Fitness Studies – PWS Pink Salmon Pedigree analyses and remaining work

Emily Lescak, K. Shedd, D. Prince, H. Hoyt, T. Dann, C. Habicht

Alaska Department of Fish and Game Gene Conservation Lab

Alaska Hatchery Research Program Informational Meeting

March 7, 2019

Alaska Hatchery Research Program

1) What is the genetic structure of pink and chum in PWS and SEAK?
2) What is the extent and annual variability of straying?
3) What is the impact on fitness (productivity) of natural pink and chum stocks due to straying hatchery pink and chum salmon?

Hatchery/Natural Fitness

Steelhead

433

Differential reproductive success of sympatric, naturally spawning hatchery and wild steelhead trout (*Oncorhynchus mykiss*) through the adult stage

Jennifer E. McLean, Paul Bentzen, and Thomas P. Quinn

MOLECULAR ECOLOGY

Molecular Ecology (2011) 20, 1860–1869 doi: 10.1111/j.1365-294X.2011.05058.x

Reduced reproductive success of hatchery coho salmon in the wild: insights into most likely mechanisms

VÉRONIQUE THÉRIAULT,* GREGORY R. MOYER,*† LAURA S. JACKSON,† MICHAEL S. BLOUIN‡ and MICHAEL A. BANKS*

Genetic Effects of Captive Breeding Cause a Rapid, Cumulative Fitness Decline in the Wild

Hitoshi Araki,* Becky Cooper, Michael S. Blouin

Pacific every year (7, 8). Although most of these hatchery programs are meant to produce fish for harvest, an increasing number of captive breeding programs are releasing fish to restore declining natural populations (8, 9). Hatchery fish breed in the wild, and many natural populations are affected by hatchery fish. The use of hatchery-reared fish as broodstock (parents of hatchery fish) for many generations has resulted in ind-

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Molecular Ecology (2007) 16, 953–966 doi: 10.1111/j.1365-294X.2006.03206.x

Effective population size of steelhead trout: influence of variance in reproductive success, hatchery programs, and genetic compensation between life-history forms

HITOSHI ARAKI,*ROBIN S. WAPLES,†WILLIAM R. ARDREN,*‡BECKY COOPER* and MICHAEL S. BLOUIN*

biology letters

Conservation biology

Biol. Lett. (2009) 5, 621–624 doi:10.1098/rsbl.2009.0315 *Published online* 10 June 2009

Carry-over effect of captive breeding reduces reproductive fitness of wild-born descendants in the wild

Hitoshi Araki[a,†], Becky Cooper and Michael S. Blouin

with captive-bred organisms (supplementation) are not clear yet.

Any negative effects of captive breeding are especially relevant for salmonid species because of the worldwide decline of native salmonid populations and the huge scale of hatchery programmes to compensate for those losses. Firstly, there is scant evidence that adding captive-bred organisms has boosted the long-term productivity of wild salmonid populations (Fraser 2008). Secondly, supplementation of declining wild populations entails risks such as disease introductions, increased competition for resources, and genetic changes in the supplemented population (Waples & Drake 2004). The genetic risk results because artificial environments can select for captive-bred individuals that are maladapted to the natural environment (hereafter 'the wild'). For example, genetically-based

Transactions of the American Fisheries Society

Publication details, including instructions for authors and subscription information: http://www.tandfonline.com/loi/utaf20

Diminished Reproductive Success of Steelhead from a Hatchery Supplementation Program (Little Sheep Creek, Imnaha Basin, Oregon)

Ewann A. Berntson [a], Richard W. Carmichael [b], Michael W. Flesher [b], Eric J. Ward [c] & Paul Moran [c]

PNAS

Genetic adaptation to captivity can occur in a single generation

Mark R. Christie[a,1], Melanie L. Marine[a], Rod A. French[b], and Michael S. Blouin[a]

[a]Department of Zoology, Oregon State University, Corvallis, OR 97331-2914; and [b]Oregon Department of Fish and Wildlife, The Dalles, OR 97058-4364

Edited by Fred W. Allendorf, University of Montana, Missoula, MT, and accepted by the Editorial Board November 11, 2011 (received for review July 14, 2011)

Captive breeding programs are widely used for the conservation and restoration of threatened and endangered species. Nevertheless, captive-born individuals frequently have reduced fitness when have a high standing mutational load or spend many generations in captivity (9). Unintentional domestication selection, on the other hand, can rapidly reduce fitness in the wild, especially if

Chinook

North American Journal of Fisheries Management 28:1472–1485, 2008 [Article]

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DOI: 10.1577/M07-195.1

Use of Parentage Analysis to Determine Reproductive Success of Hatchery-Origin Spring Chinook Salmon Outplanted into Shitike Creek, Oregon

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DAVID M. HAND[2] AND DOUGLAS E. OLSON

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ROBERT SPATEHOLTS[2] AND GEOFF FITZGERALD[3]

Confederated Tribes of the Warm Springs Reservation of Oregon, Department of Natural Resources, Warm Springs, Oregon 97761, USA

WILLIAM R. ARDREN[4]

U.S. Fish and Wildlife Service, Abernathy Fish Technology Center, 1440 Abernathy Creek Road, Longview, Washington 98632, USA

@15 30 May 2014

1840

Factors influencing the relative fitness of hatchery and wild spring Chinook salmon (*Oncorhynchus tshawytscha*) in the Wenatchee River, Washington, USA

Kevin S. Williamson, Andrew R. Murdoch, Todd N. Pearsons, Eric J. Ward, and Michael J. Ford

MOLECULAR ECOLOGY

Molecular Ecology (2012) 21, 5236–5250 doi: 10.1111/mec.12046

Supportive breeding boosts natural population abundance with minimal negative impacts on fitness of a wild population of Chinook salmon

MAUREEN A. HESS,* CRAIG D. RABE,† JASON L. VOGEL,‡ JEFF J. STEPHENSON,* DOUG D. NELSON† and SHAWN R. NARUM*

Evolutionary Applications

Evolutionary Applications ISSN 1752-4571

ORIGINAL ARTICLE

Reproductive success of captively bred and naturally spawned Chinook salmon colonizing newly accessible habitat

Joseph H. Anderson,[1,3,*] Paul L. Faulds,[2] William I. Atlas[1,4] and Thomas P. Quinn[1]

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[3] Present address: Northwest Fisheries Science Center, National Marine Fisheries Service Seattle, WA, USA
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Keywords
conservation, dams, hatchery, natural selection, pedigree, reintroduction, sexual selection

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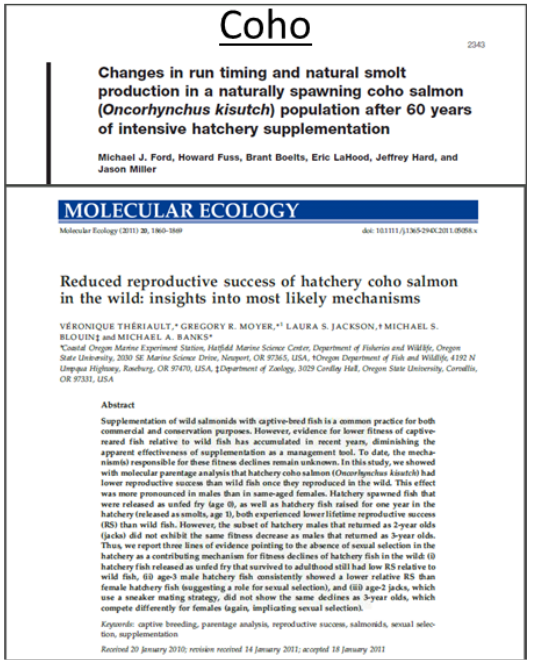
Received: 23 March 2012
Accepted: 2 April 2012

doi:10.1111/j.1752-4571.2012.00271.x

Abstract

Captively reared animals can provide an immediate demographic boost in reintroduction programs, but may also reduce the fitness of colonizing populations. Construction of a fish passage facility at Landsburg Diversion Dam on the Cedar River, WA, USA, provided a unique opportunity to explore this trade-off. We thoroughly sampled adult Chinook salmon (*Oncorhynchus tshawytscha*) at the onset of colonization (2003–2009), constructed a pedigree from genotypes at 10 microsatellite loci, and calculated reproductive success (RS) as the total number of returning adult offspring. Hatchery males were consistently but not significantly less productive than naturally spawned males (range in relative RS: 0.70–0.90), but the pattern for females varied between years. The sex ratio was heavily biased toward males; therefore, inclusion of the hatchery males increased the risk of a genetic fitness cost with little demographic benefit. Measurements of natural selection indicated that larger salmon had higher RS than smaller fish. Fish that arrived early to the spawning grounds tended to be more productive than later fish, although in some years, RS was maximized at intermediate dates. Our results underscore the importance of natural and sexual selection in promoting adapta-

Coho



2343

Changes in run timing and natural smolt production in a naturally spawning coho salmon (*Oncorhynchus kisutch*) population after 60 years of intensive hatchery supplementation

Michael J. Ford, Howard Fuss, Brant Boelts, Eric LaHood, Jeffrey Hard, and Jason Miller

MOLECULAR ECOLOGY

Molecular Ecology (2011) 20, 1860–1869 doi: 10.1111/j.1365-294X.2011.05058.x

Reduced reproductive success of hatchery coho salmon in the wild: insights into most likely mechanisms

VÉRONIQUE THÉRIAULT,* GREGORY R. MOYER,*† LAURA S. JACKSON,† MICHAEL S. BLOUIN‡ and MICHAEL A. BANKS*

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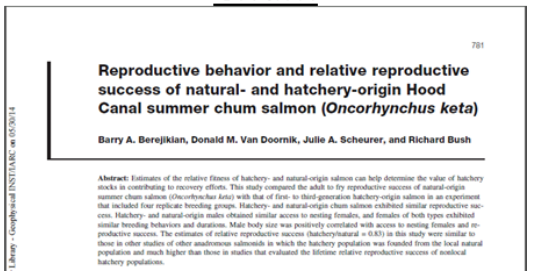
Abstract

Supplementation of wild salmonids with captive-bred fish is a common practice for both commercial and conservation purposes. However, evidence for lower fitness of captive-reared fish relative to wild fish has accumulated in recent years, diminishing the apparent effectiveness of supplementation as a management tool. To date, the mechanism(s) responsible for these fitness declines remain unknown. In this study, we showed with molecular parentage analysis that hatchery coho salmon (*Oncorhynchus kisutch*) had lower reproductive success than wild fish once they reproduced in the wild. This effect was more pronounced in males than in same-aged females. Hatchery spawned fish that were released as unfed fry (age 0), as well as hatchery fish raised for one year in the hatchery (released as smolts, age 1), both experienced lower lifetime reproductive success (RS) than wild fish. However, the subset of hatchery males that returned as 2-year olds (jacks) did not exhibit the same fitness decrease as males that returned as 3-year olds. Thus, we report those lines of evidence pointing to the absence of sexual selection in the hatchery as a contributing mechanism for fitness declines of hatchery fish in the wild: (i) hatchery fish released as unfed fry that survived to adulthood still had low RS relative to wild fish, (ii) age-3 male hatchery fish consistently showed a lower relative RS than female hatchery fish (suggesting a role for sexual selection), and (iii) age-2 jacks, which use a sneaker mating strategy, did not show the same declines as 3-year olds, which compete differently for females (again, implicating sexual selection).

Keywords: captive breeding, parentage analysis, reproductive success, salmonids, sexual selection, supplementation

Received 20 January 2010; revision received 14 January 2011; accepted 18 January 2011

Chum



781

Reproductive behavior and relative reproductive success of natural- and hatchery-origin Hood Canal summer chum salmon (*Oncorhynchus keta*)

Barry A. Berejikian, Donald M. Van Doornik, Julie A. Scheurer, and Richard Bush

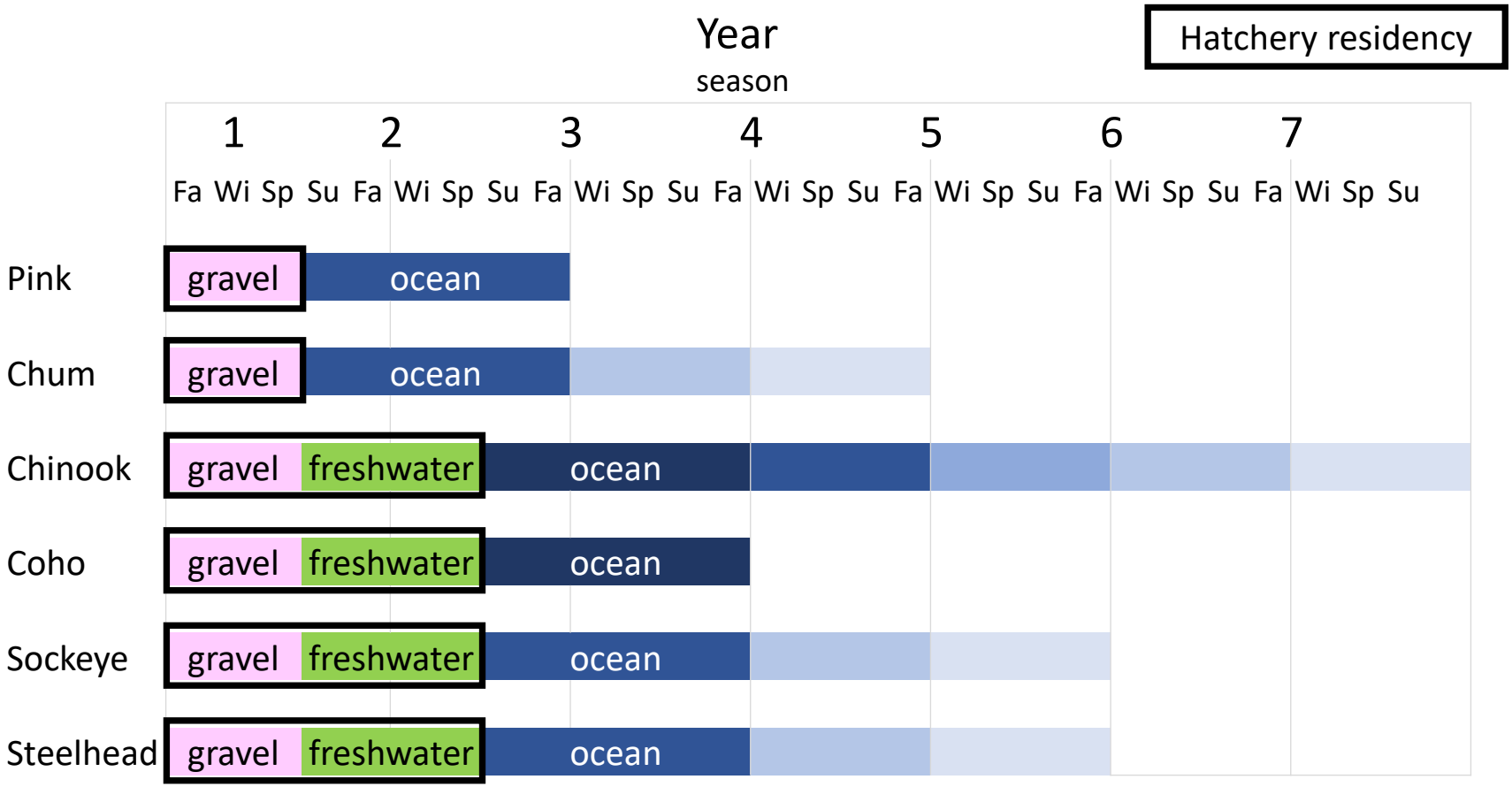
Abstract: Estimates of the relative fitness of hatchery- and natural-origin salmon can help determine the value of hatchery stocks in contributing to recovery efforts. This study compared the adult to fry reproductive success of natural-origin summer chum salmon (*Oncorhynchus keta*) with that of first- to third-generation hatchery-origin salmon in an experiment that included four replicate breeding groups. Hatchery- and natural-origin chum salmon exhibited similar reproductive success. Hatchery- and natural-origin males obtained similar access to nesting females, and females of both types exhibited similar breeding behaviors and durations. Male body size was positively correlated with access to nesting females and reproductive success. The estimates of relative reproductive success (hatchery/natural = 0.83) in this study were similar to those in other studies of other anadromous salmonids in which the hatchery population was founded from the local natural population and much higher than those in studies that evaluated the lifetime relative reproductive success of nonlocal hatchery populations.

Library - Geophysical INST/ARC on 05/20/14

Hatchery/Natural Fitness

- No pinks and only one chum study

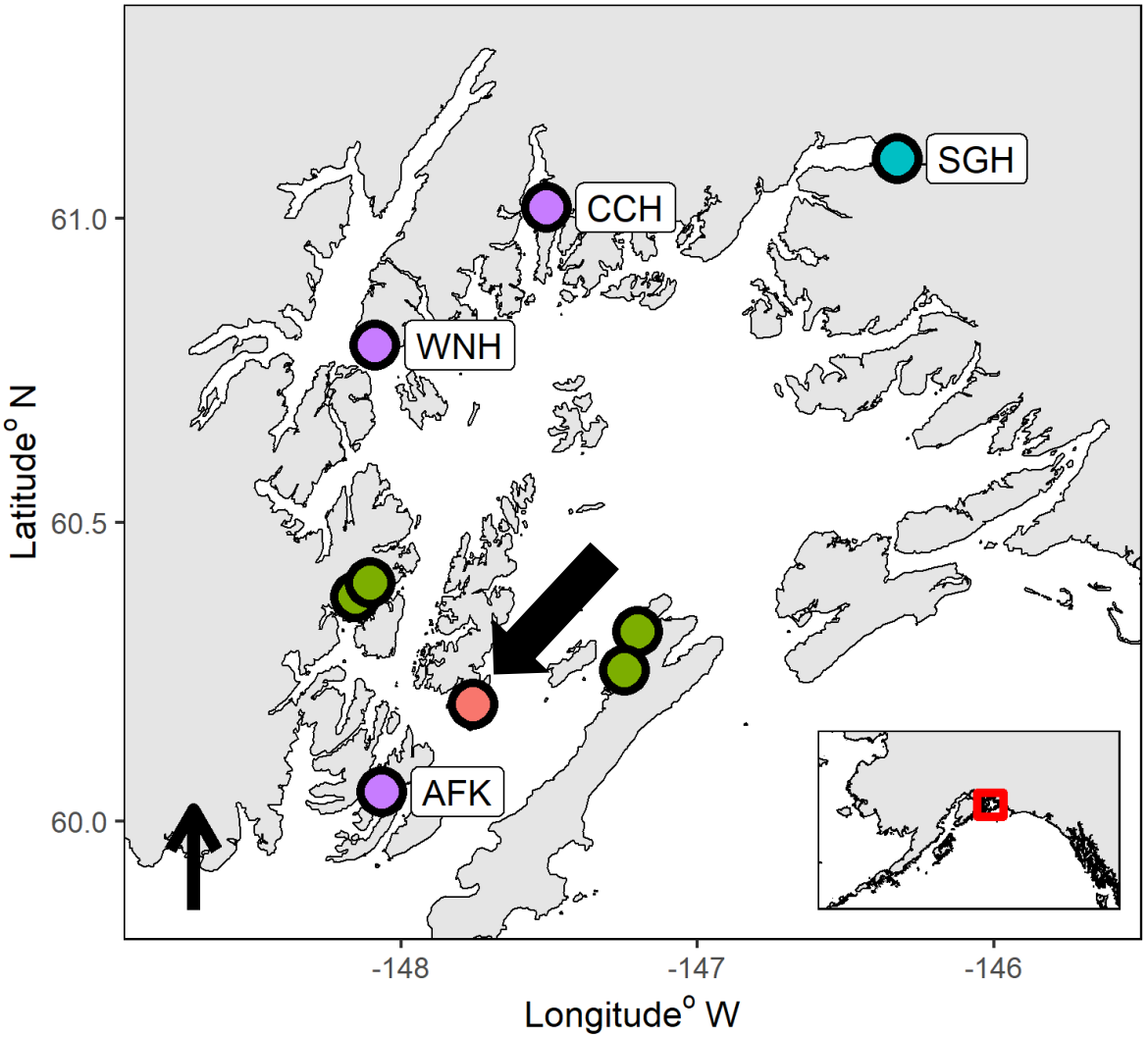
Life history and hatchery residencies for Pacific Salmon species



Hatchery/Natural Fitness

- No pinks and only one chum study
- No studies in Alaska
- Different hatchery objectives
- Local + large brood stock population size

AHRP Streams in PWS



VFDA = Valdez Fisheries Development Association
PWSAC = Prince William Sound Aquaculture Corporation

Figure 1 – Lescak et al. *in prep*

Fitness = Reproductive Success

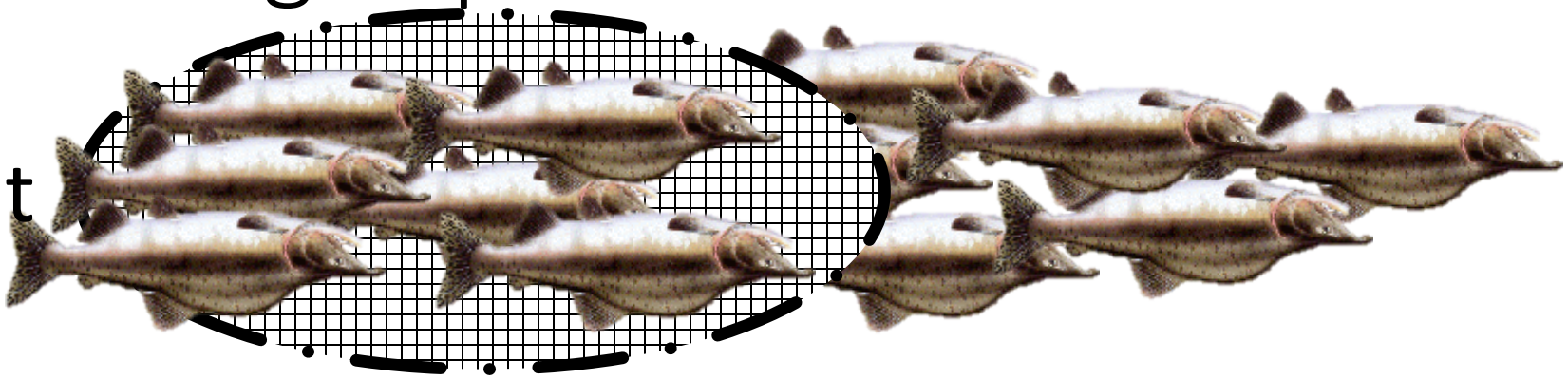
Parent 

Measuring Reproductive Success

Parent

Measuring Reproductive Success

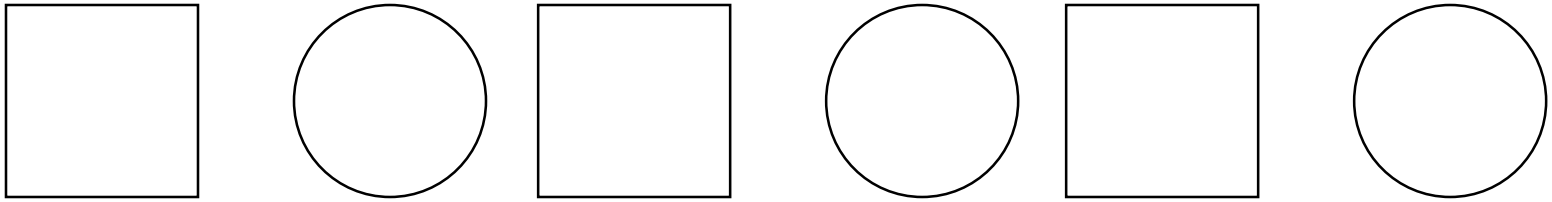
Parent



Measuring Reproductive Success

Parent 

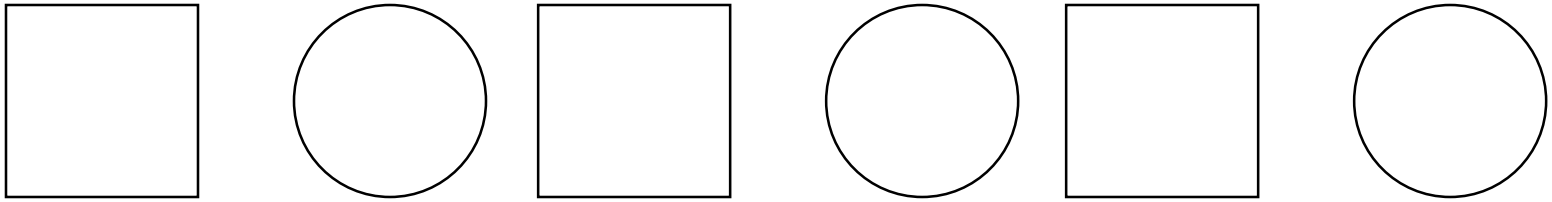
Measuring Reproductive Success

P 

Male

Female

Measuring Reproductive Success

P 

Male

Female

Measuring Reproductive Success

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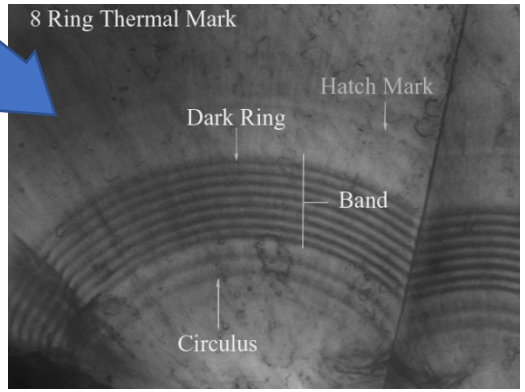
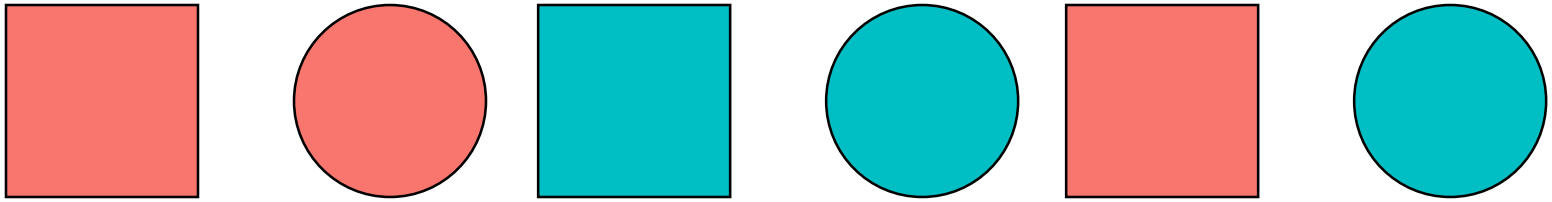


Male

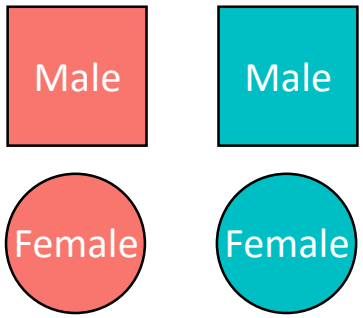
Female

Hatchery-origin

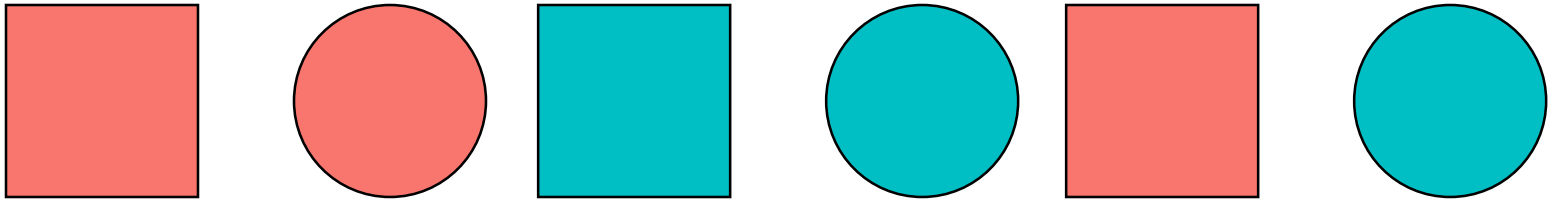
Measuring Reproductive Success

P 

Natural **Hatchery**



Measuring Reproductive Success

P 

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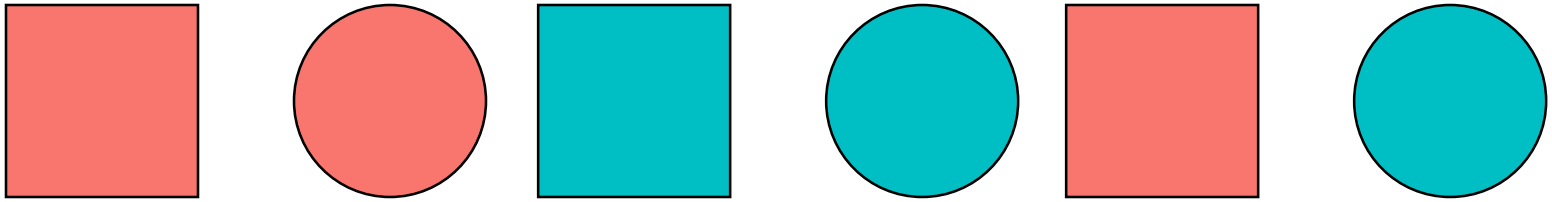
Natural **Hatchery**

Male Male

Female Female

Measuring Reproductive Success

P 

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Natural **Hatchery**

Male Male

Female Female

Measuring Reproductive Success

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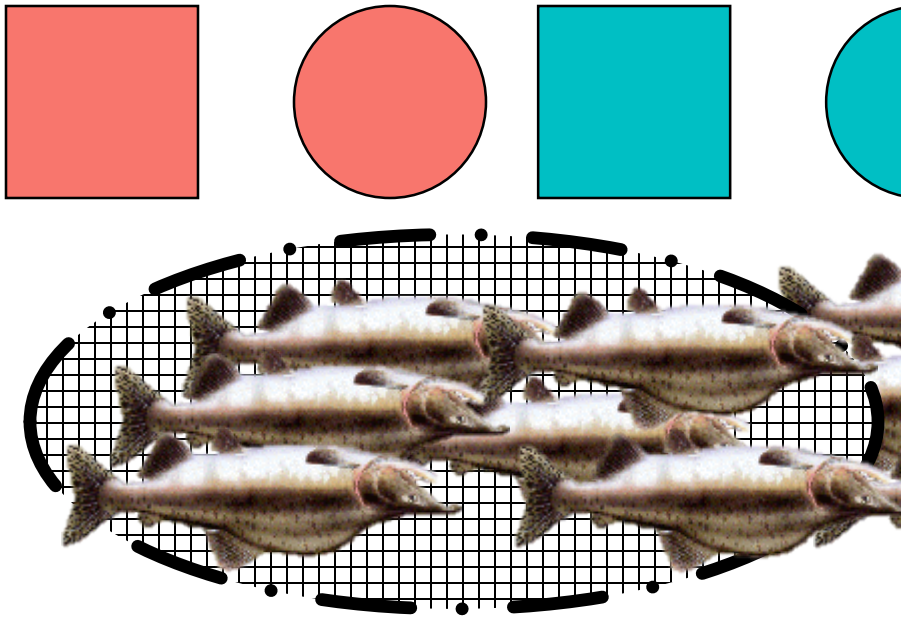

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Natural **Hatchery**

Male Male

Female Female

Measuring Reproductive Success

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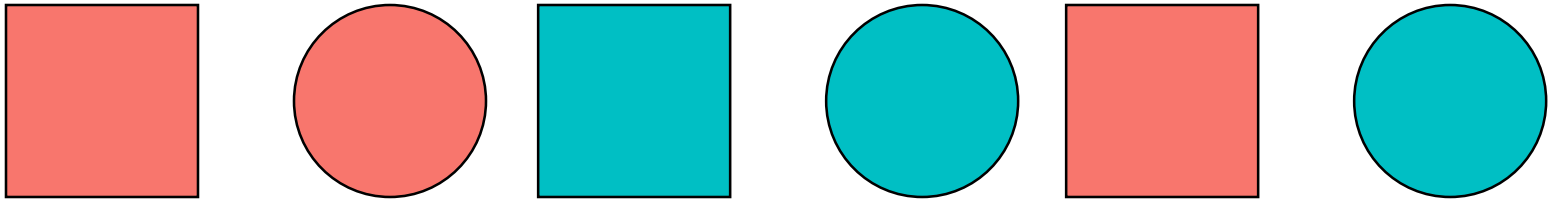

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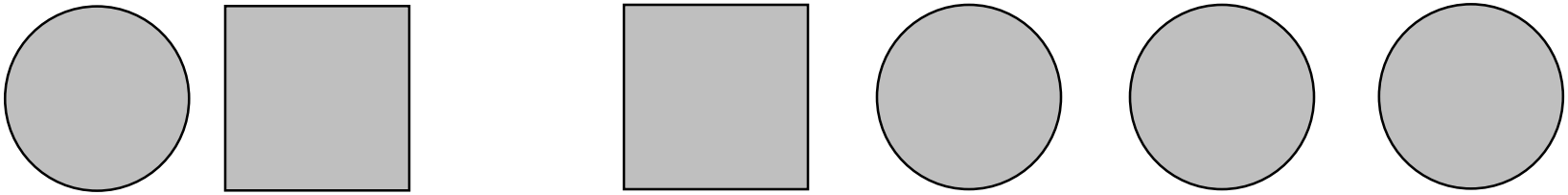
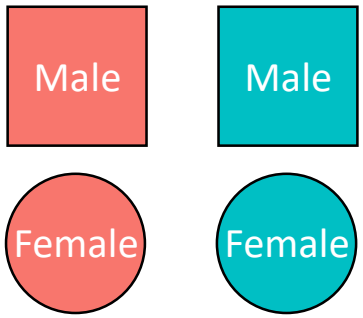


Natural **Hatchery**



Measuring Reproductive Success

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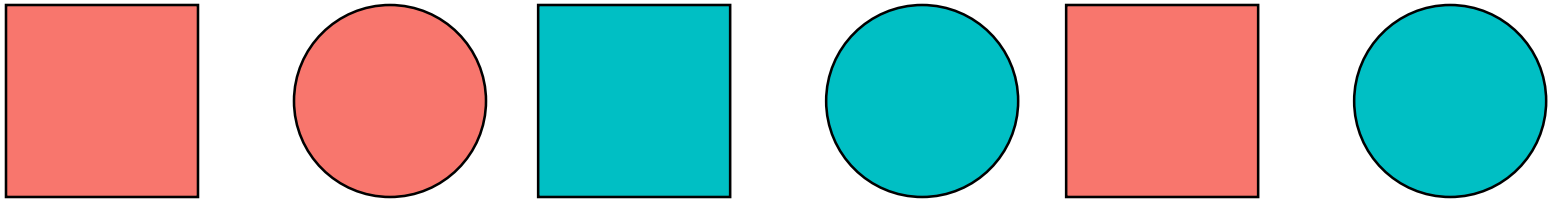

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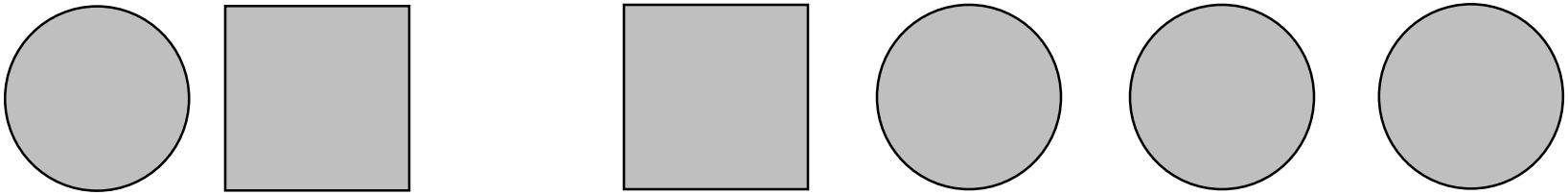
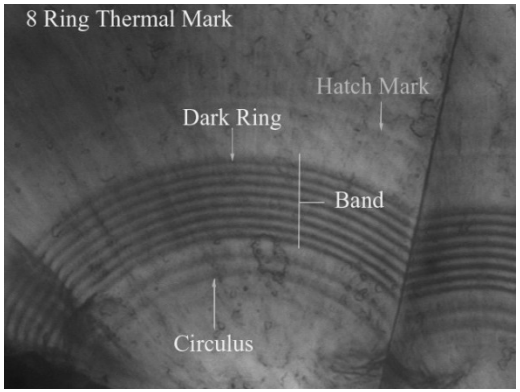


Natural Hatchery

Male Male

Female Female



Hatchery-origin

Measuring Reproductive Success

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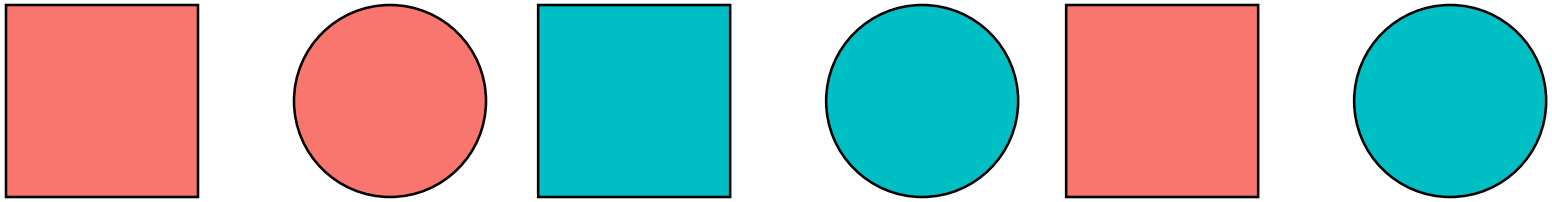

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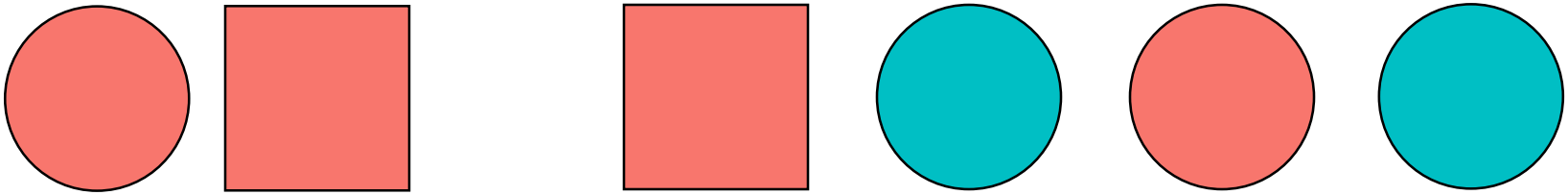

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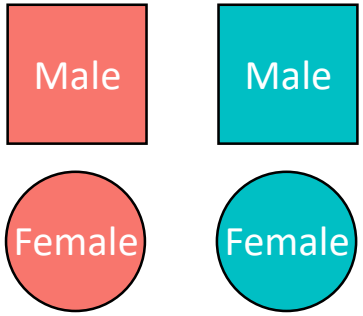
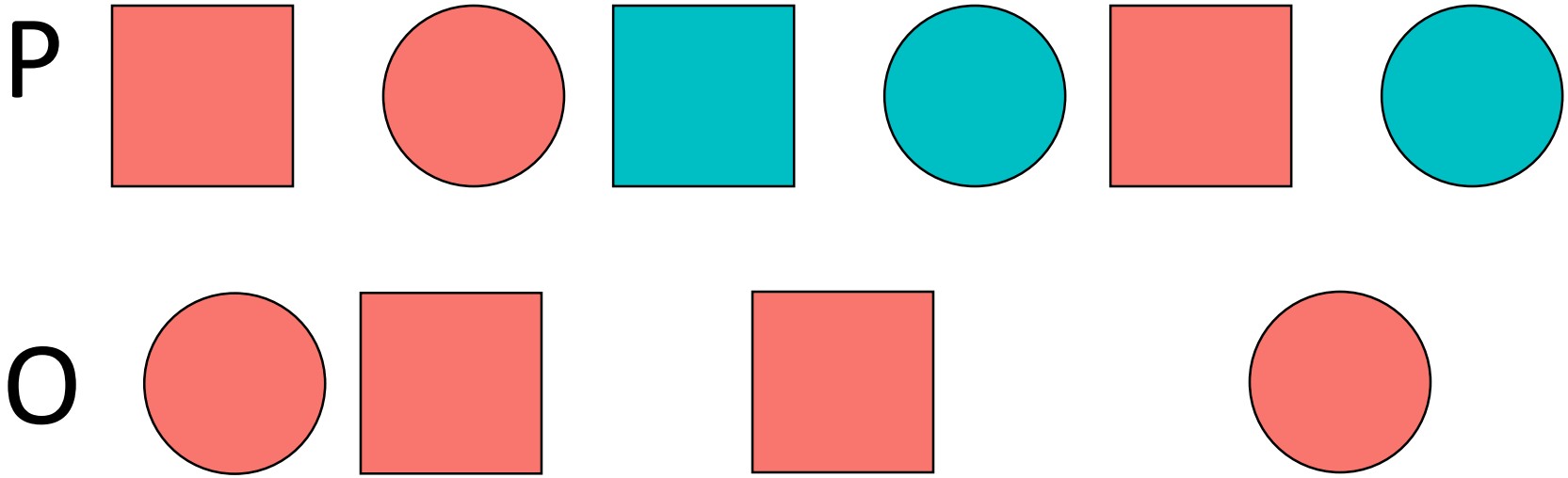


Measuring Reproductive Success



Natural **Hatchery**

Male Male

Female Female

Hatchery-origin fish are not genotyped in the offspring generation because they have a known origin.

Measuring Reproductive Success

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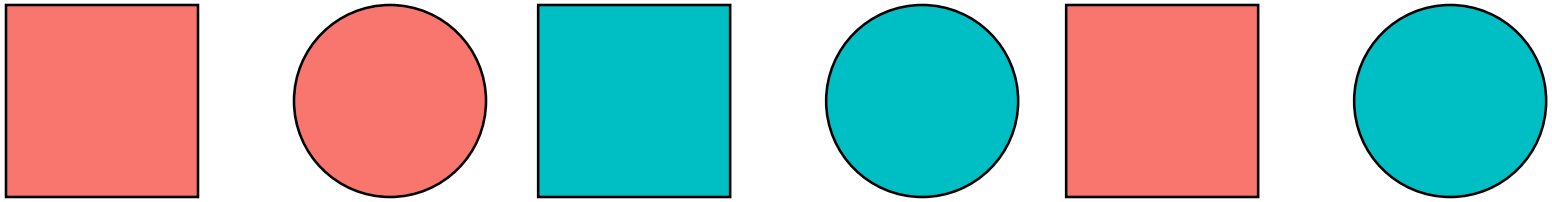

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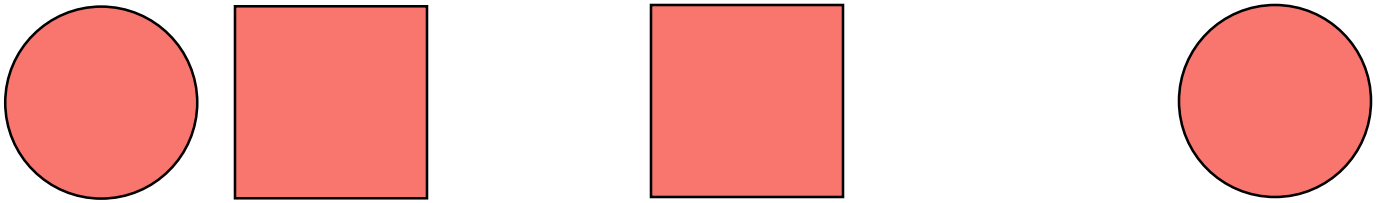
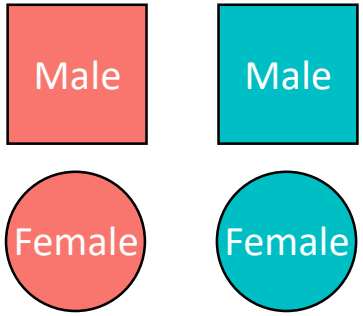


Natural **Hatchery**



298 markers

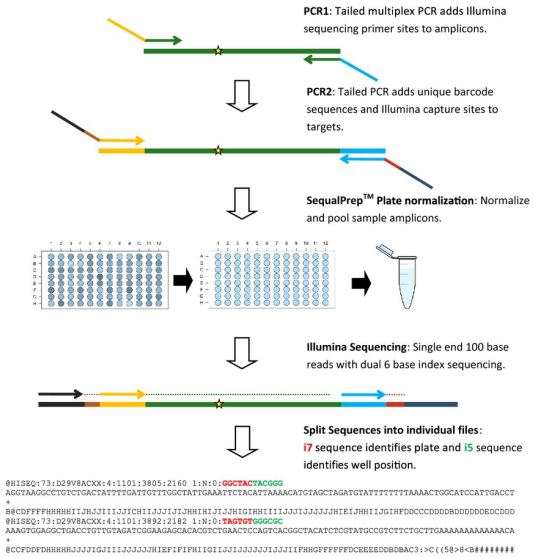


Figure 1 – Campbell et al. 2015

Measuring Reproductive Success

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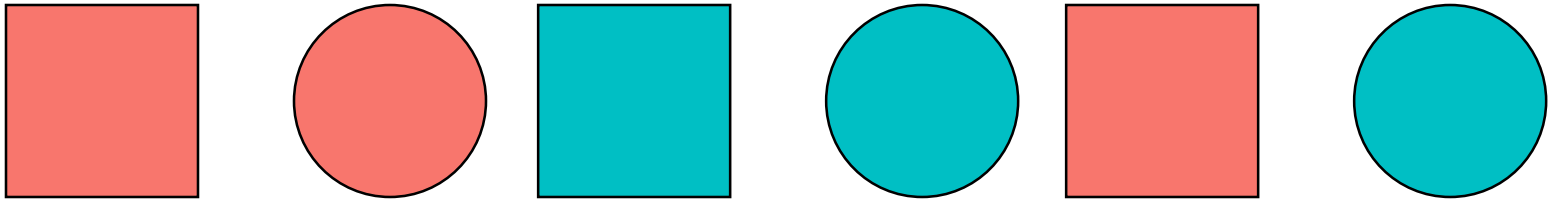

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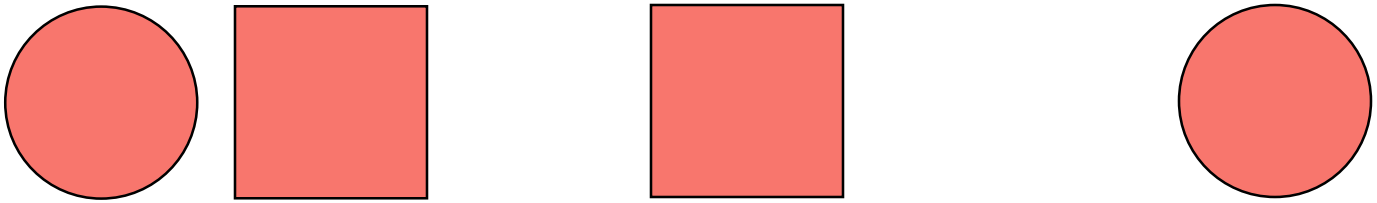


Natural **Hatchery**

Male Male

Female Female

298 markers

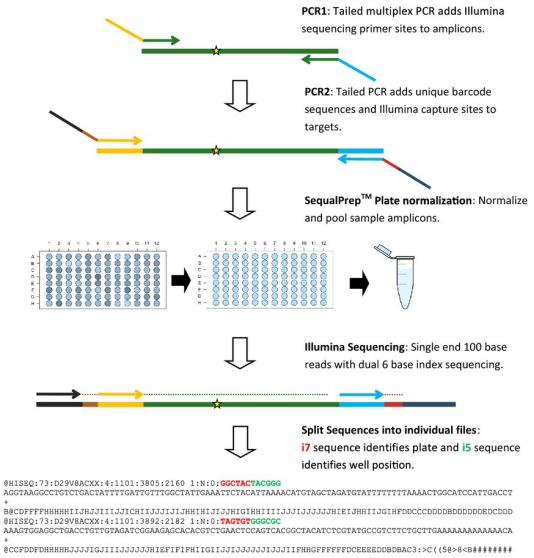


Figure 1 – Campbell et al. 2015

Riester et al. 2009

Genetic markers for parentage analysis

CTATGTA**T**TAAATGTTAATAATAATAACTAGCTAACC — ***T*** *allele*

CTATGTA**A**TAAATGTTAATAATAATAACTAGCTAACC — ***A*** *allele*

CTATGTA**A**TAAATGTTAATAATAATAACTAGCTAACC — ***A*** *allele*

CTATGTA**A**TAAATGTTAATAATAATAACTAGCTAACC — ***A*** *allele*

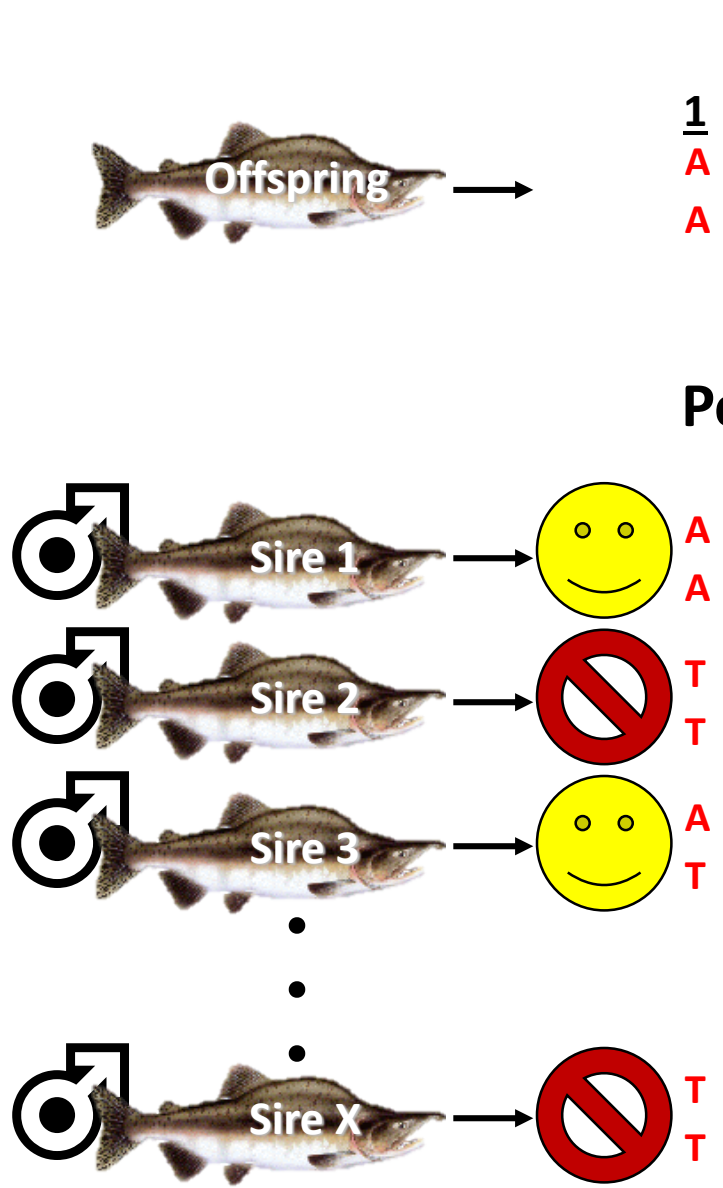
CTATGTA**A**TAAATGTTAATAATAATAACTAGCTAACC — ***A*** *allele*

CTATGTA**T**TAAATGTTAATAATAATAACTAGCTAACC — ***T*** *allele*

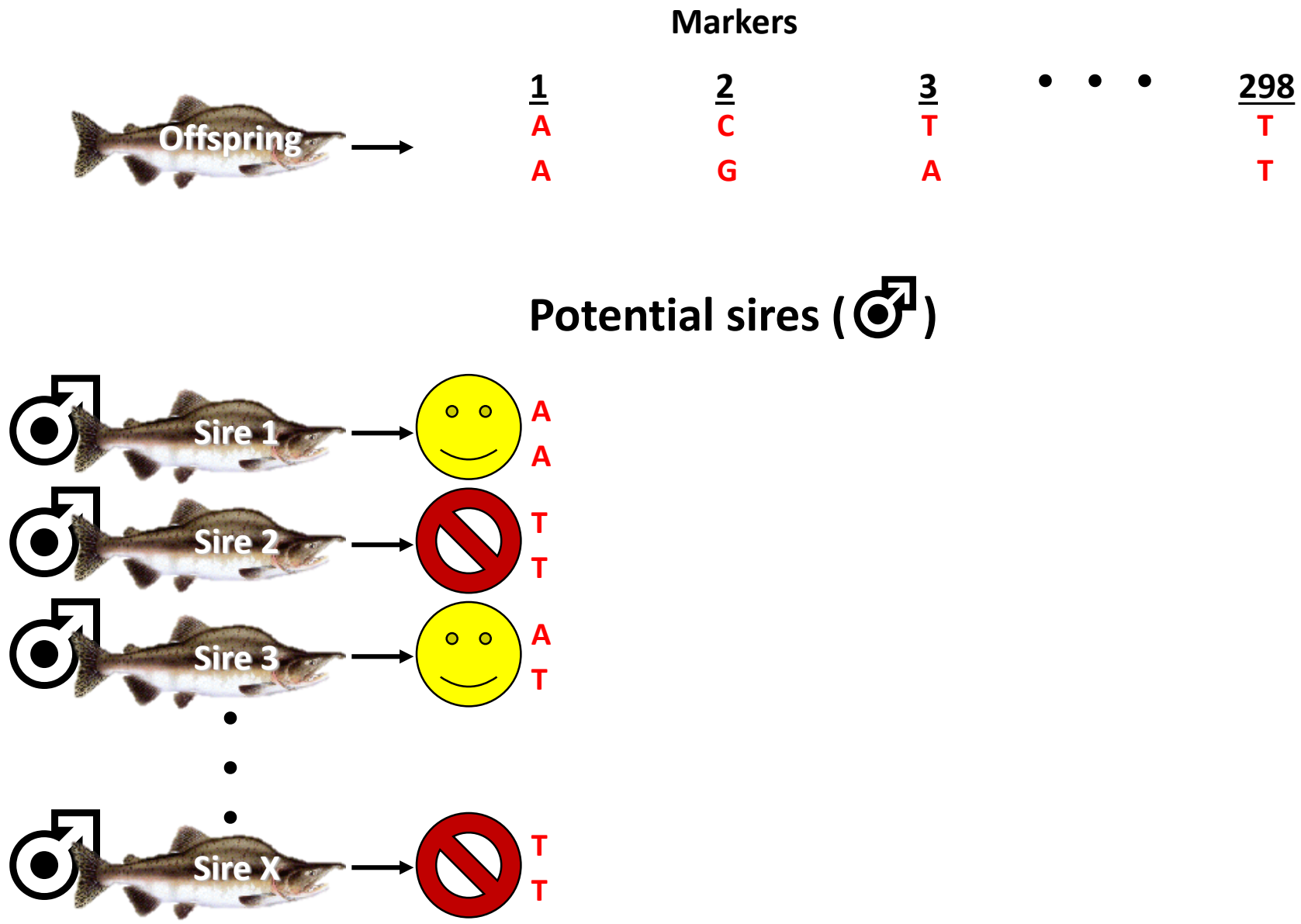
CTATGTA**T**TAAATGTTAATAATAATAACTAGCTAACC — ***T*** *allele*

CTATGTA**T**TAAATGTTAATAATAATAACTAGCTAACC — ***T*** *allele*

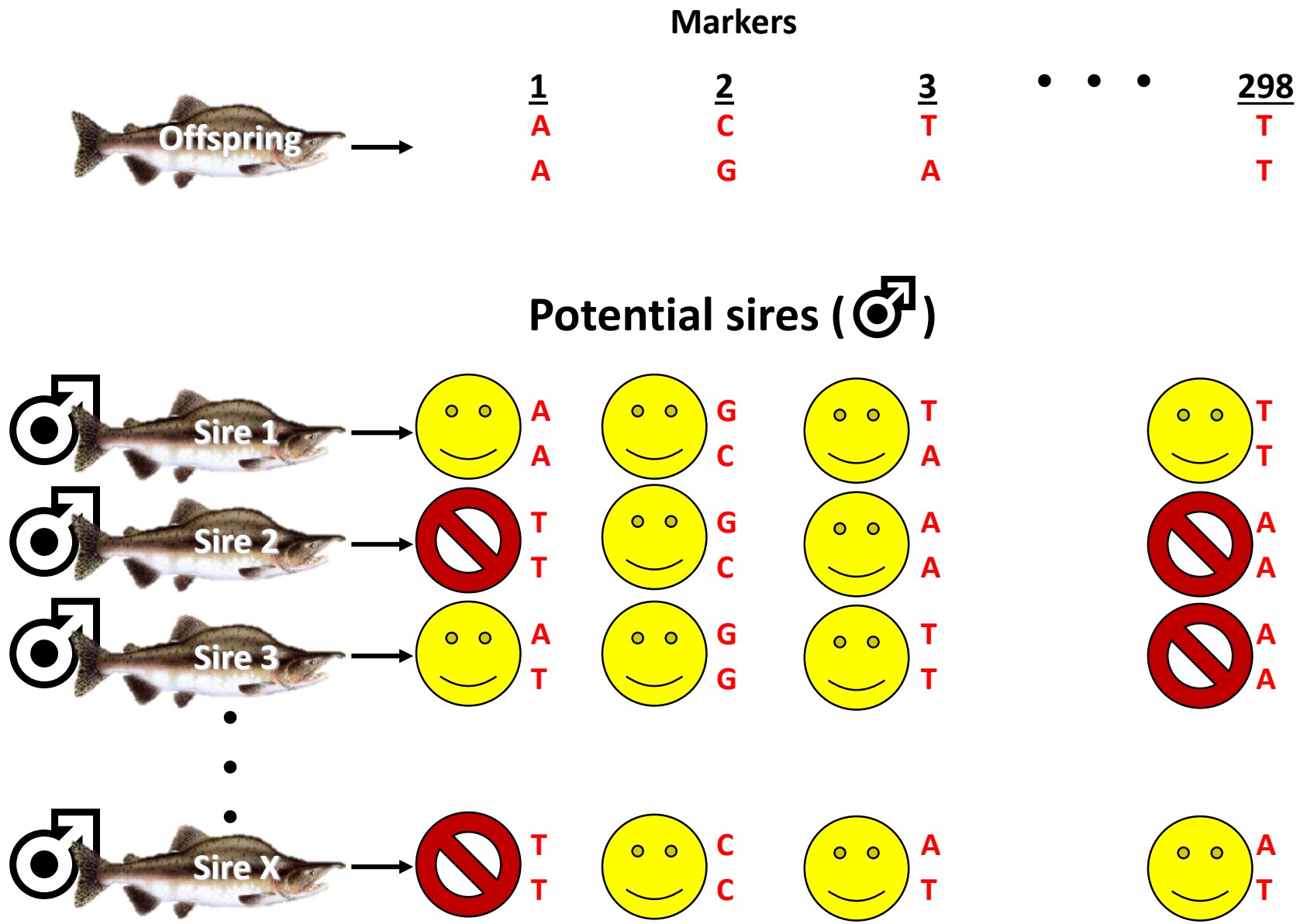
Genetic markers for parentage analysis



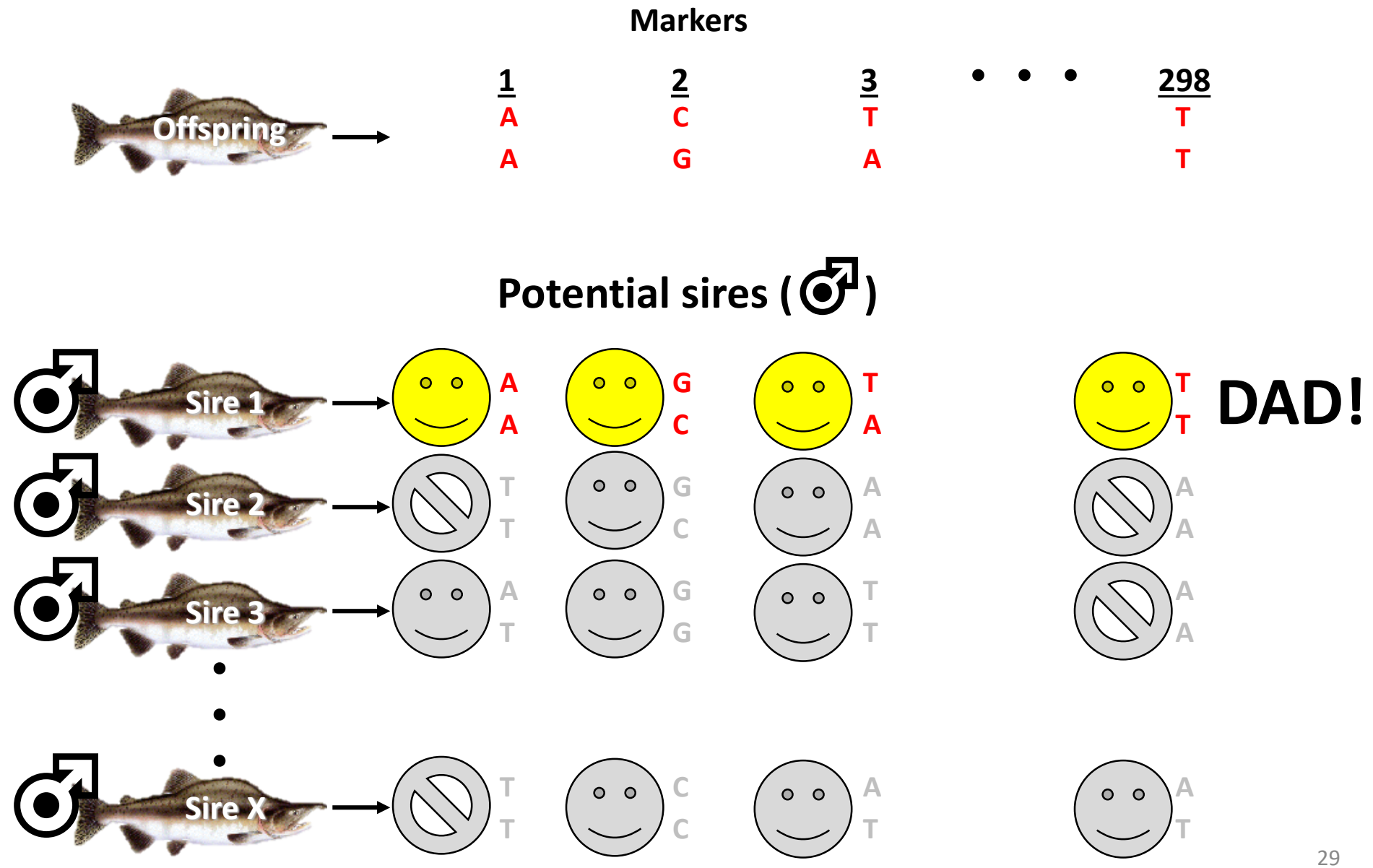
Genetic markers for parentage analysis



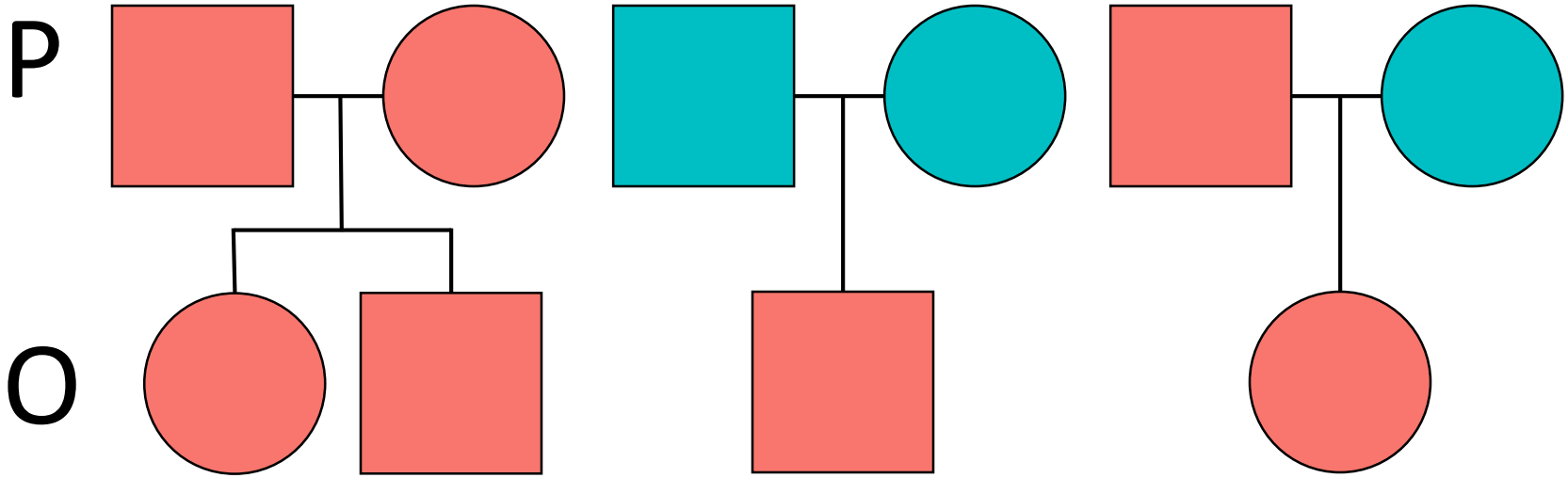
Genetic markers for parentage analysis



Genetic markers for parentage analysis



Measuring Reproductive Success

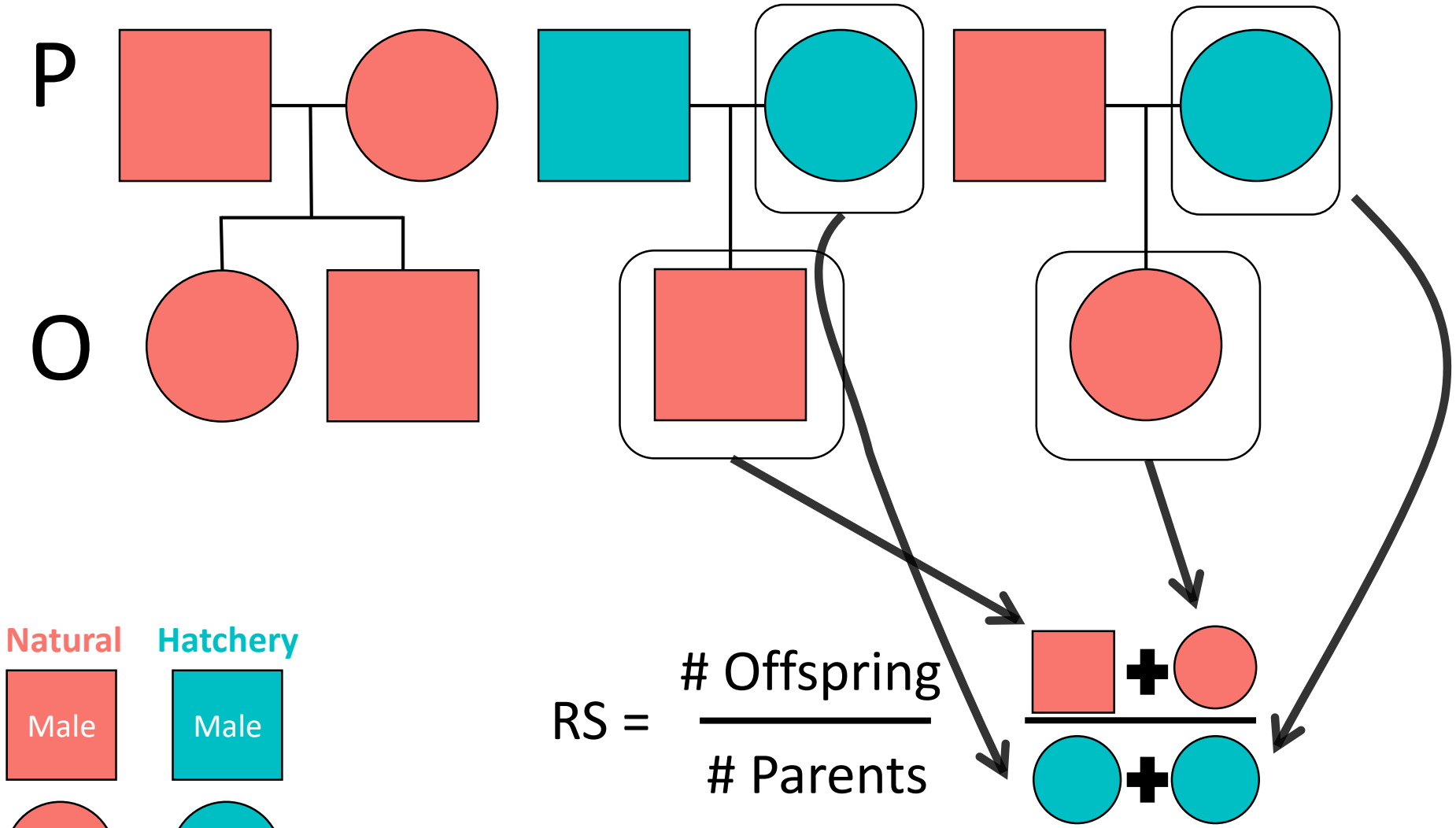


Natural Hatchery

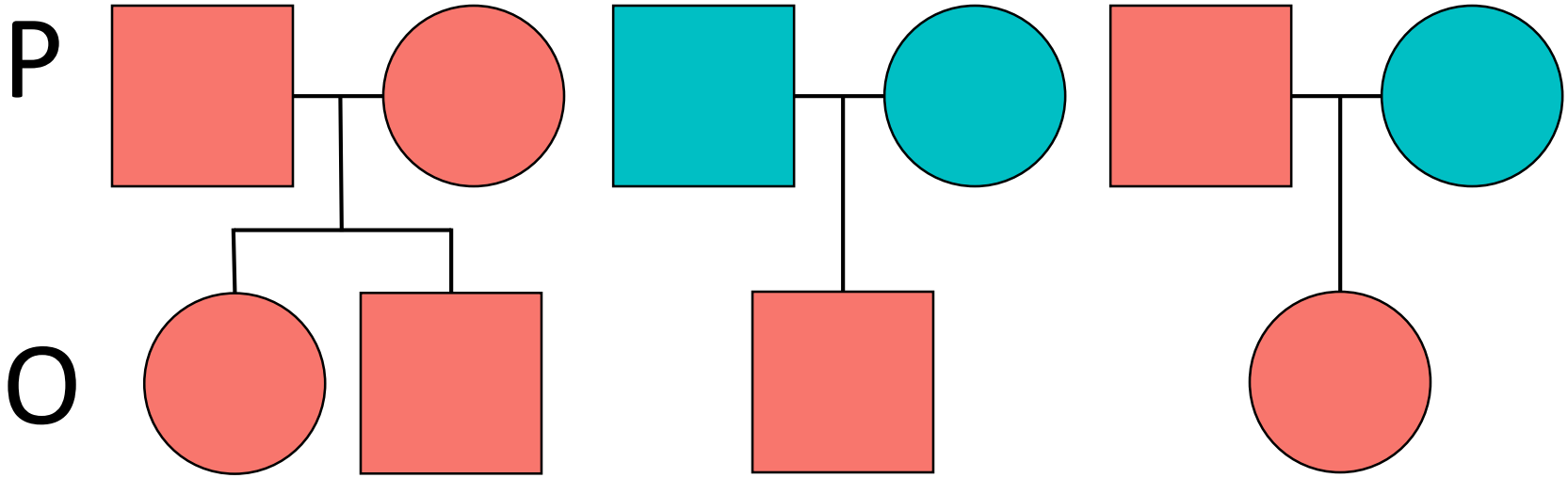
Male Male

Female Female

Measuring Reproductive Success



Measuring Reproductive Success



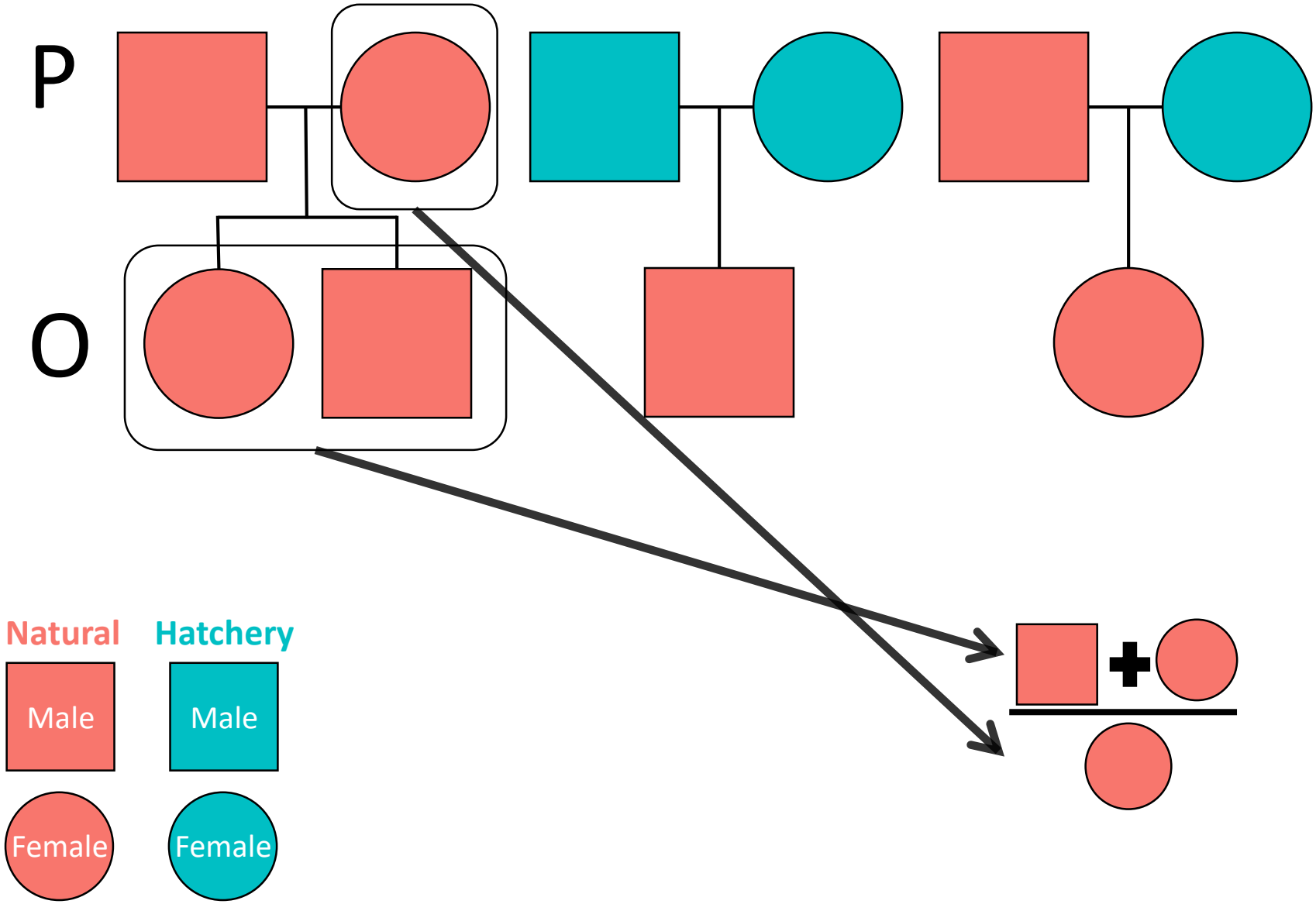
$RS_{H\ Female} = 1$

Natural Hatchery

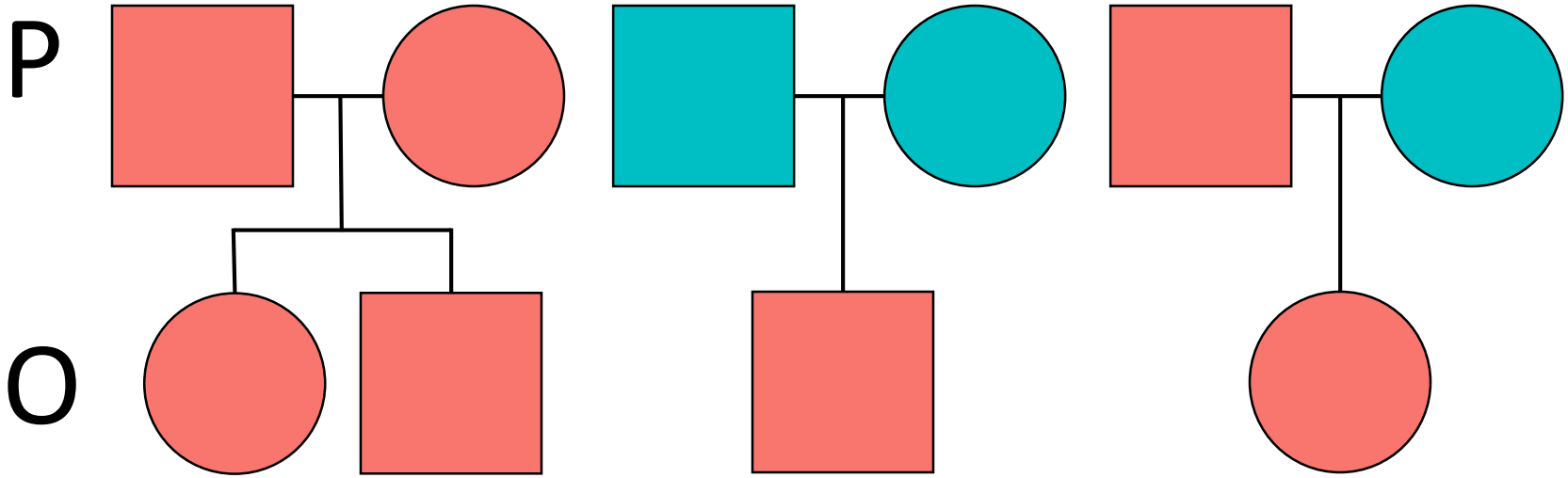
Male Male

Female Female

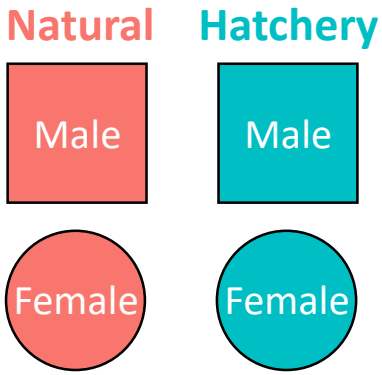
Measuring Reproductive Success



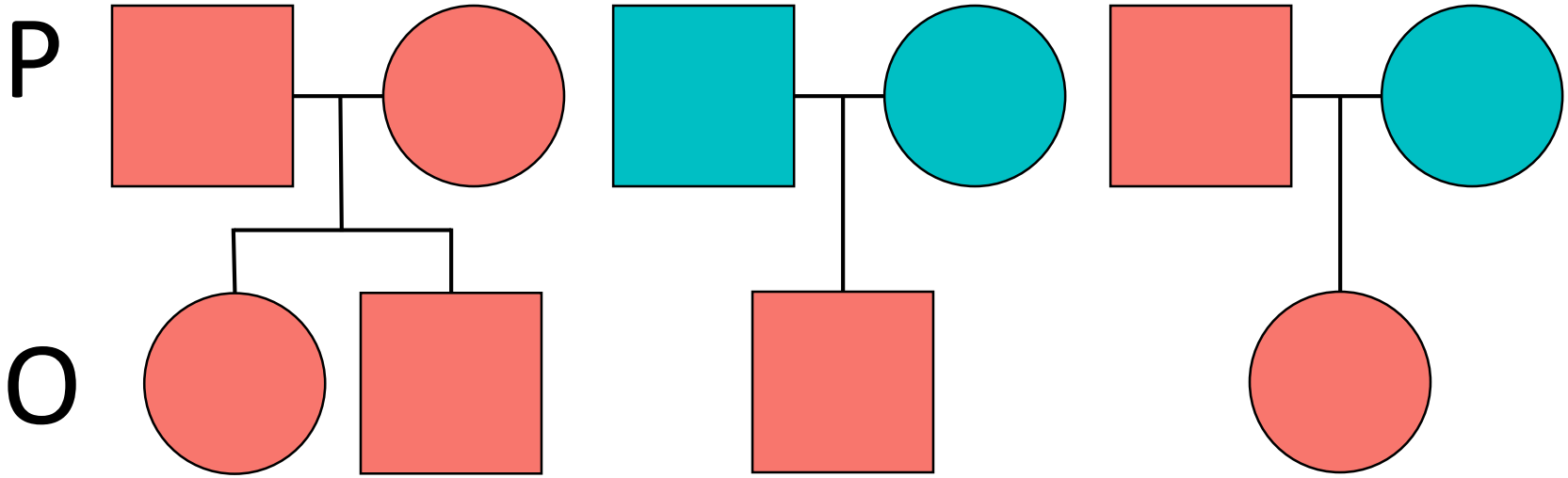
Measuring Reproductive Success



$RS_{N\ Female} = 2$ $RS_{H\ Female} = 1$



Measuring Reproductive Success



$RS_{N\ Female} = 2$ $RS_{H\ Female} = 1$

Natural Hatchery

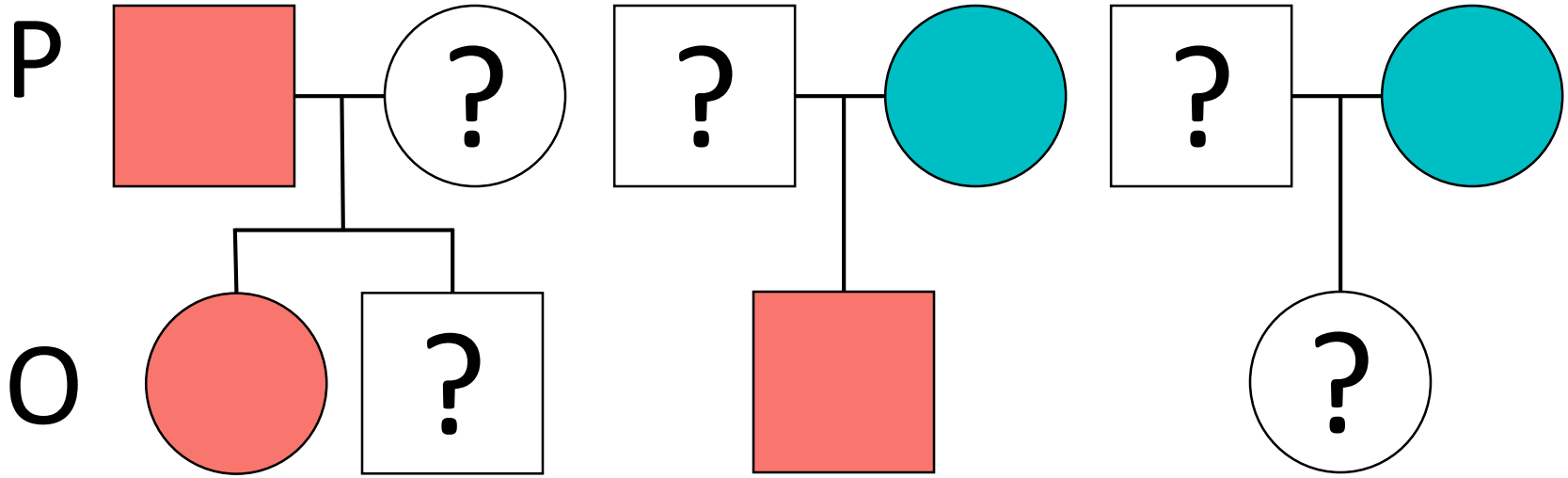
Male Male

Female Female

Relative Reproductive Success (RRS)

$$RRS = \frac{1}{2} = 0.5$$

Measuring Reproductive Success



Natural Hatchery

Male Male

Female Female

Relative Reproductive Success (RRS)

$$\mathbf{RRS} = \frac{\overline{RS}_{Hatchery}}{\overline{RS}_{Natural}}$$

Analyzed Samples: Even-Lineage

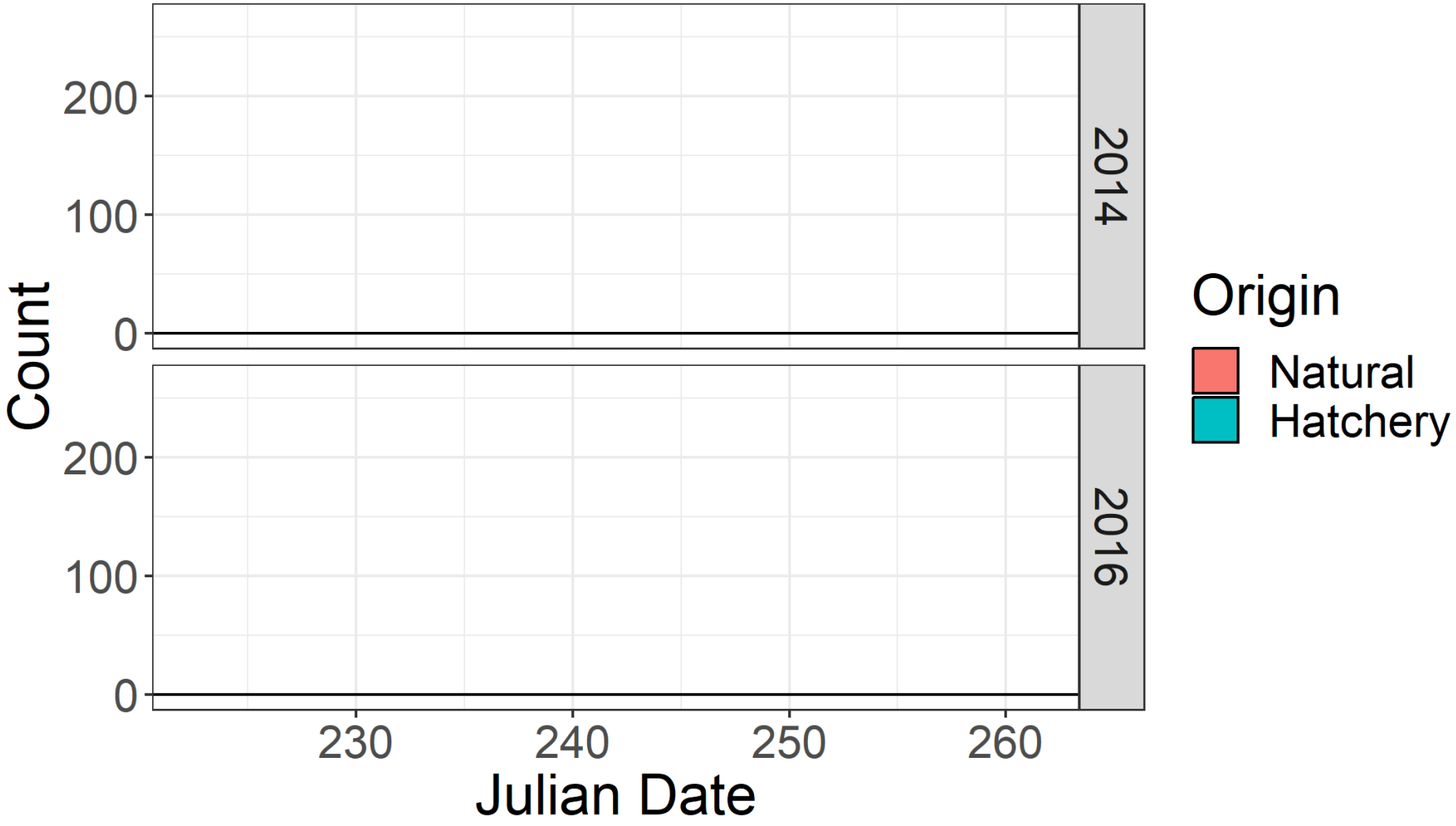


Figure 2b – Lescak et al. *in prep*

Analyzed Samples: Even-Lineage

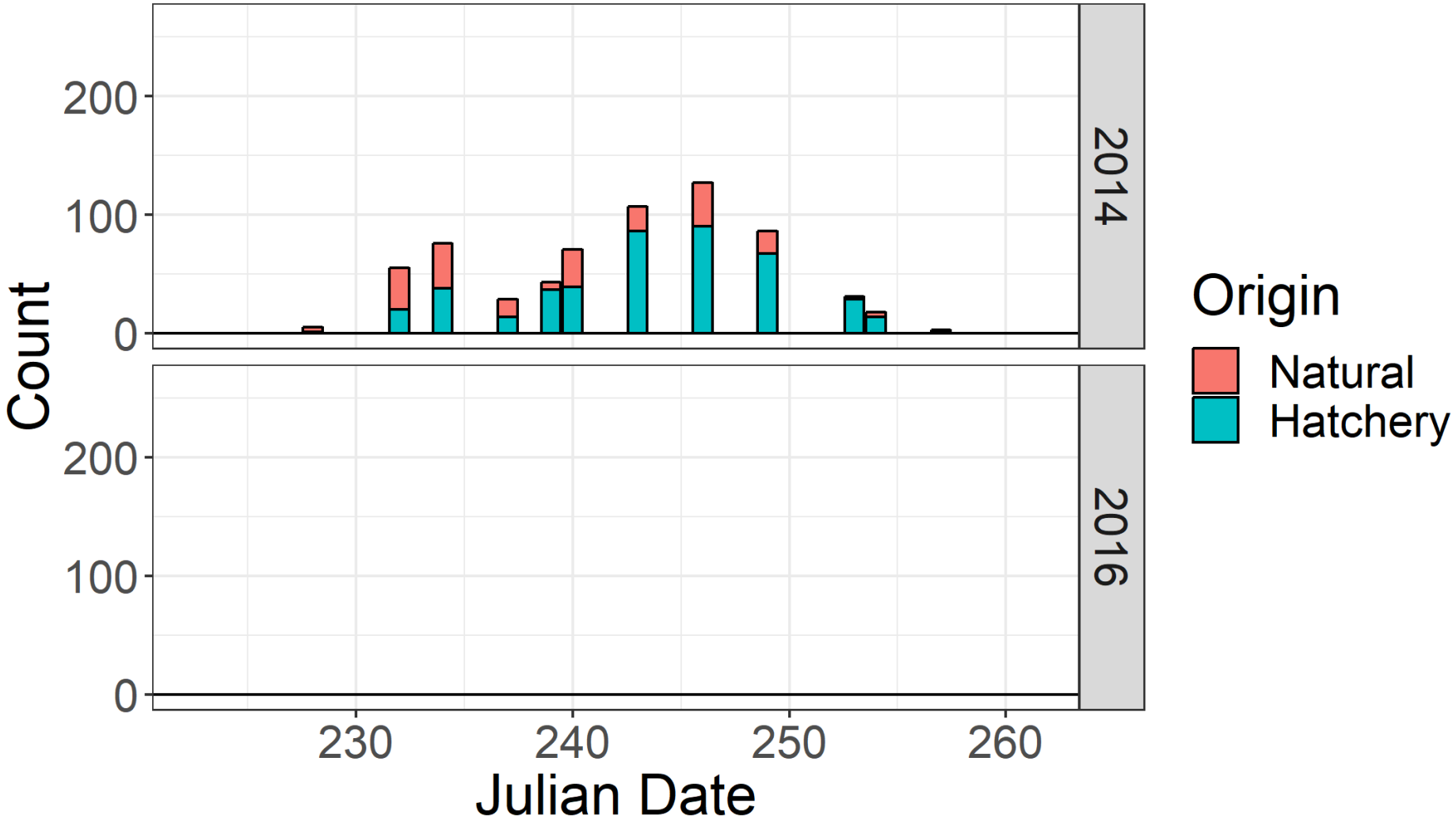


Figure 2b – Lescak et al. *in prep*

Analyzed Samples: Even-Lineage

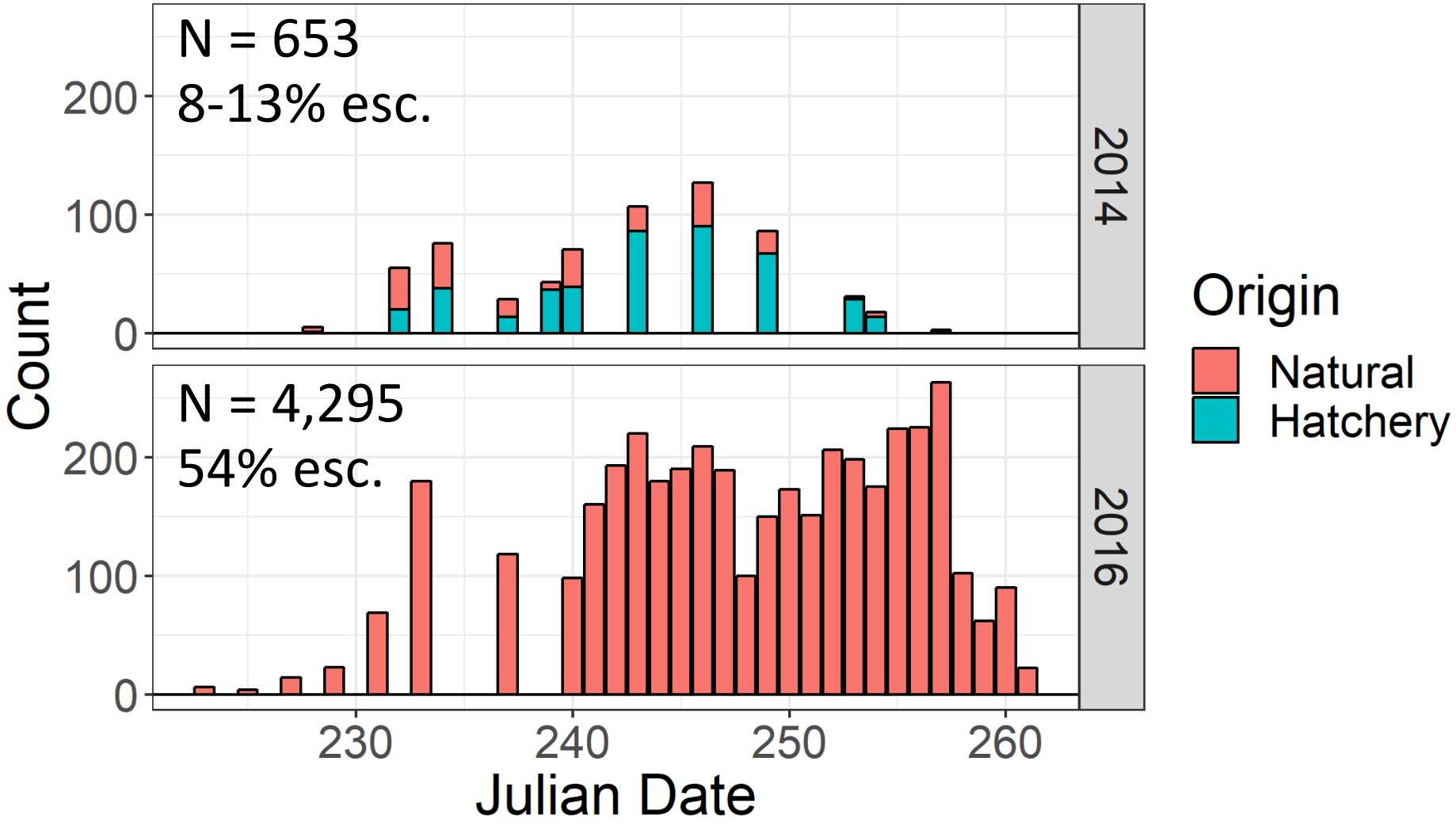


Figure 2b – Lescak et al. *in prep*

Pedigree Results: Even-Lineage

- 451 offspring (11%) assigned to 184 parents
  - 208 → natural-origin parents
  - 265 → hatchery-origin parents
    - 202 – AFK
    - 41 – WNH
    - 22 – CCH
    - 0 – SGH

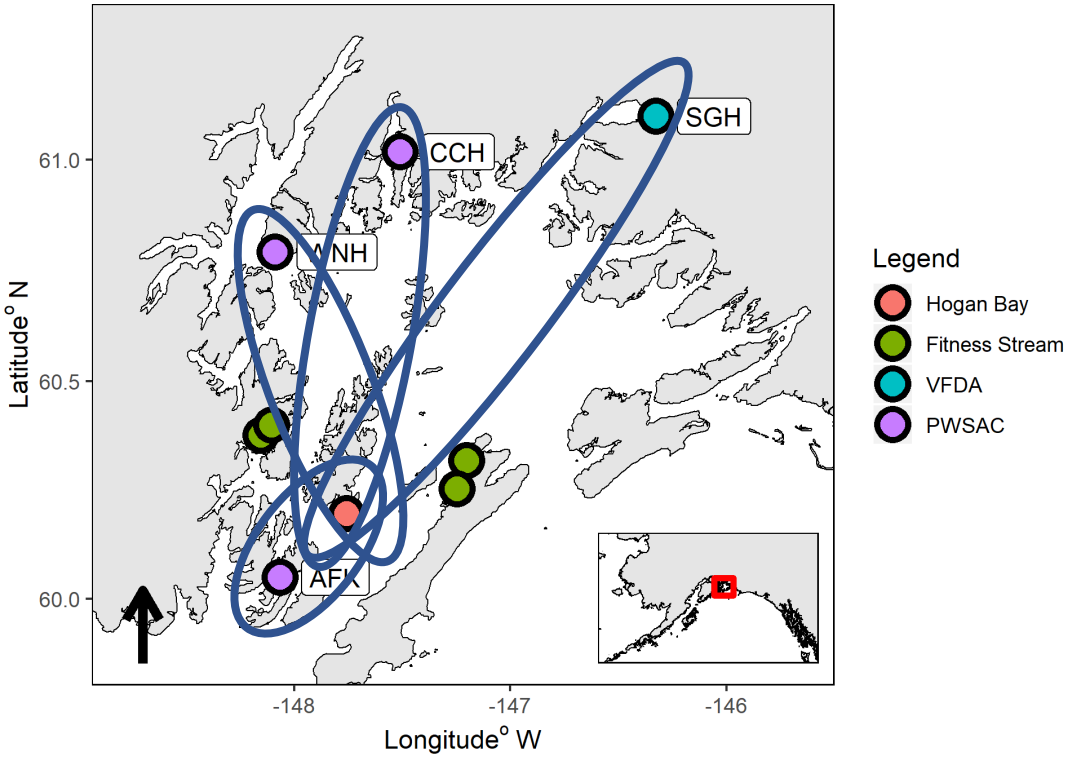


Figure 1 – Lescak et al. *in prep*

RS Distribution: Even-Lineage

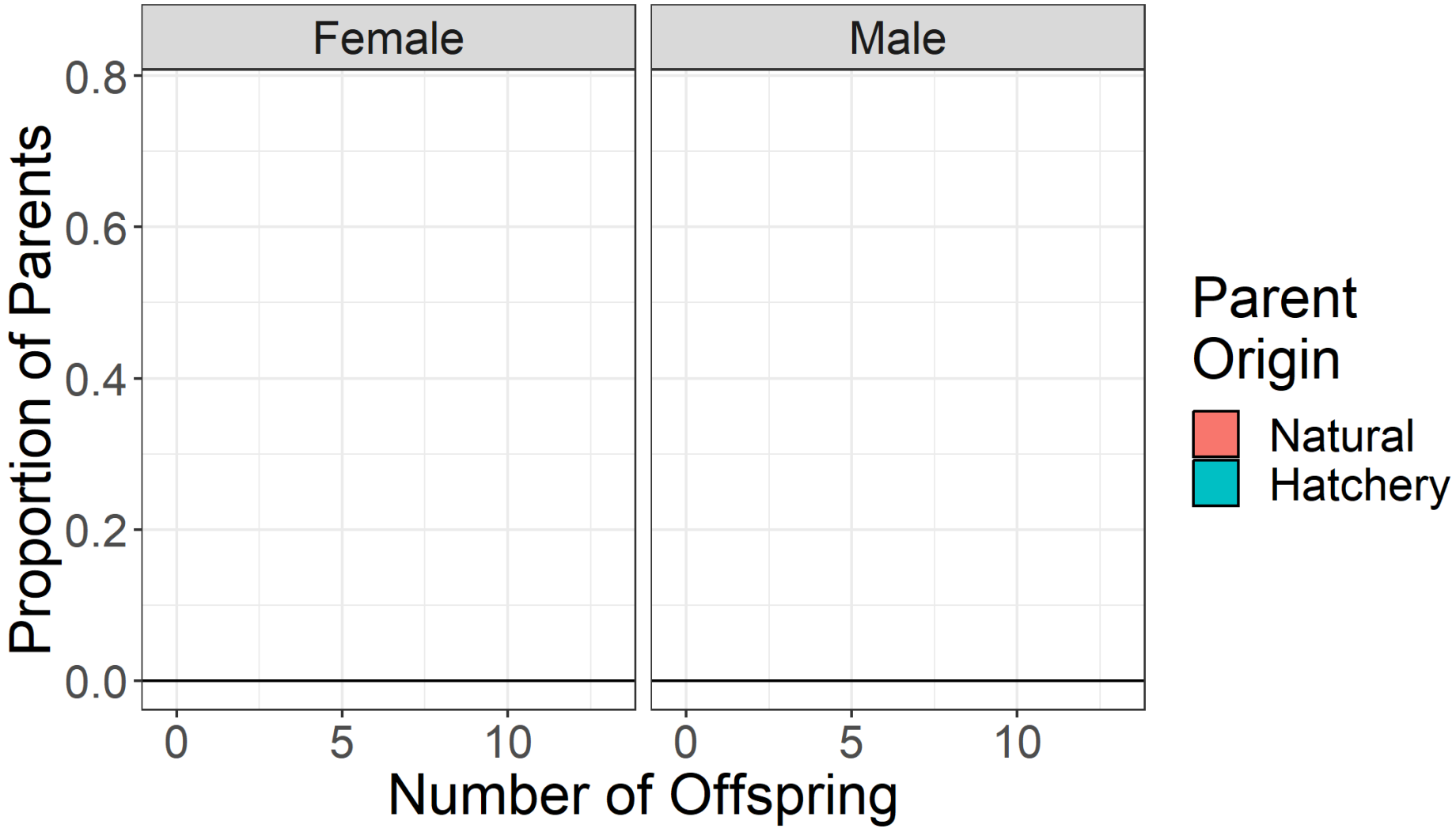


Figure 3b – Lescak et al. *in prep*

RS Distribution: Even-Lineage

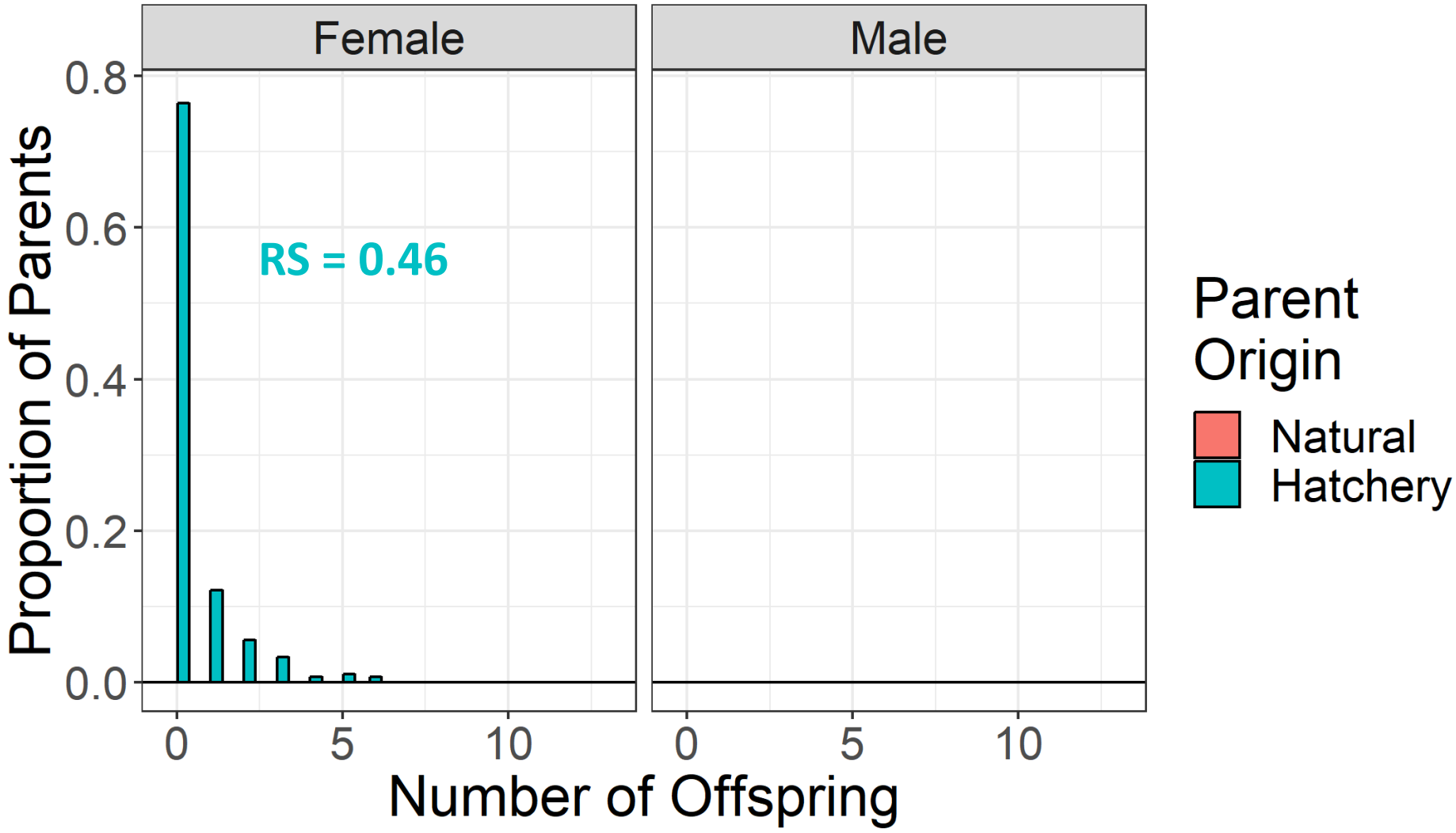


Figure 3b – Lescak et al. *in prep*

RS Distribution: Even-Lineage

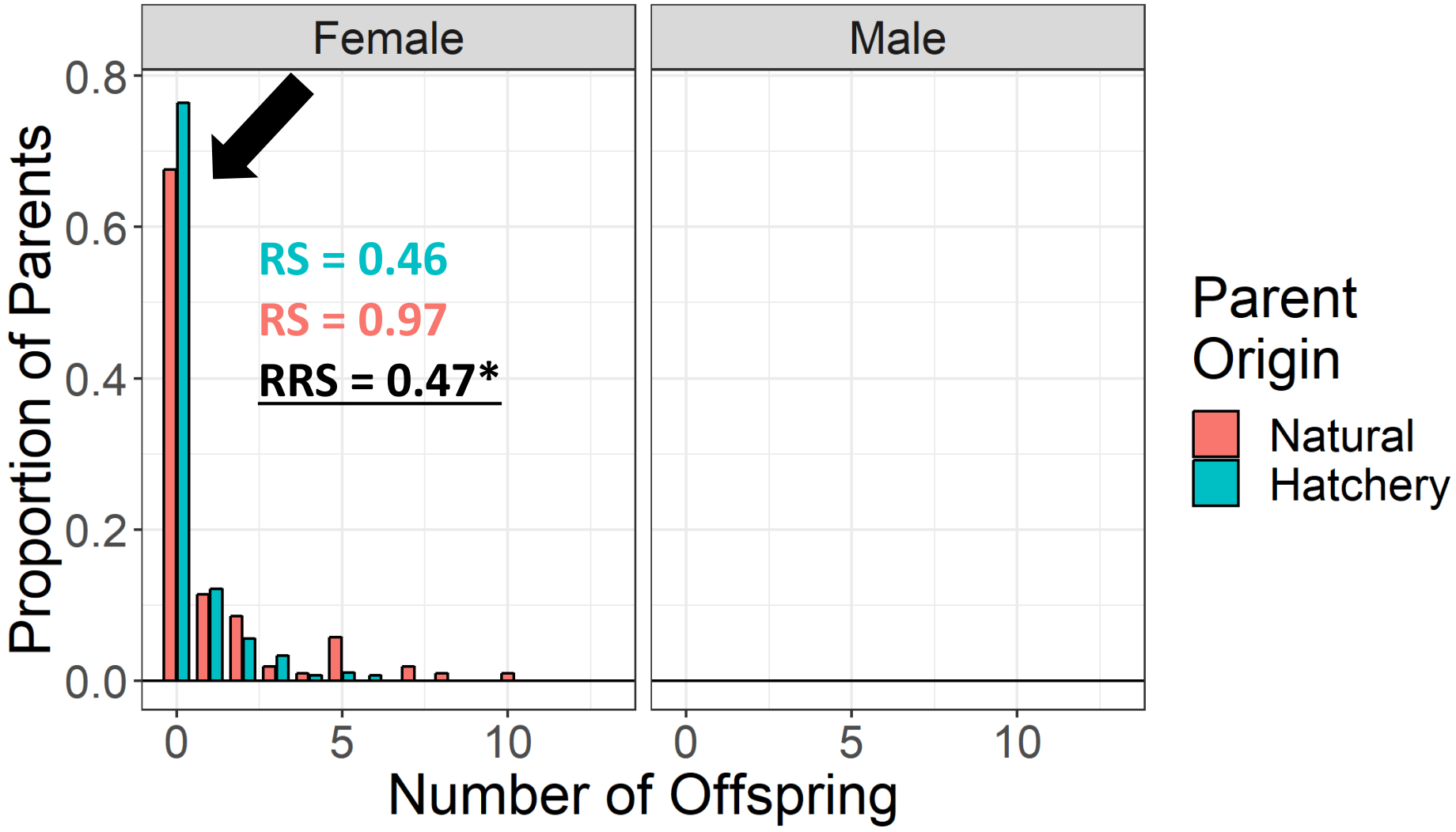


Figure 3b – Lescak et al. *in prep*

RS Distribution: Even-Lineage

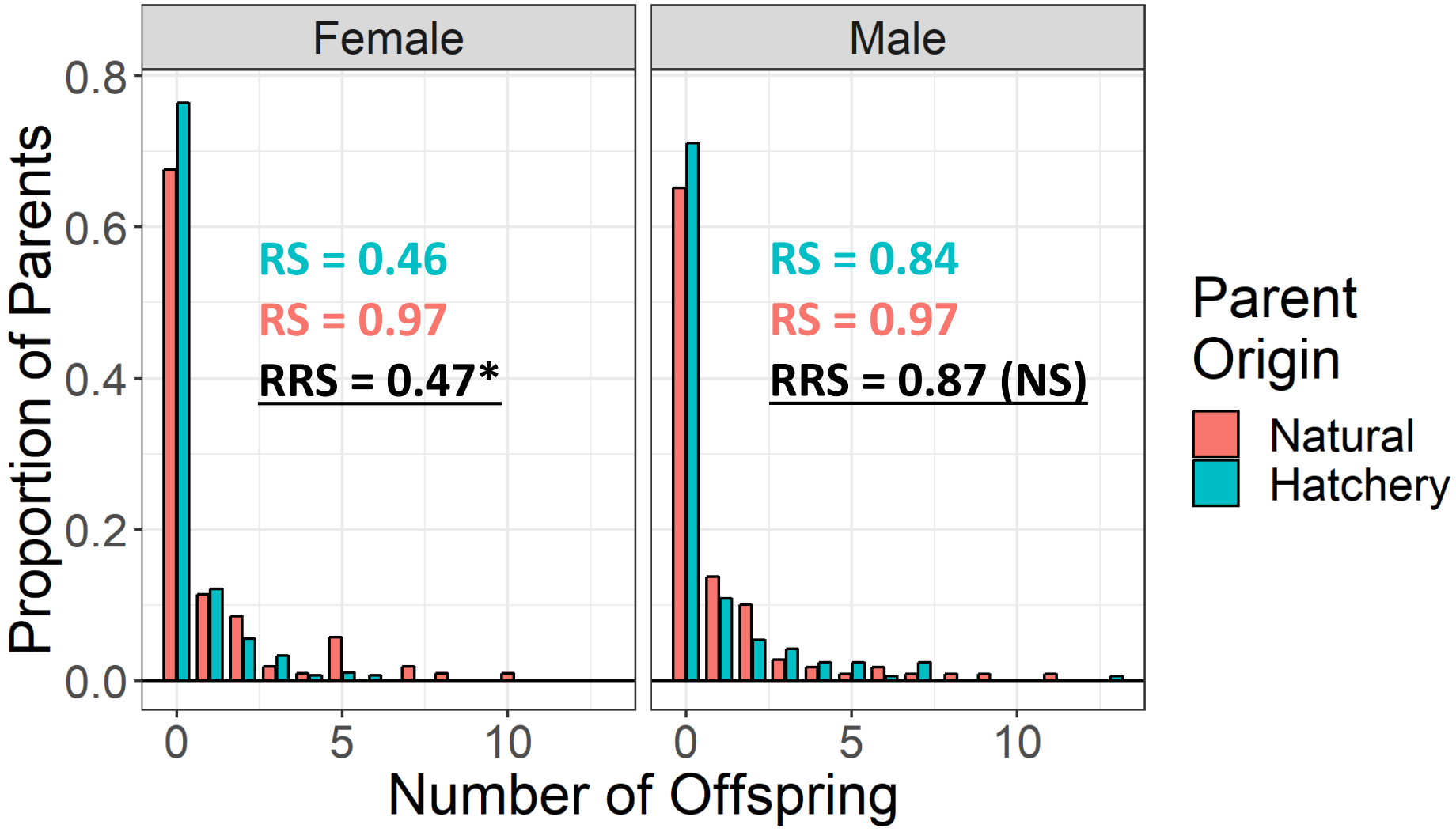
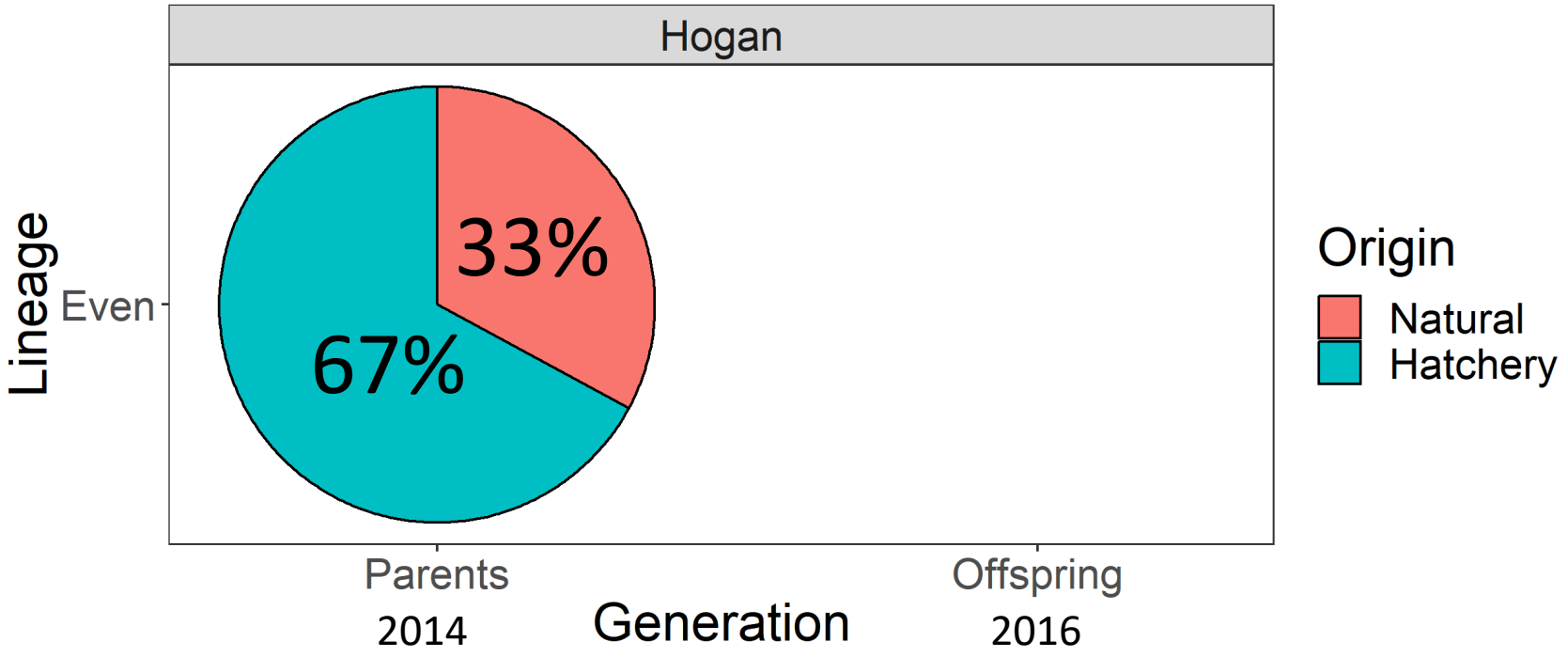
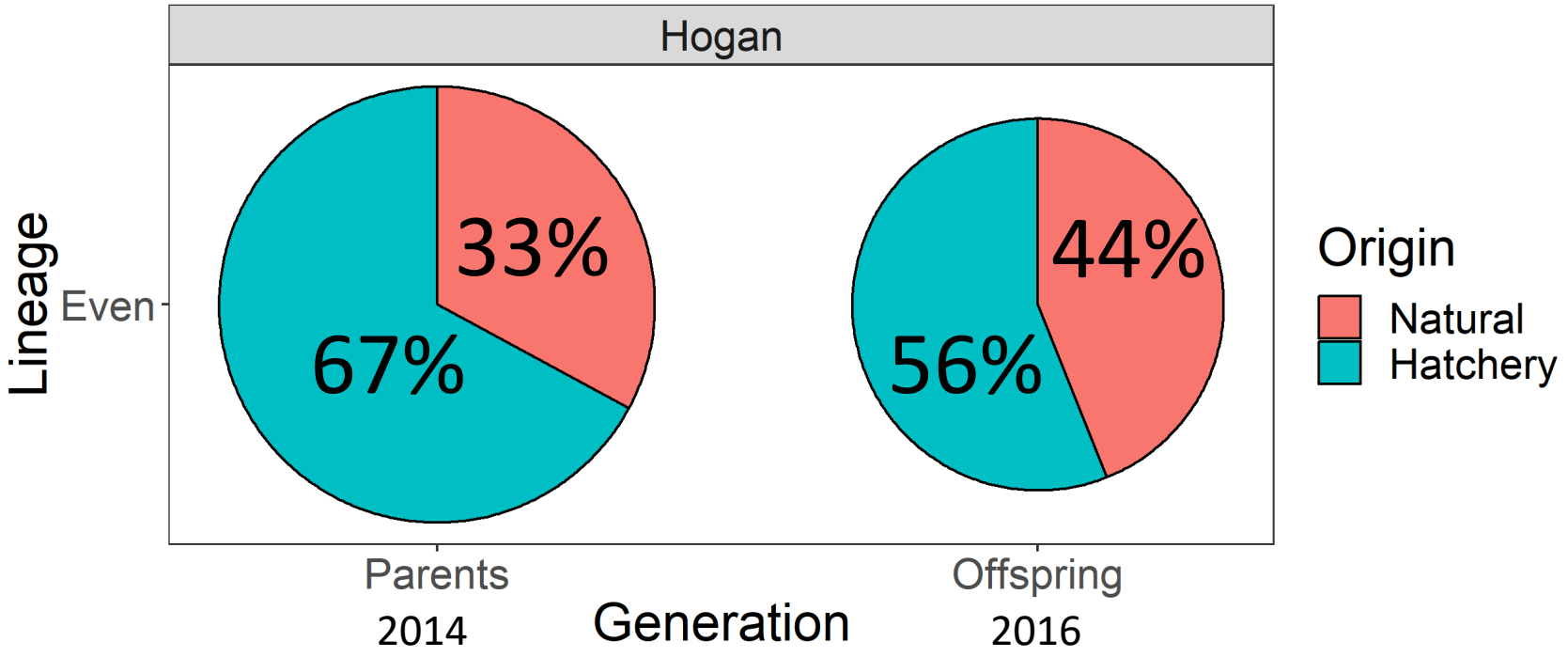


Figure 3b – Lescak et al. *in prep*

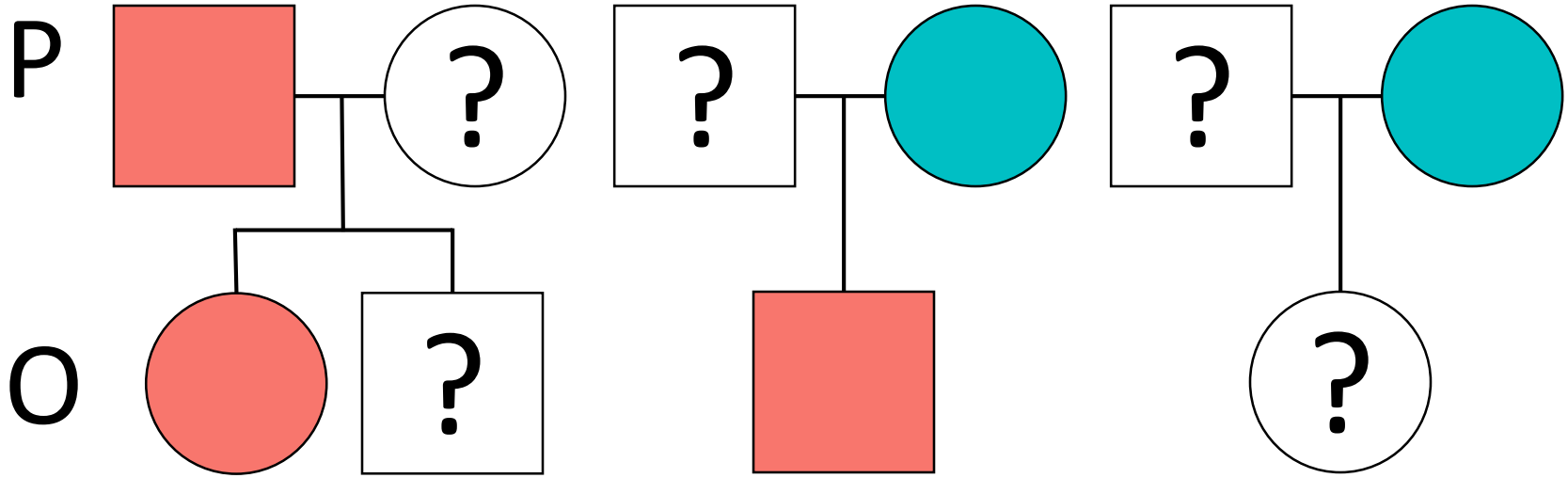
Proportion Test: Even-Lineage



Proportion Test: Even-Lineage



Parent-Offspring Duos

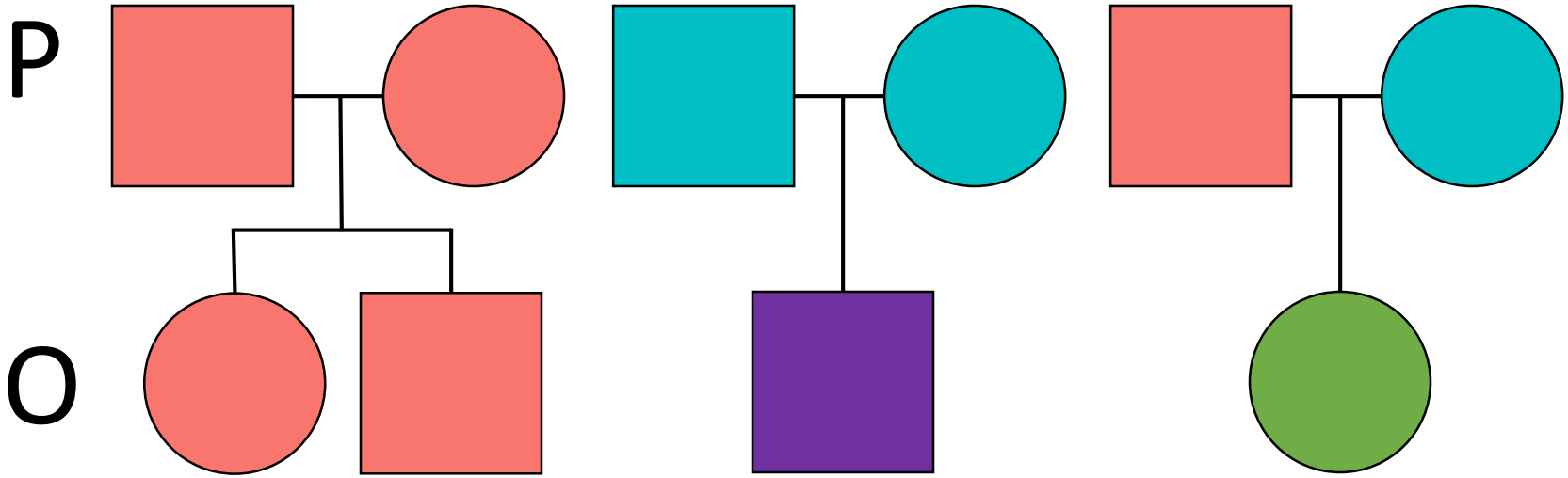


Natural **Hatchery**

Male Male

Female Female

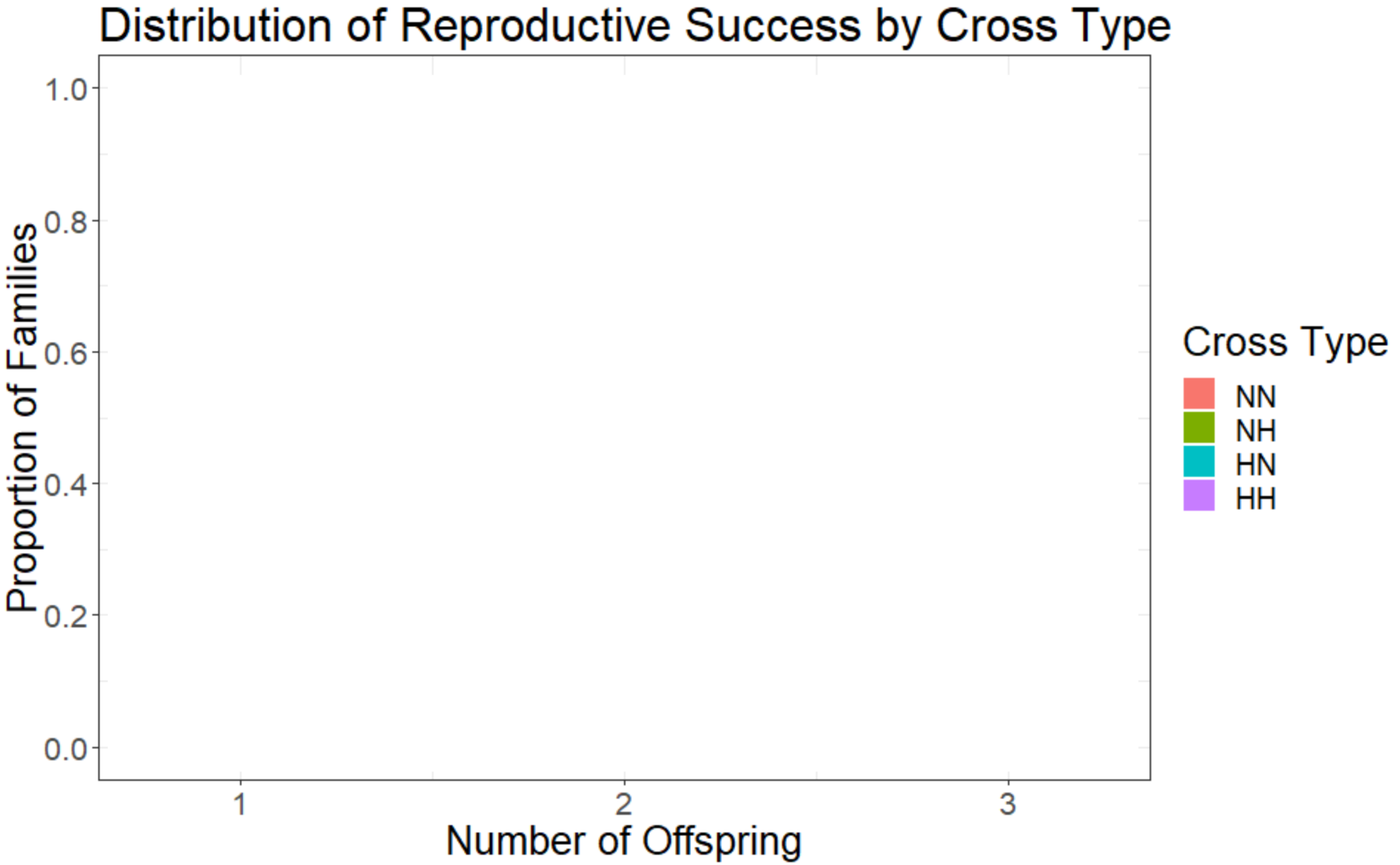
Parent-Offspring Trios

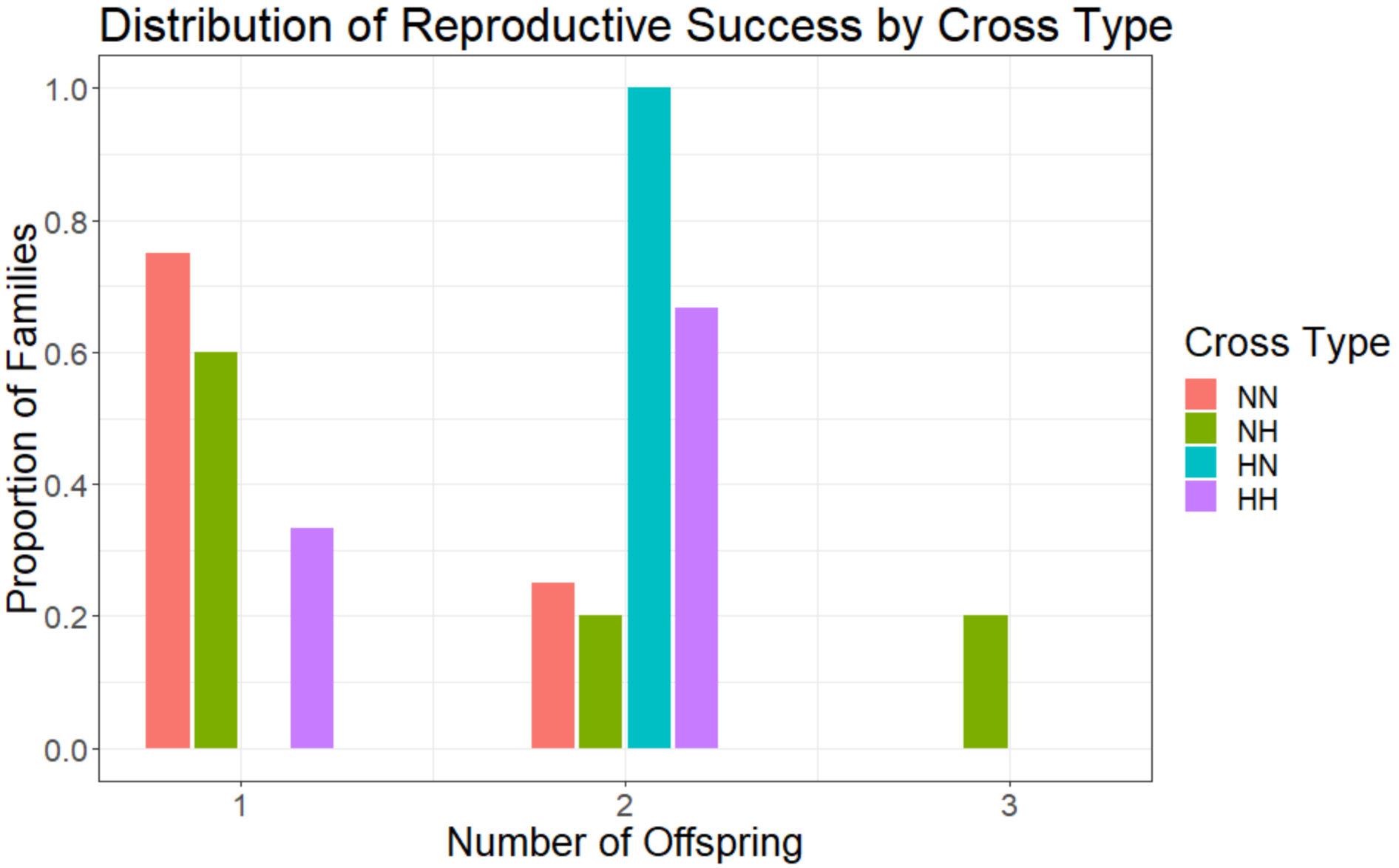


Natural **Hatchery**

Male Male

Female Female


Distribution of Reproductive Success by Cross Type
Proportion of Families
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
Number of Offspring
Cross Type
NN
NH
HN
HH


Distribution of Reproductive Success by Cross Type
Proportion of Families
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
Number of Offspring
Cross Type
NN
NH
HN
HH

Analyzed Samples: Odd-Lineage

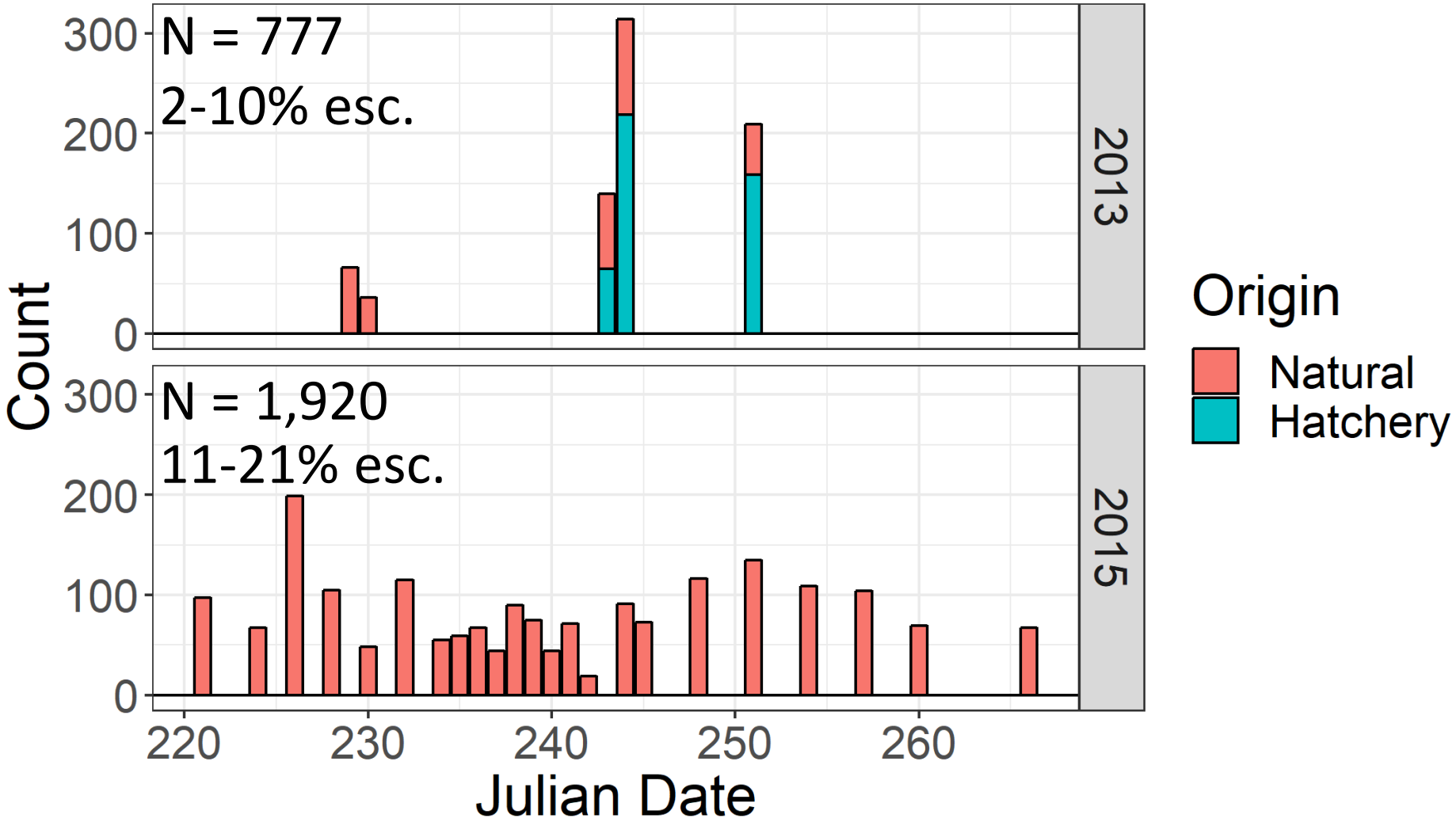


Figure 2a – Lescak et al. *in prep*

Pedigree Results: Odd-Lineage

- 48 offspring (2.3%) assigned to 20 parents
  - 45 → natural-origin parents
  - 3→ hatchery-origin parents
    - 2 – AFK
    - 1 – WNH
    - 0 – CCH
    - 0 – SGH

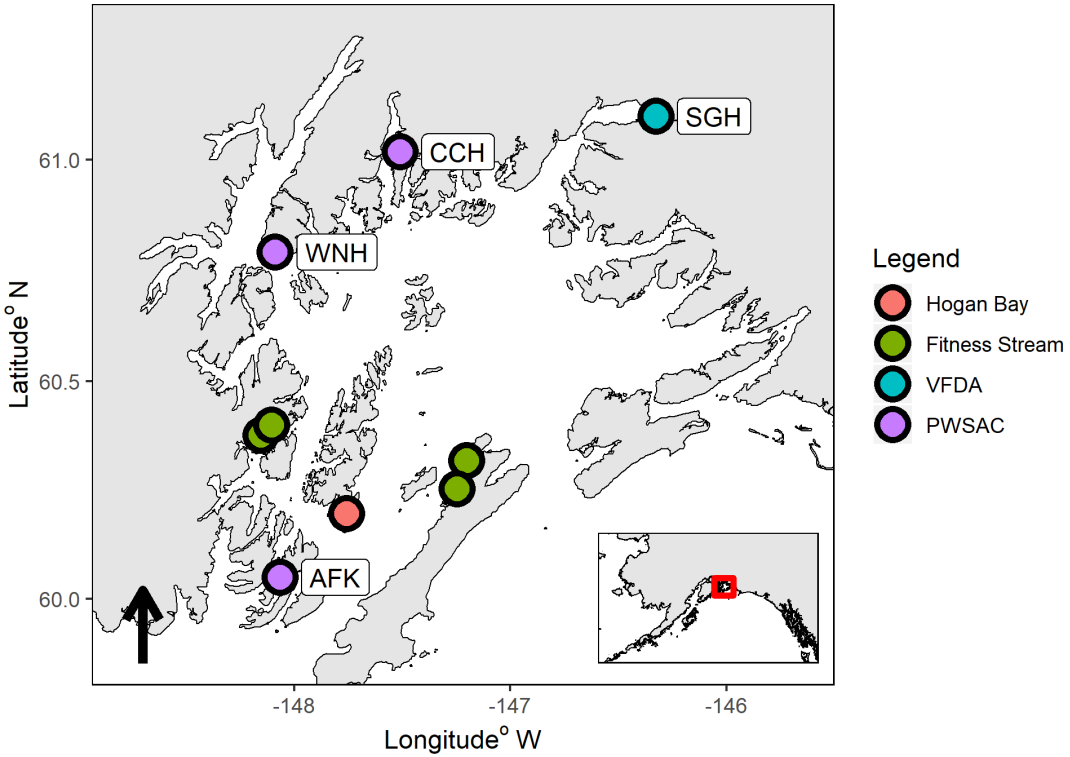


Figure 1 – Lescak et al. *in prep*

RS Distribution: Odd-Lineage

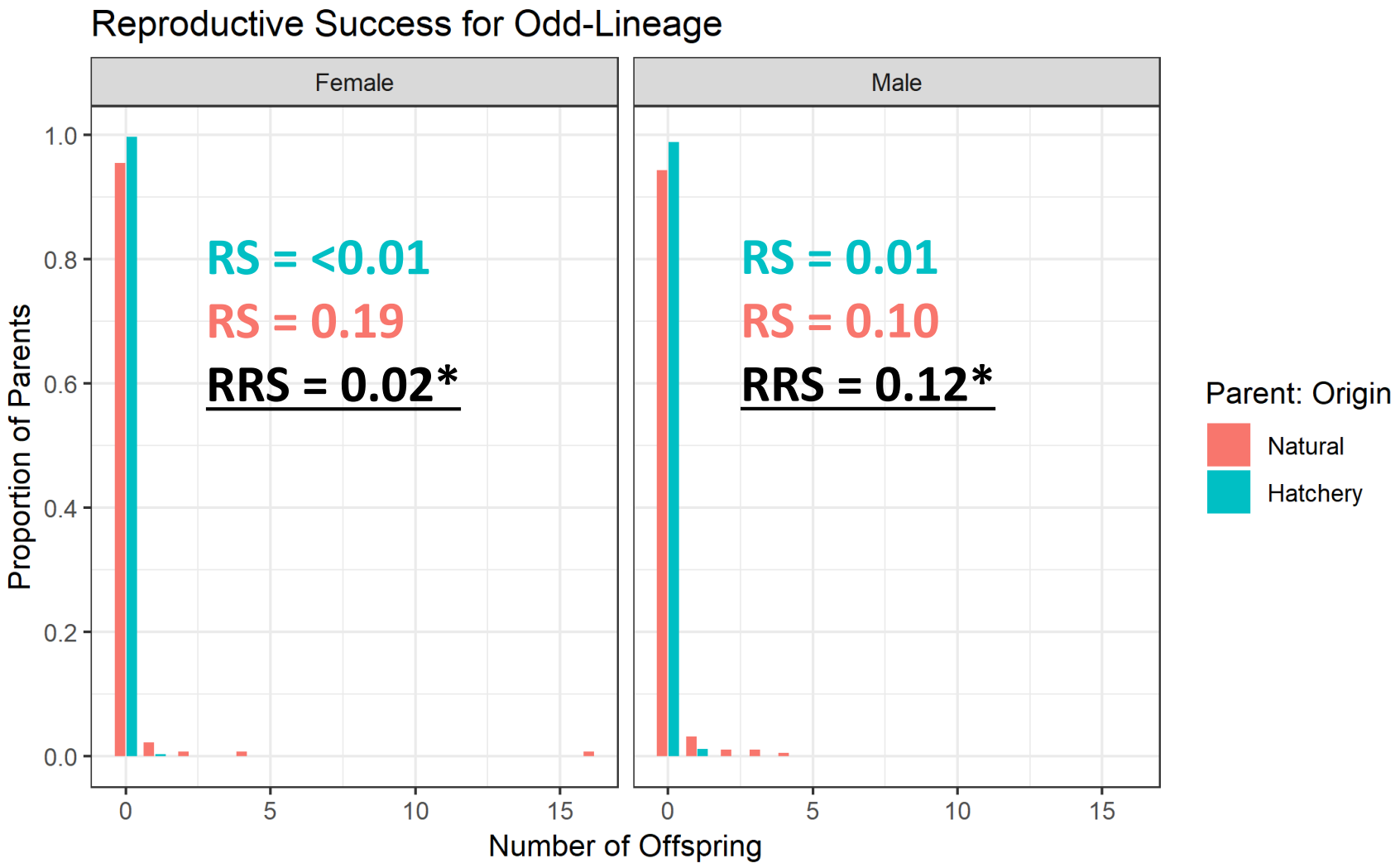
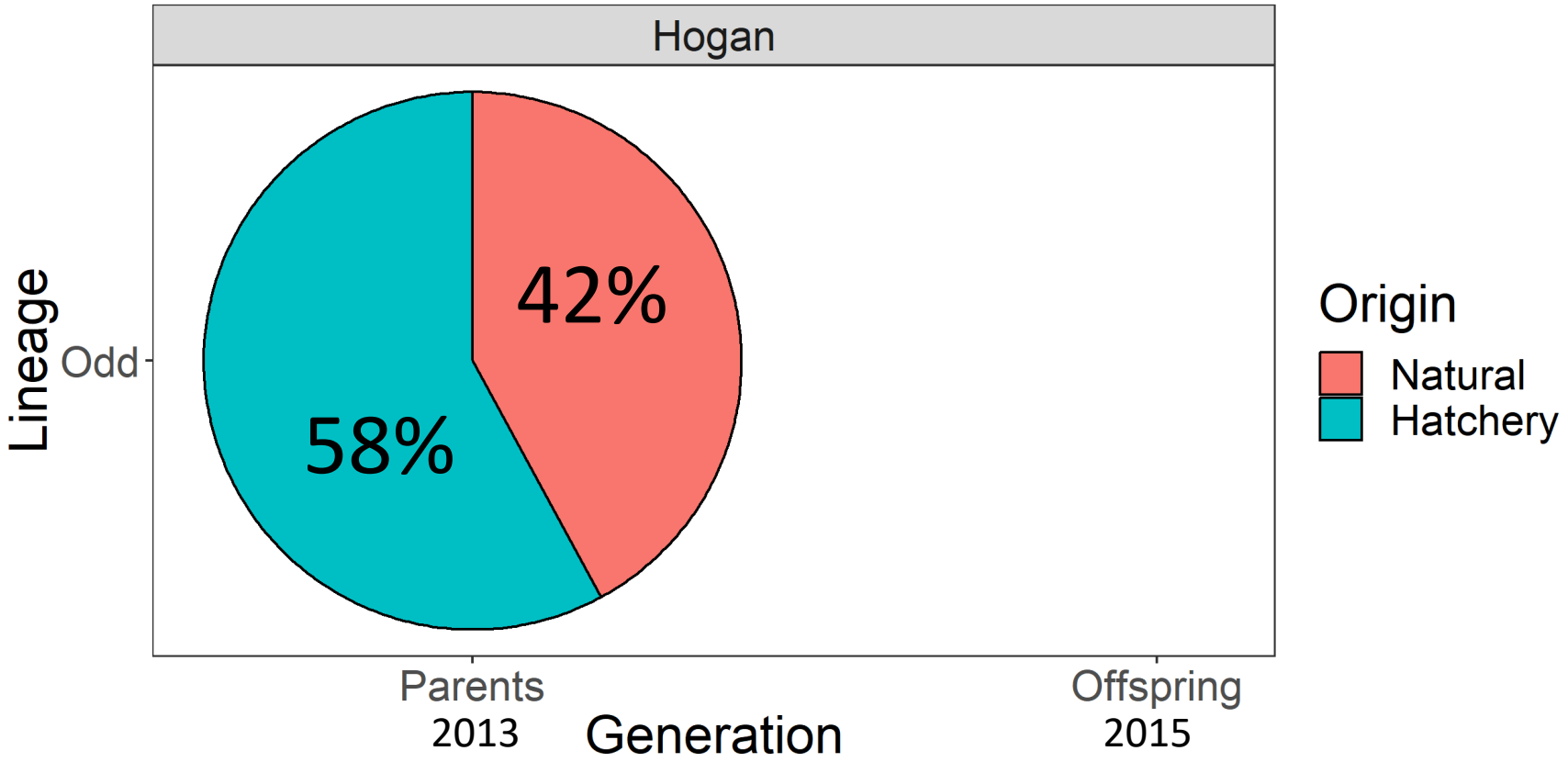
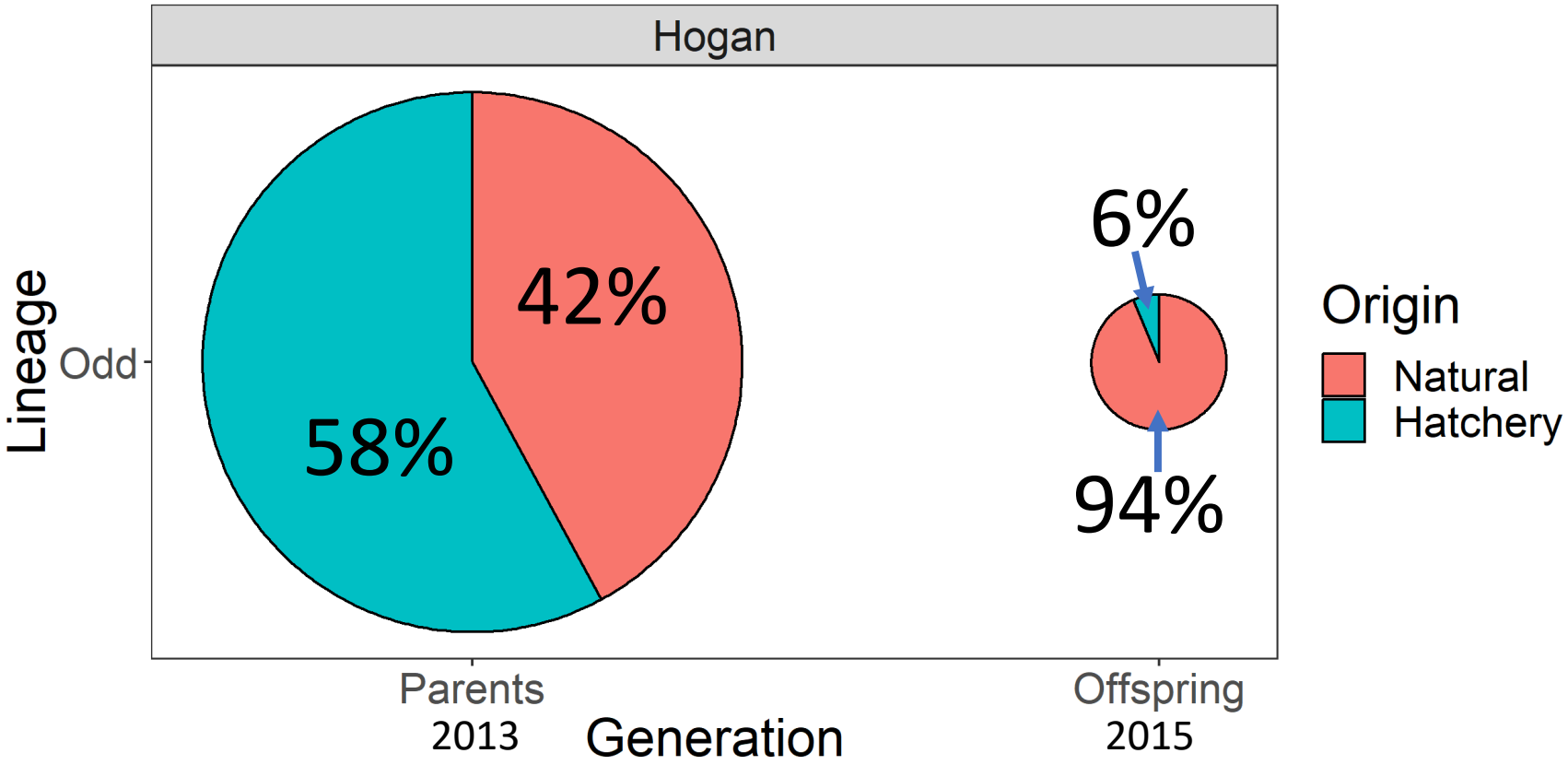


Figure 3b – Lescak et al. *in prep*

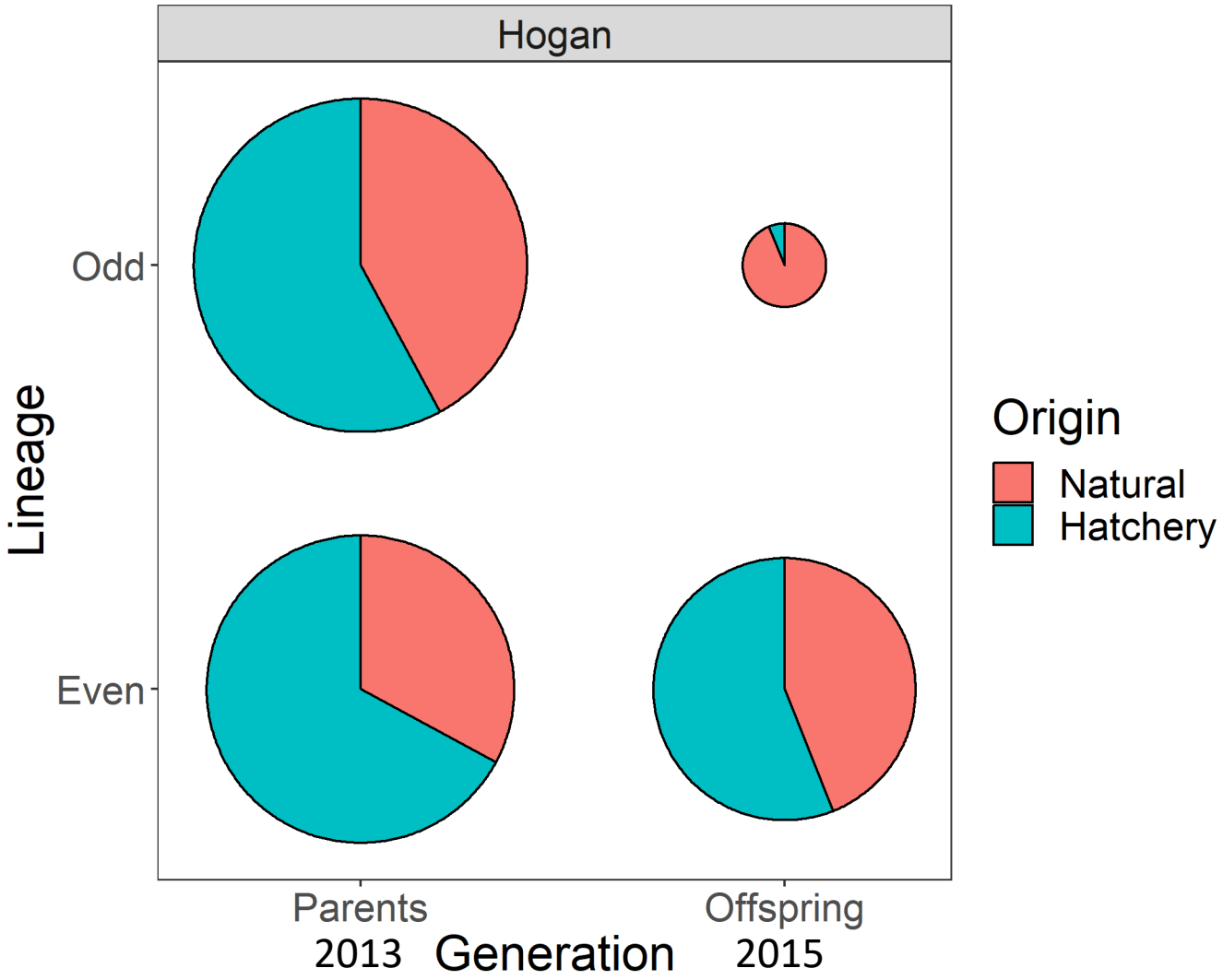
Proportion Test: Odd-Lineage



Proportion Test: Odd-Lineage



Proportions for Both Lineages



How robust are our pedigrees?

- Simulations
  - No incorrect or missed assignments
- Sensitivity analysis for *FRANz* parameters
  - Results robust to changes in genotyping error rates and maximum numbers of potential parents
- All parentage assignments unequivocal
  - No split pedigrees

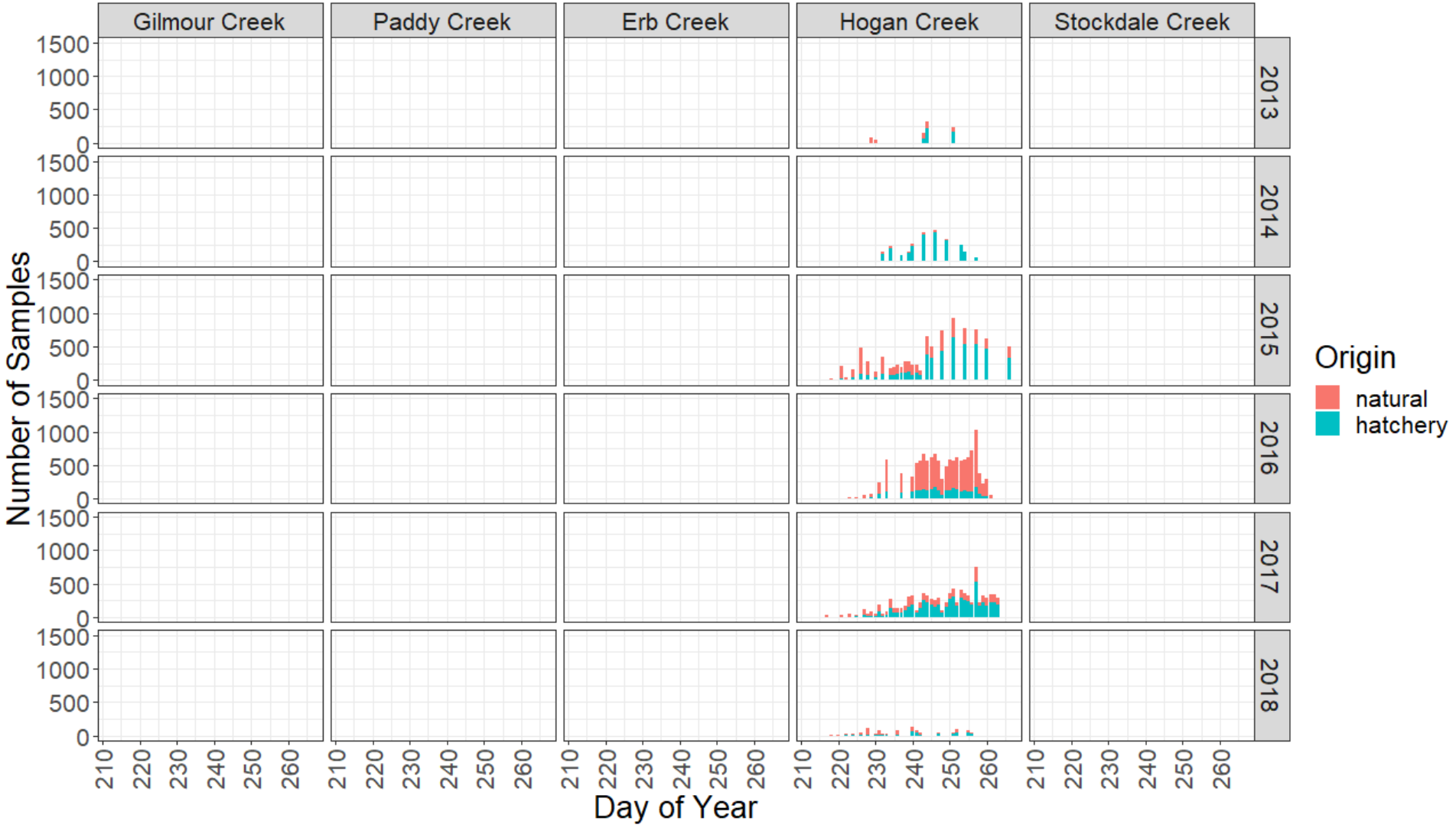
Results from 1 generation of Hogan

- Pedigree in natural system possible
- Even-lineage
  - 451 offspring to 184 parents
  - Offspring assignment rate 11.0%
  - RRS = **0.47** (significant) for females
  - RRS = **0.87** (not significant) for males
- Odd-lineage
  - 48 offspring to 20 parents
  - Offspring assignment rate 2.5%
- Under-representation of offspring assigned to hatchery-origin parents in both lineages

Conclusions from Hogan Bay

- Hatchery-origin fish spawned and produced adult offspring that were sampled
- Hatchery-origin fish spawned with both other hatchery-origin fish as well as natural-origin fish
- On average, hatchery-origin fish produced fewer adult offspring that returned to Hogan Bay and were sampled than their natural-origin conspecifics
- There are potentially important differences in RS between male and female hatchery-origin fish

Future Analyses



Future Analyses

Acknowledgements

- Alaska Hatchery Research Program
  - State of Alaska
  - Seafood industry
  - Private non-profit hatcheries
- North Pacific Research Board (Project #1619)
  - Funding for Hogan Bay analyses
- Prince William Sound Science Center
  - Field collection
- ADF&G Cordova Otolith Lab
- University of Washington - Seeb Lab
- ADF&G Gene Conservation Laboratory