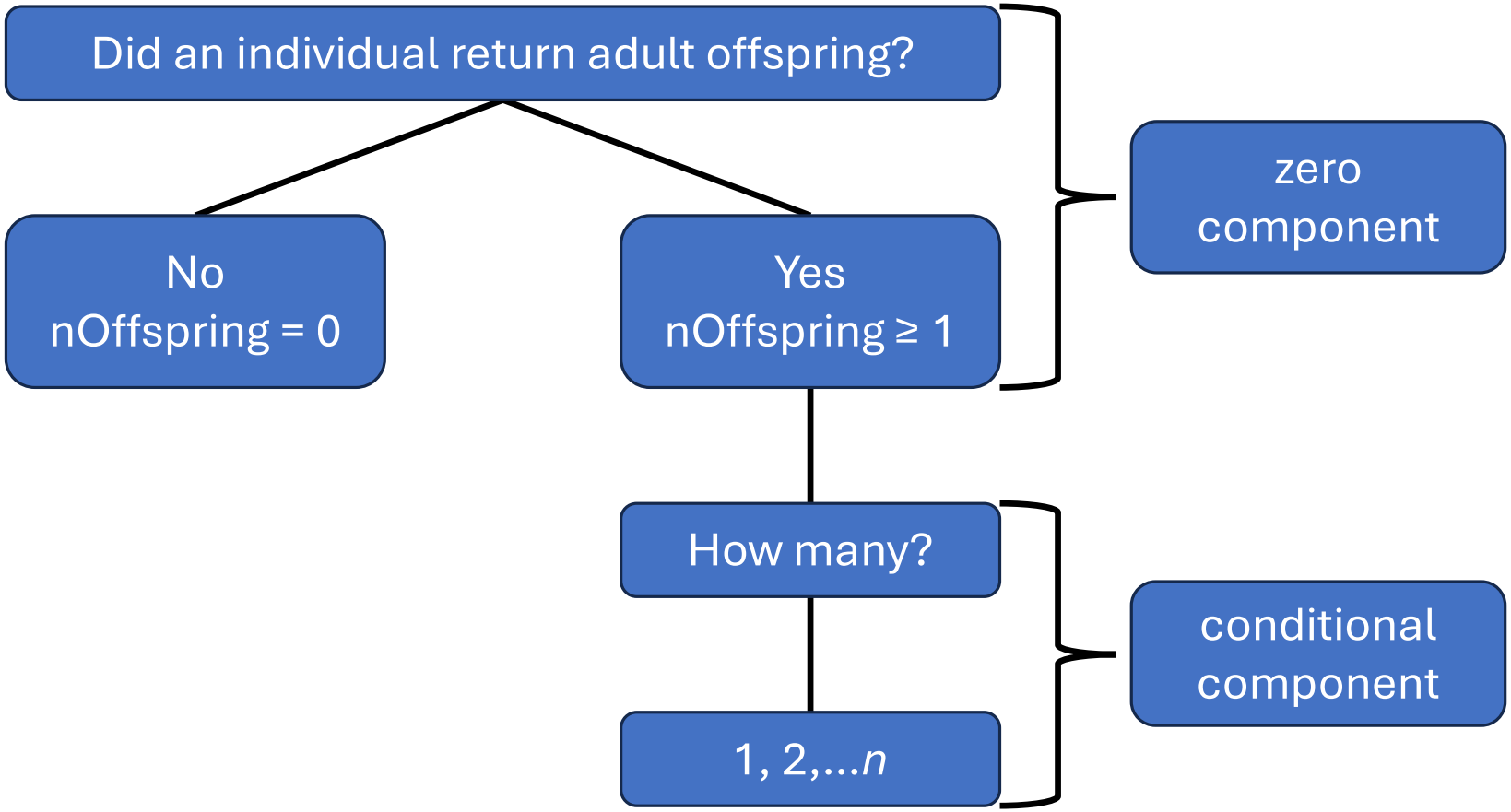
Negative binomial hurdle model



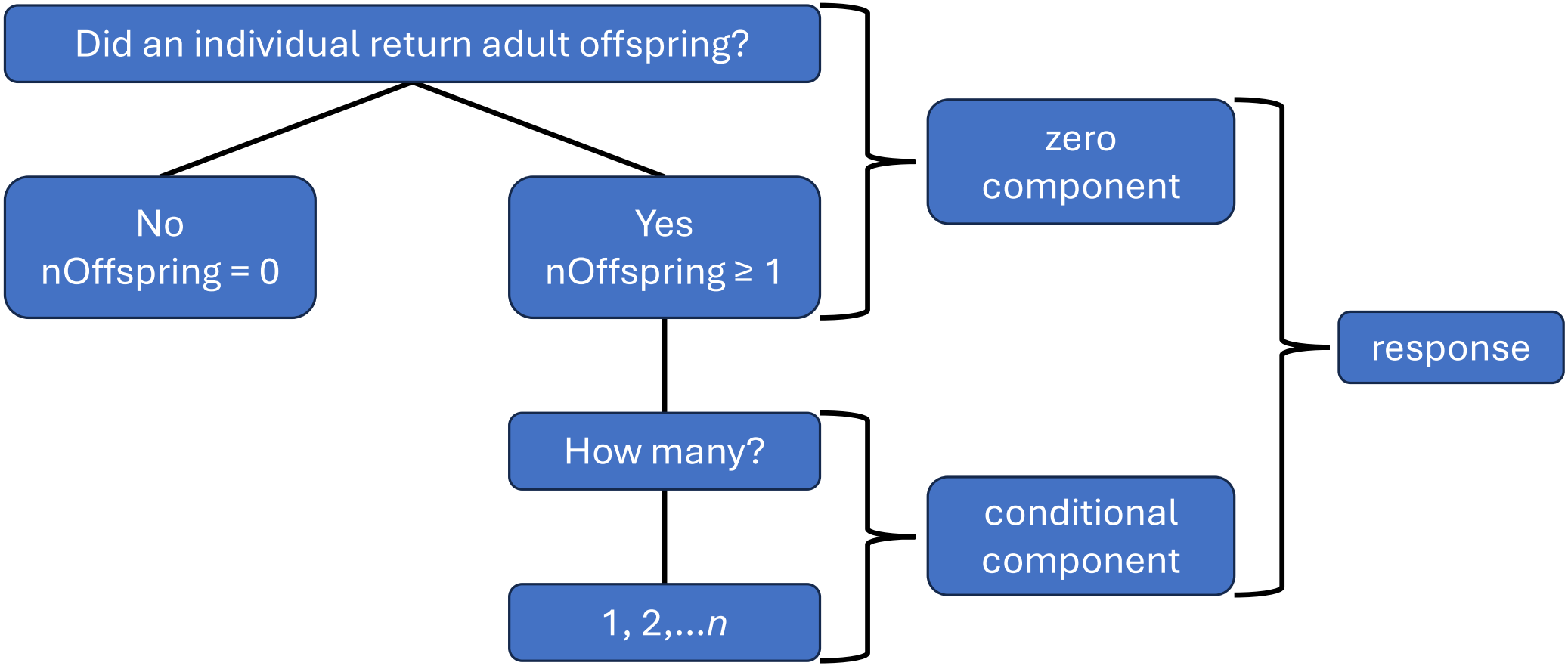
Negative binomial hurdle model



Negative binomial hurdle model

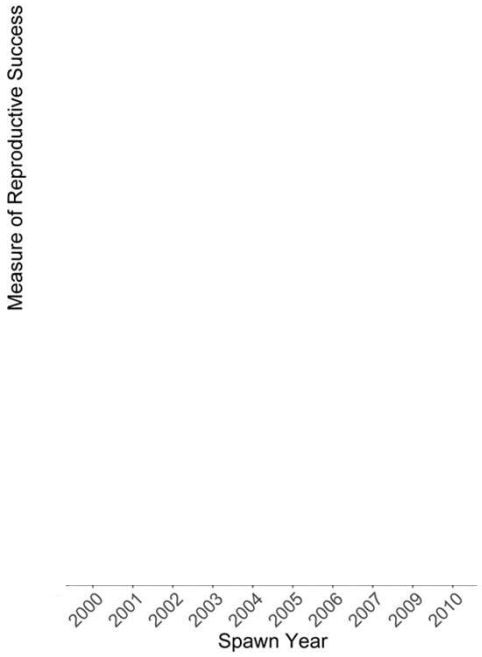


Negative binomial hurdle model



Hurdle model interpretation

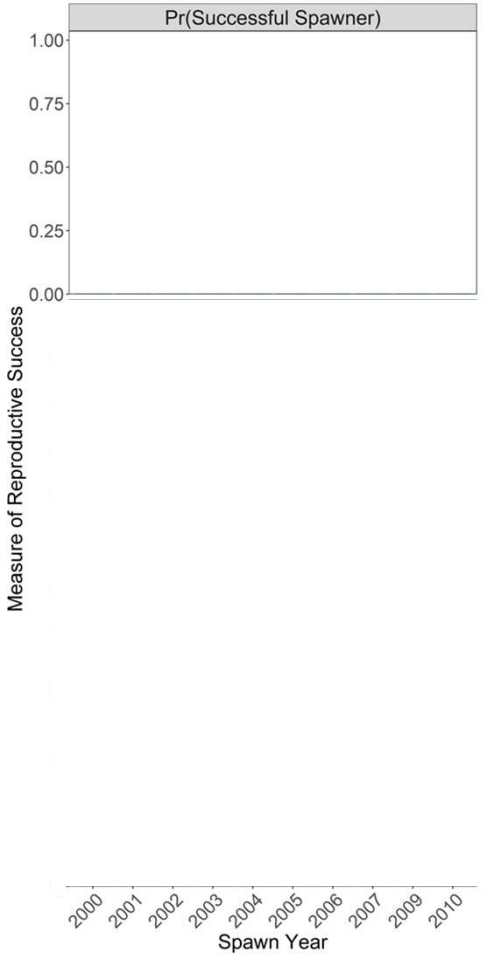
zero component



Hurdle model interpretation

zero component

probability that an individual will successfully spawn

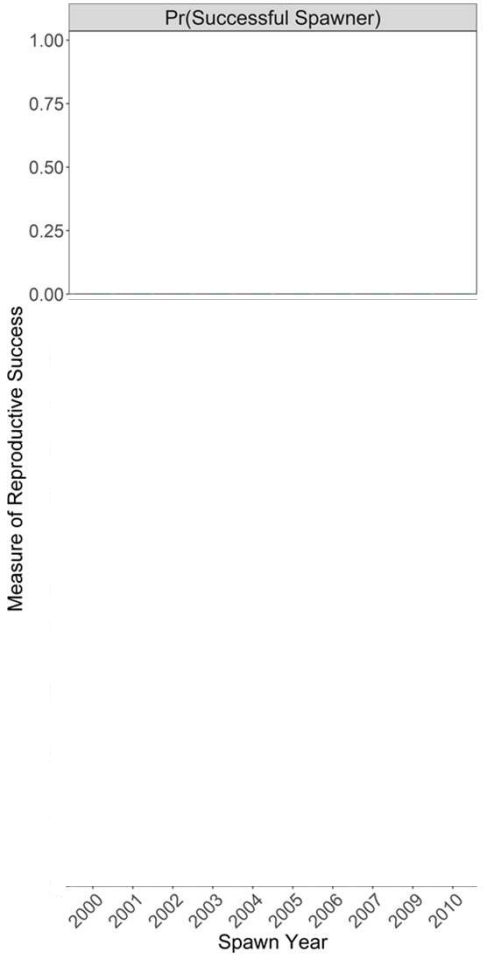


Hurdle model interpretation

zero component

probability that an individual will successfully spawn

conditional component



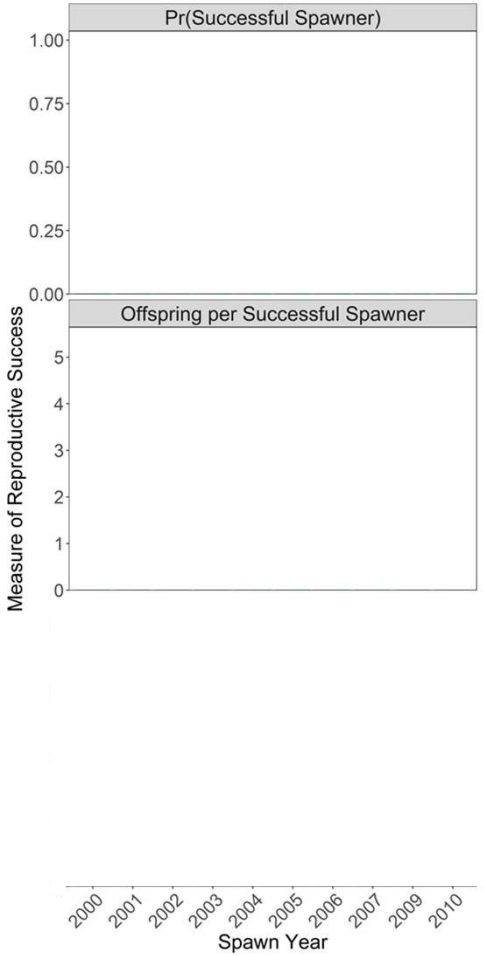
Hurdle model interpretation

zero component

probability that an individual will successfully spawn

conditional component

number of offspring per successful spawner



Hurdle model interpretation

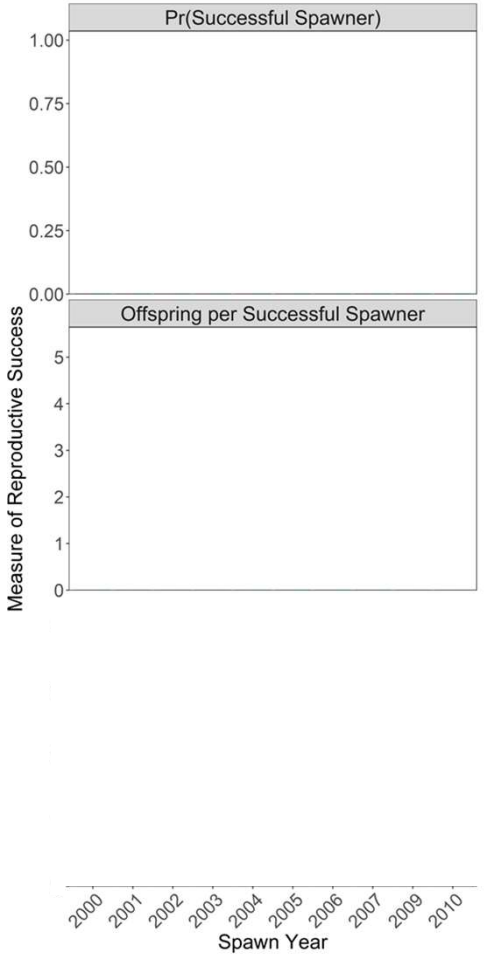
zero component

probability that an individual will successfully spawn

conditional component

number of offspring per successful spawner

response



Hurdle model interpretation

zero component

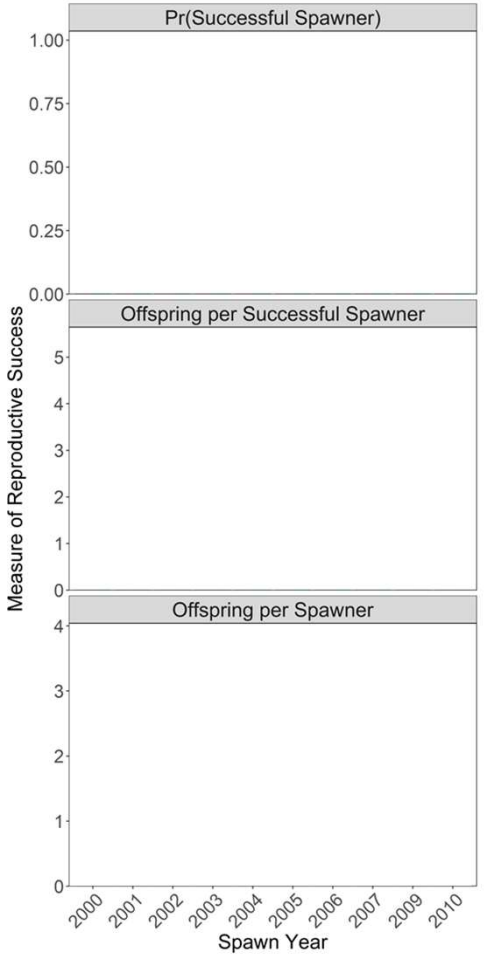
probability that an individual will successfully spawn

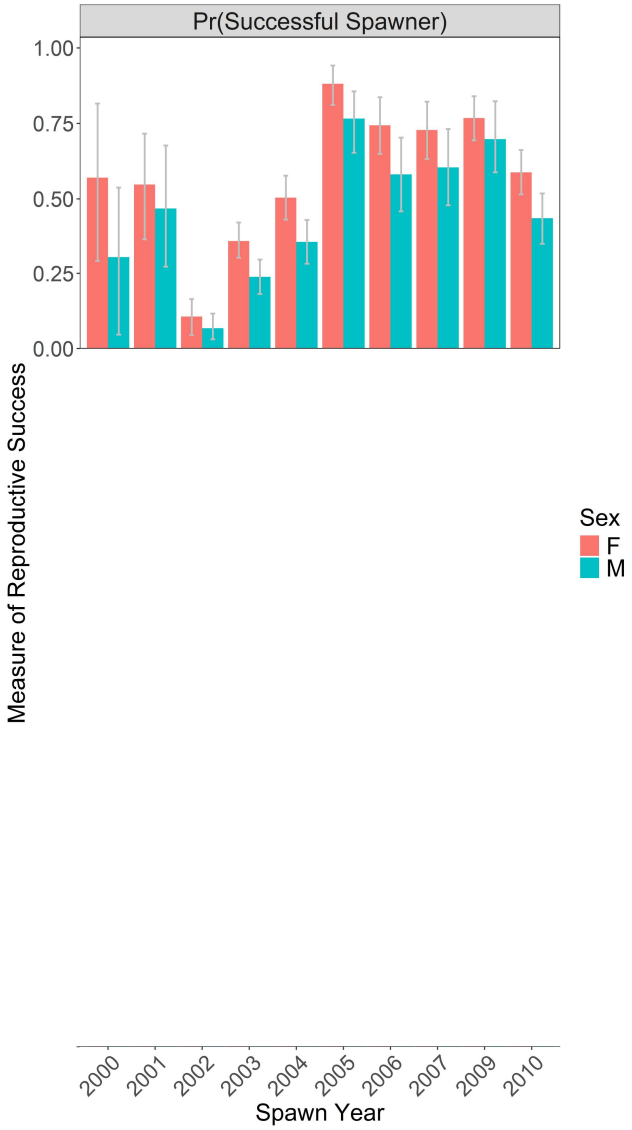
conditional component

number of offspring per successful spawner

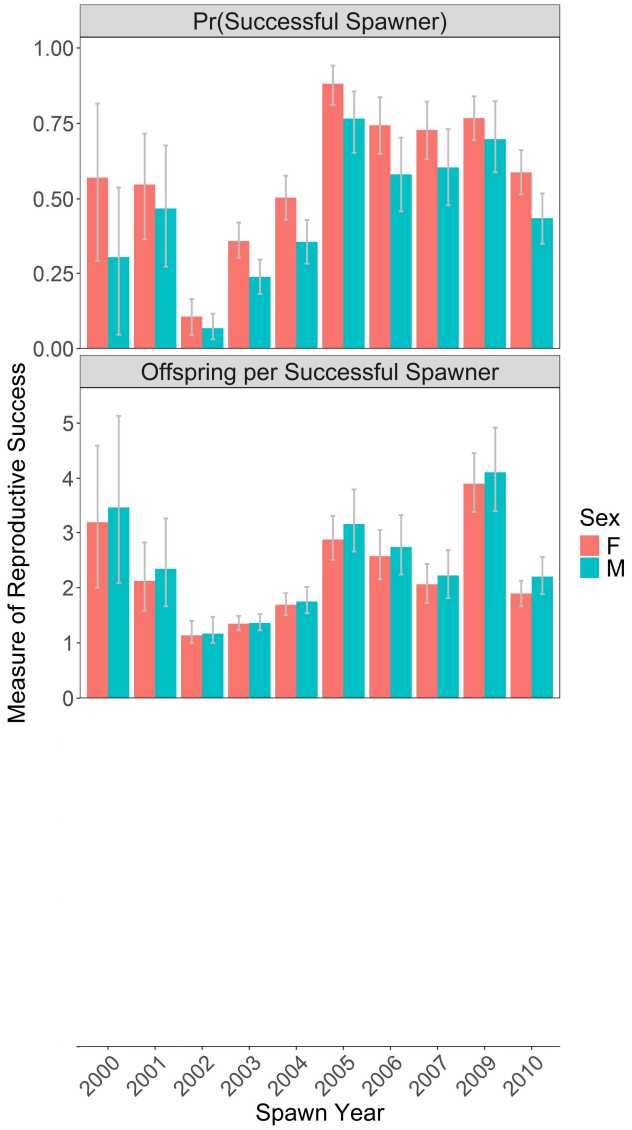
response

number of offspring per spawner



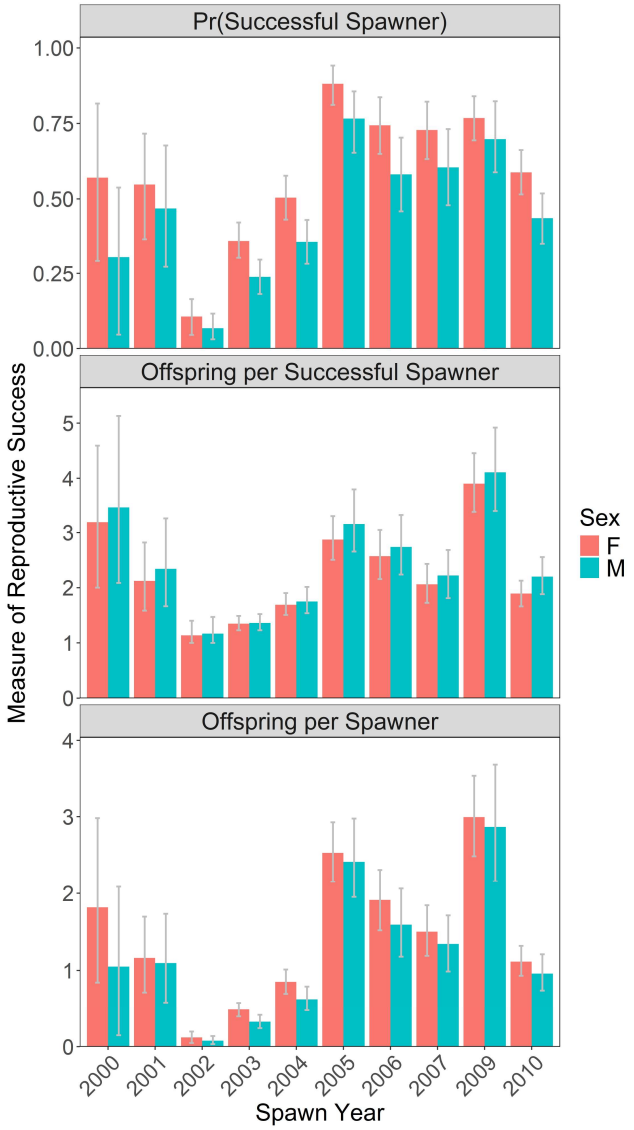


Probability of spawning success is highly variable across years, but on average, females are more likely to be successful.



Probability of spawning success is highly variable across years, but on average, females are more likely to be successful.

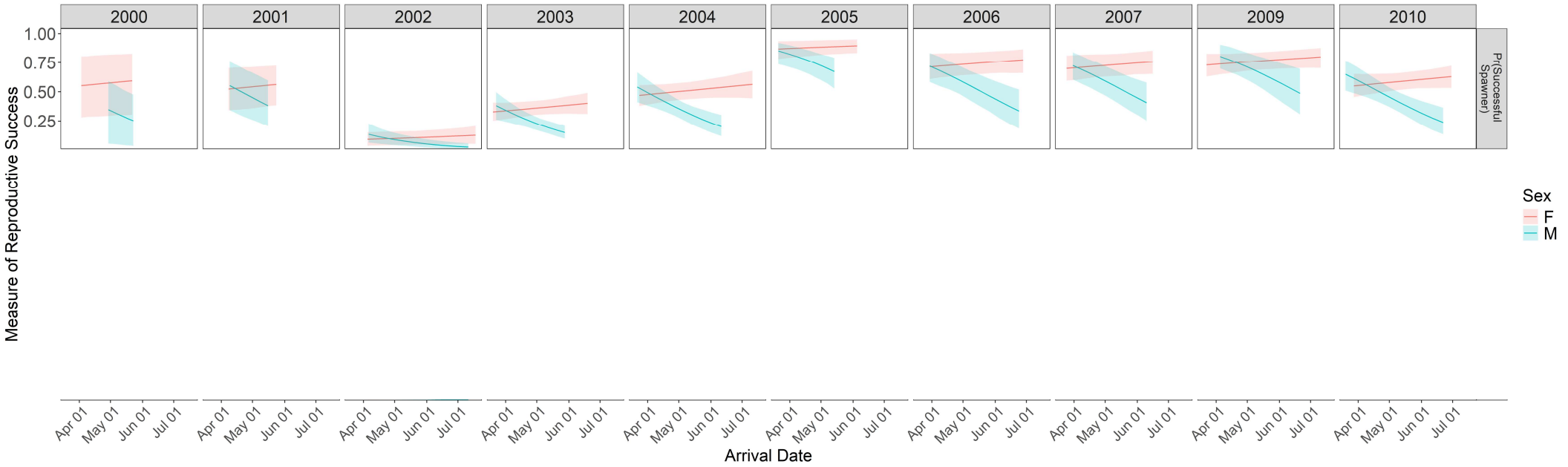
On average, successful males return more offspring than successful females.



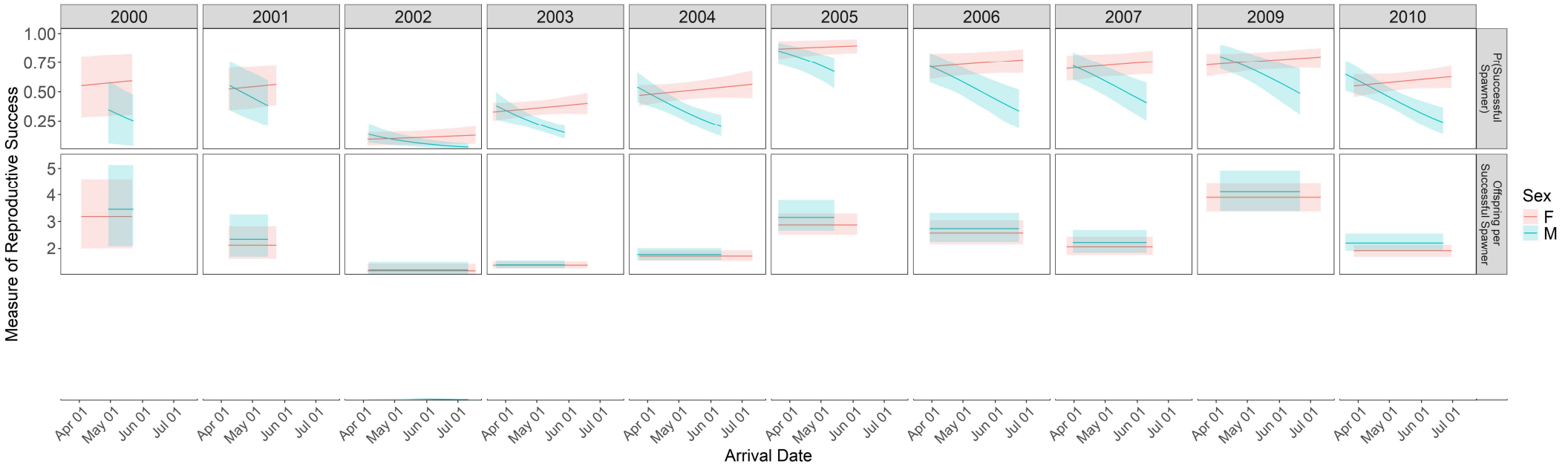
Probability of spawning success is highly variable across years, but on average, females are more likely to be successful.

On average, successful males return more offspring than successful females.

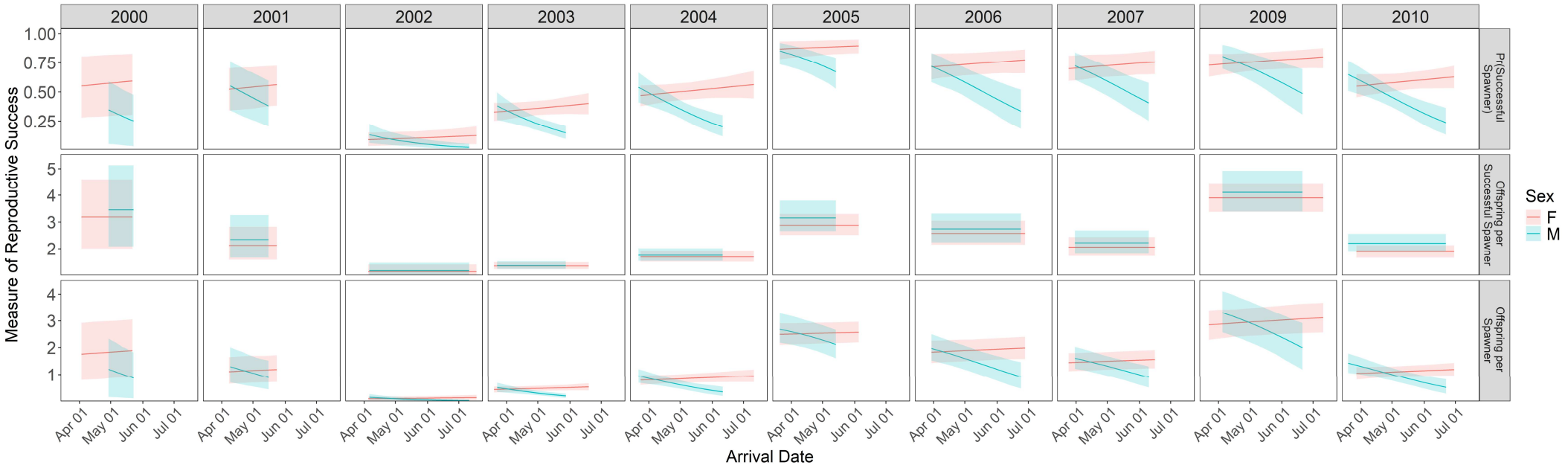
Considering both zero and conditional components, reproductive success is comparable between males and females.



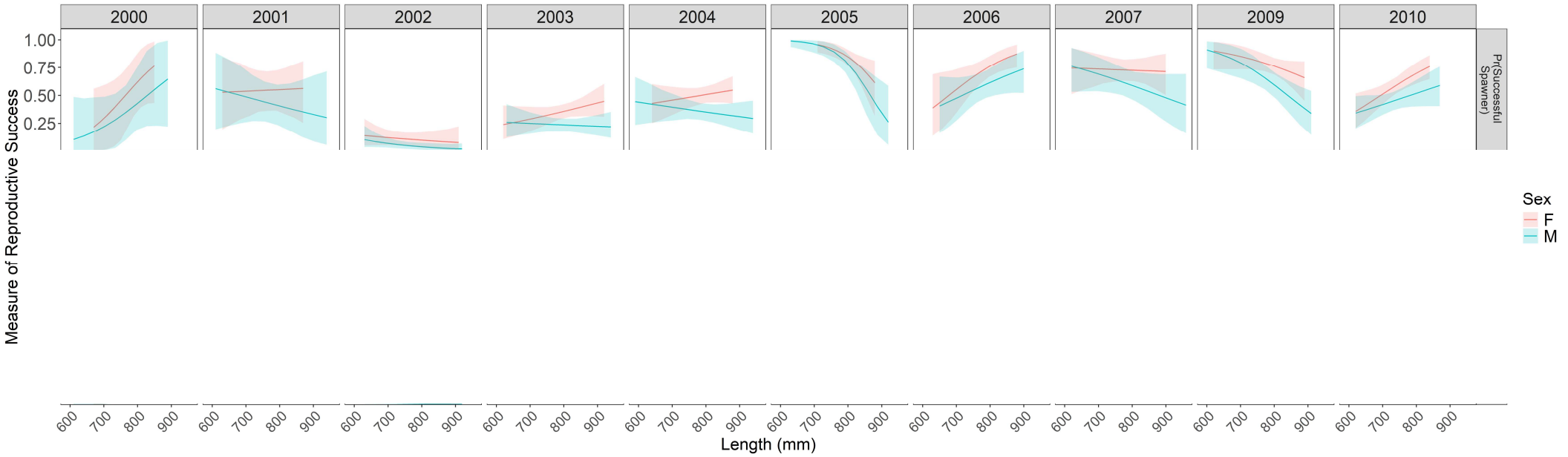
For females, probability of spawning success slightly increases with later arrival. For males, probability of successfully spawning decreases with later arrival.



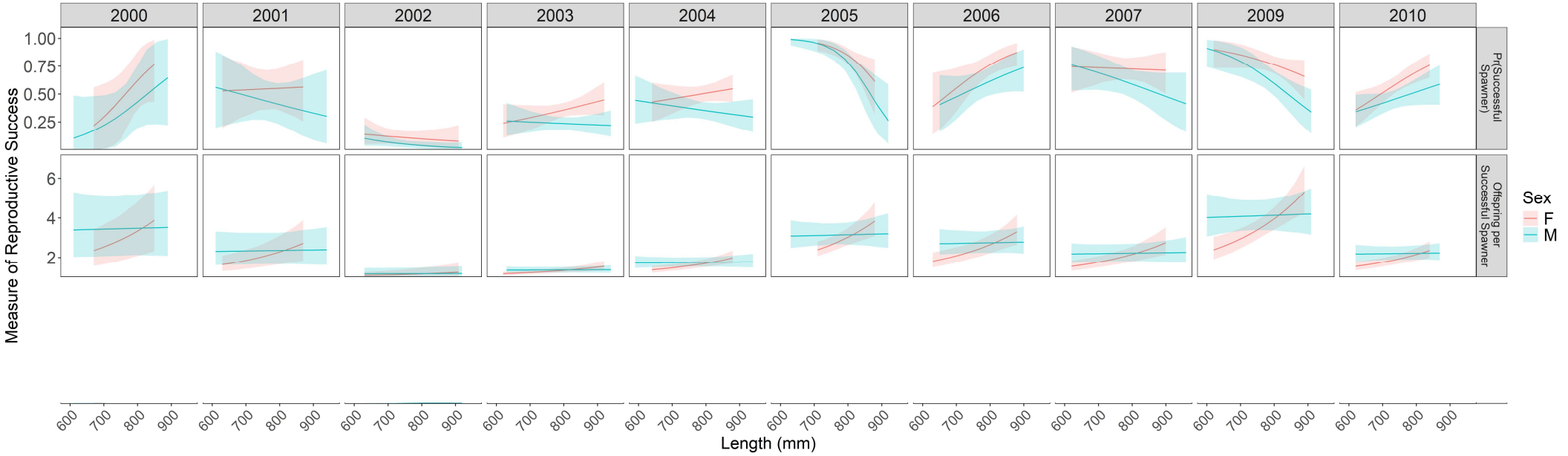
Arrival date was not supported as a covariate for the conditional component, so offspring per successful spawner is constant for males and females, regardless of arrival date.



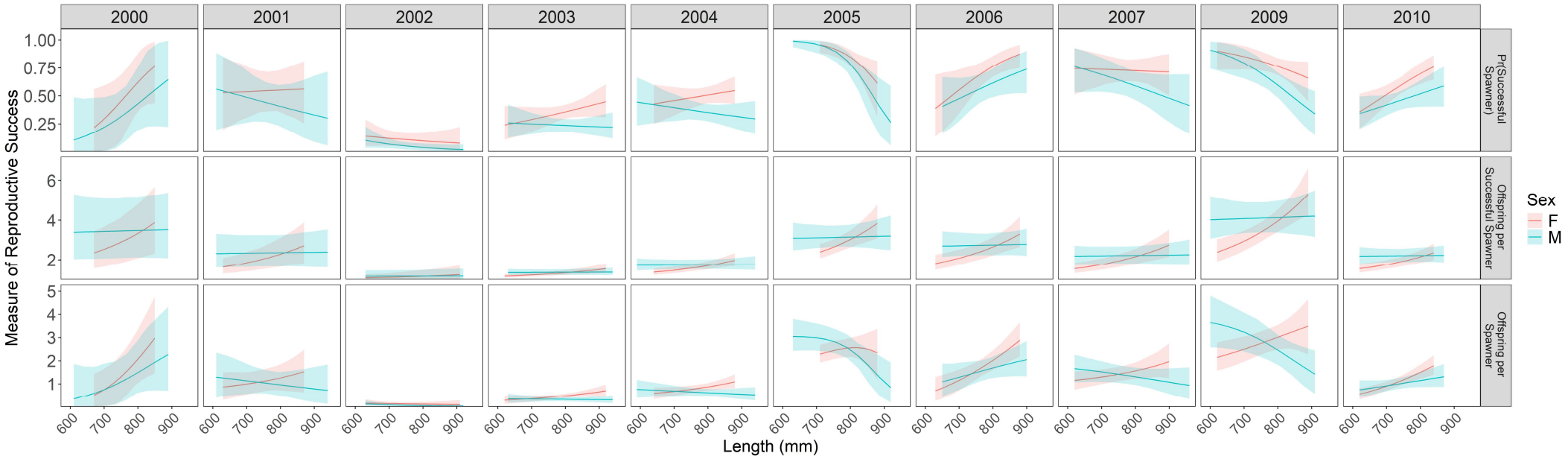
Taking both model components into account, males that arrive earlier return more offspring. In contrast, later arrival results in slightly higher reproductive success for females.



The relationship between spawning success, sex, and length is complex and varies across years.



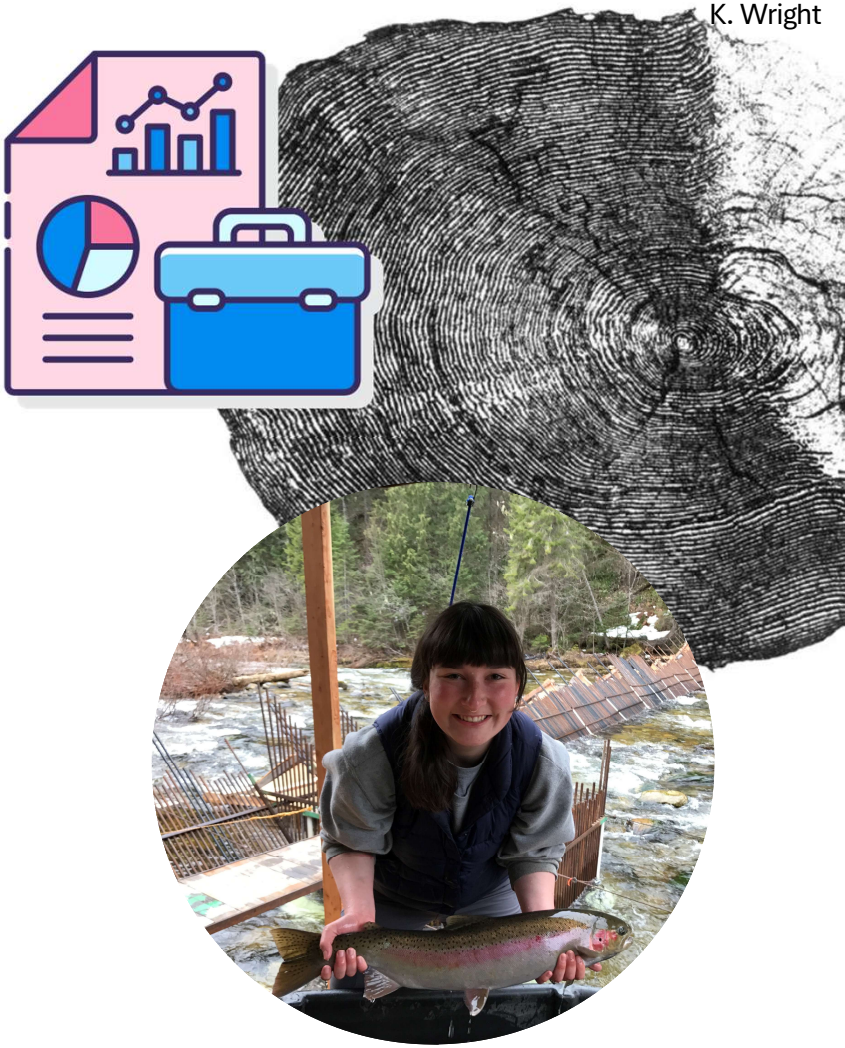
Successful males return consistent numbers of offspring regardless of size, whereas larger successful females tend to return more offspring.



Considering both zero and conditional components, smaller males and larger females tend to have higher overall reproductive success, but relationships are complex and vary significantly across years.

Fish Creek conclusions

- Opportunity to incorporate long-term demographic and genetic data across multiple generations
  - What drives population persistence?
  - How are populations buffered against stochasticity?
  - What purpose does life history diversity serve?



K. Wright

Acknowledgements


Marika Dobos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Funding
- Bonneville Power Administration

Sample collection
- Staff at the Fish Creek weir

Other analyses
- Nolan Smith

Sample inventory and genetic analysis
- Jesse McCane
- Natalie Beeken
- Lynn Schrader

Scale mounting and ageing
- Leslie Reinhardt
- Micah Davison


Questions?
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$$unsampled\ anadromous\ males = \frac{\left(\frac{sampled\ anadromous\ males}{proportion\ genotyped\ successfully}\right)}{weir\ efficiency} - sampled\ anadromous\ males$$

$$probability\ of\ success\ for\ anadromous\ males = \frac{unique\ successful\ sampled\ males}{sampled\ anadromous\ males}$$

$$successful\ unsampled\ anadromous\ males = unsampled\ anadromous\ males \times mean\ anadromous\ male\ reproductive\ success$$

$$successful\ unsampled\ resident\ males = unique\ males\ involved\ in\ SP\ assignments\ to\ females - successful\ unsampled\ anadromous\ males$$

$$mean\ reproductive\ success\ of\ anadromous\ males = \frac{offspring\ assigned\ to\ sampled\ anadromous\ males}{unique\ successful\ sampled\ males}$$

$$offspring\ of\ unsampled\ anadromous\ males = successful\ unsampled\ anadromous\ males \times mean\ reproductive\ success\ of\ anadromous\ males$$

$$offspring\ of\ unsampled\ resident\ males = offspring\ involved\ in\ SP\ assignments\ to\ females\ - offspring\ of\ unsampled\ anadromous\ males$$

$$mean\ reproductive\ success\ of\ resident\ males = \frac{offspring\ of\ unsampled\ resident\ males}{successful\ unsampled\ resident\ males}$$

$$proportion\ of\ offspring\ from\ unsampled\ resident\ males = \frac{offspring\ of\ unsampled\ resident\ males}{offspring\ of\ sampled\ anadromous\ males + offspring\ of\ unsampled\ anadromous\ males + offspring\ of\ unsampled\ resident\ males}$$

Global model

cond: $nOffspring \sim sex * dayOfYear + sex * length + sex * year + year * dayOfYear + year * length$

zi: $\sim sex * dayOfYear + sex * length + sex * year + year * dayOfYear + year * length$

Best fit model

cond: $nOffspring \sim length + sex + year + length{:}\, sex$

zi: $\sim dayOfYear + length + sex + year + dayOfYear{:}\, sex + length{:}\, sex + length{:}\, year$