

Pink Salmon pedigree analyses methods



Kyle Shedd
Gene Conservation Laboratory
Alaska Department of Fish and Game
AHRP Informational Meeting
March 9, 2022

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.1365-2942.2011.02584.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,¹ Becky Cooper, Michael S. Blouin

Molecular Ecology (2007) 16, 955–966

doi: 10.1111/j.1365-2942.2006.01236.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. ARDEN,[†] BECKY COOPER* and MICHAEL S. BLOUIN*

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biology letters

Biol. Lett. (2009) 5, 631–634
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 Araki¹, 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 large 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 introduction, 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

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

Ewans A. Berntson*, Richard W. Carmichael[†], Michael V. Fleisher[‡], Eric J. Ward[§] & Paul Moran[¶]

Genetic adaptation to captivity can occur in a single generation

Mark R. Christie¹, Melanie L. Marino², Rod A. French³, and Michael S. Blouin⁴

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³Edited by Brett A. Blackwell, University of Minnesota, Minnesota, MN, and accepted by the Editorial Board on 11 October 2009 for review on 26 July 2010

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

[Article]

North American Journal of Fisheries Management 29:1472–1485, 2009
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DOI: 10.1577/M07-105.1

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

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³Confederated Tribes of the Warm Springs Reservation of Oregon, Department of Natural Resources, Warm Springs, Oregon 97149, USA

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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.12066

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 (2012) 15, 273–281

ORIGINAL ARTICLE

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

Joseph H. Anderson,^{1,2*} Paul L. Faulds,³ William L. Atlas⁴ and Thomas P. Quinn⁵

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Keywords: conservation, dams, hatchery, natural selection, pedigree, reintroduction, sexual selection

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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 Leaning 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 30 microsatellite loci, and calculated reproductive success (RS) as the total number of surviving adult offspring. Hatchery males were consistently but not significantly less productive than naturally spawned males (range in relative RS 0.20–0.90), 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 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

2243

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.1365-2942.2011.02584.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 mechanisms 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 (age 2) did not exhibit the same fitness decrease as males that returned as 3-year olds. Thus, we report three 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: 0) hatchery fish released as unfed fry that survived to adulthood still had low RS relative to wild fish, 0) age-1 male hatchery fish consistently showed a lower relative RS than female hatchery fish (suggesting a role for sexual selection), and 0) age-2 jacks, which use a weaker 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

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Chum

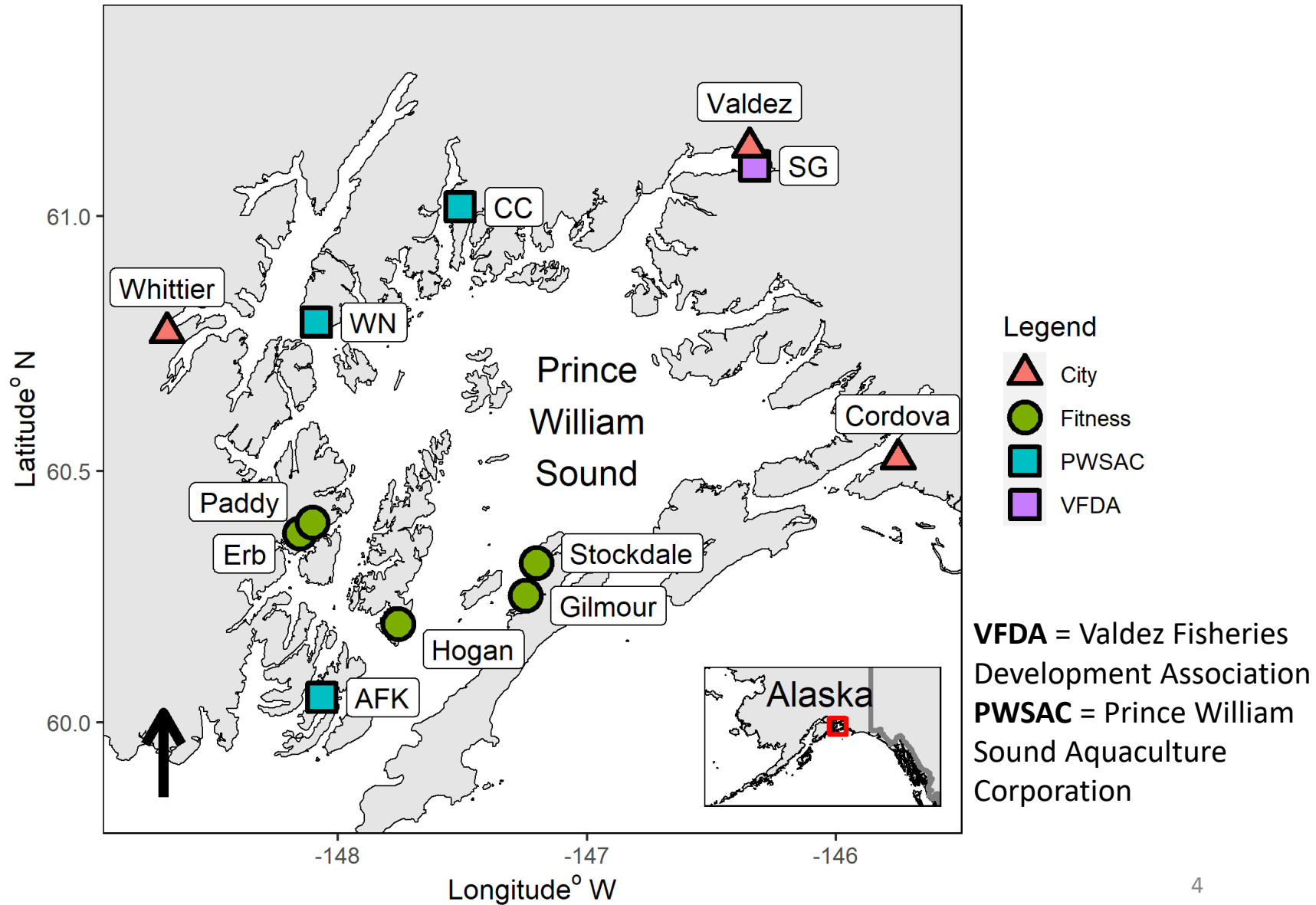
701

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 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 mating females, and females of both types exhibited similar breeding behaviors and duration. Male body size was positively correlated with access to mating females and reproductive success. The estimate 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 medical hatchery populations.

AHRP Streams in PWS



Fitness = Reproductive Success

Parent



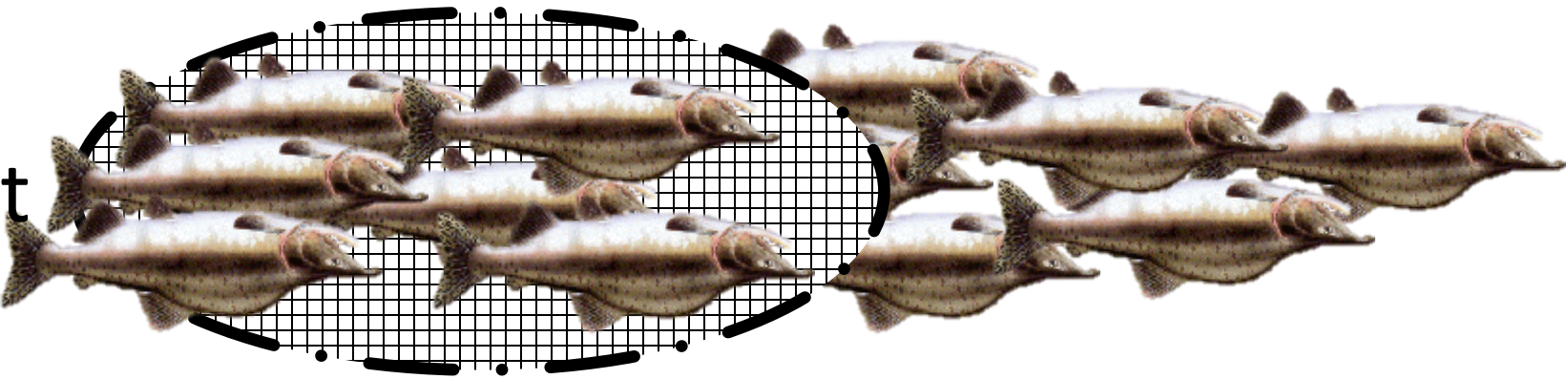
Measuring Reproductive Success

Parent



Measuring Reproductive Success

Parent



Measuring Reproductive Success



Parent

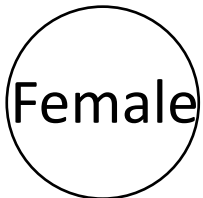
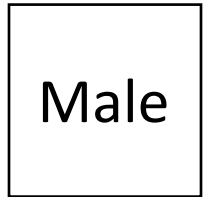
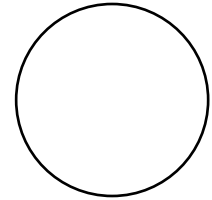
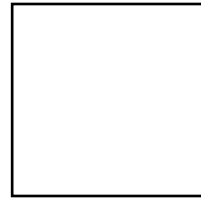
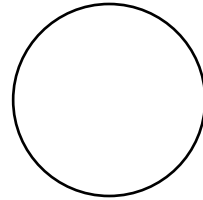
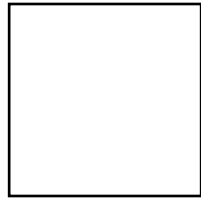
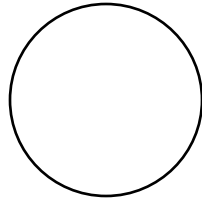
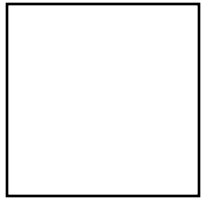
- Carcass sampling
 - Body length
 - Date
 - Location
 - Otolith
 - Tissue



Photo credit: Brad von Wichman

Measuring Reproductive Success

P



Measuring Reproductive Success

P

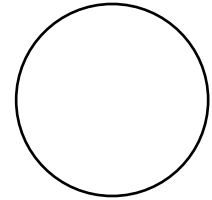
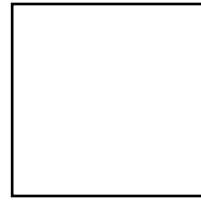
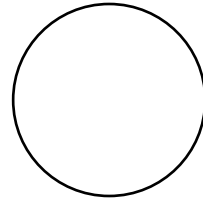
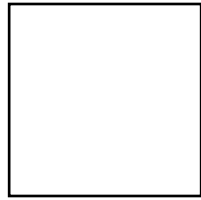
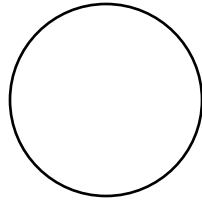
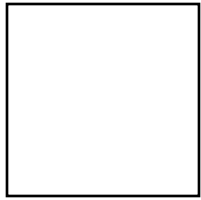
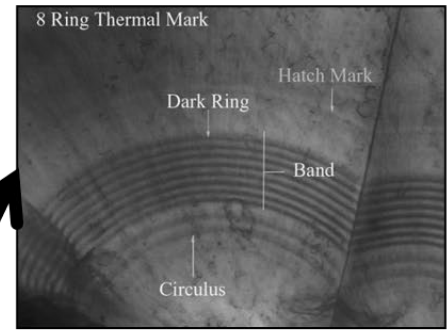


Photo credit: David Janka



Hatchery-origin

No thermal mark

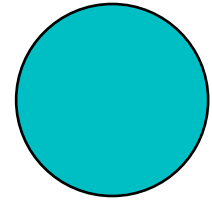
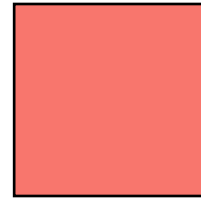
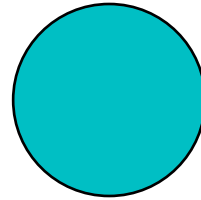
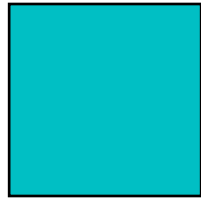
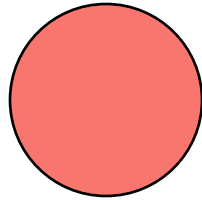
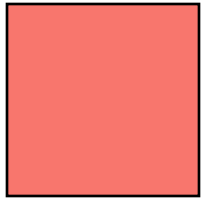
Natural-origin

Male

Female

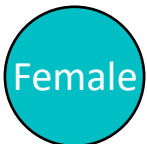
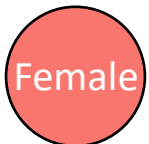
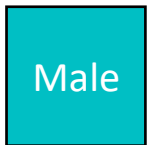
Measuring Reproductive Success

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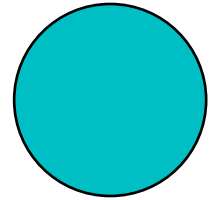
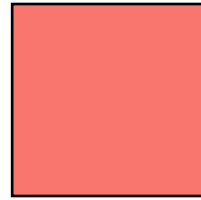
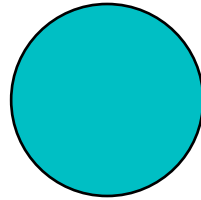
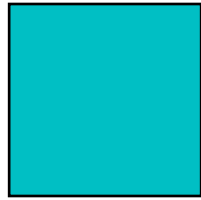
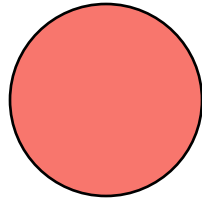
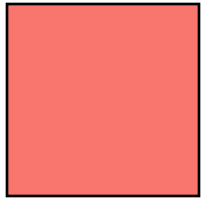
Natural

Hatchery



Measuring Reproductive Success

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return to stream

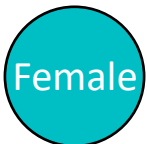
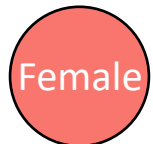
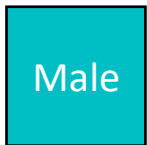
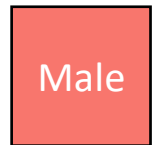


Offspring

harvest

Natural

Hatchery



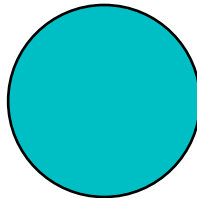
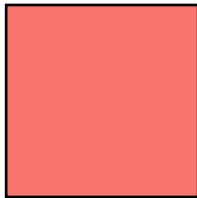
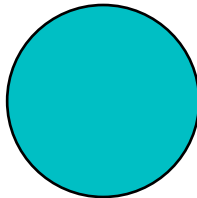
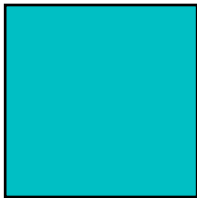
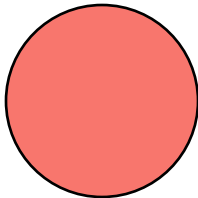
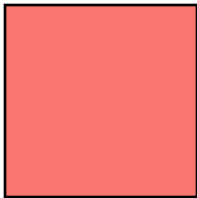
stray



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Measuring Reproductive Success

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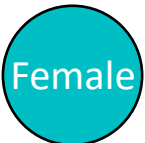
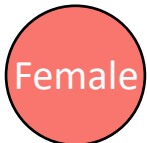


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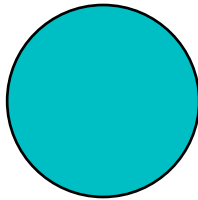
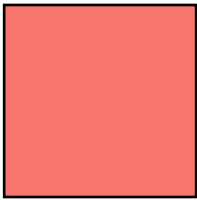
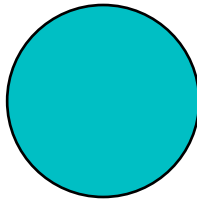
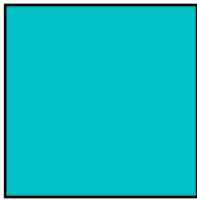
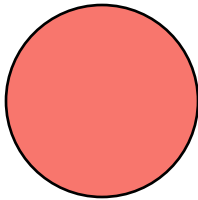
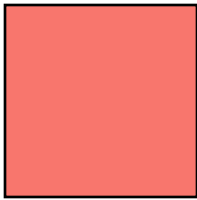
Natural

Hatchery



Measuring Reproductive Success

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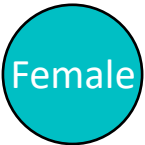
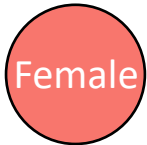
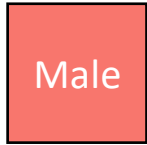


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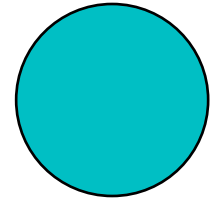
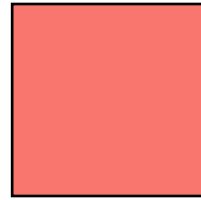
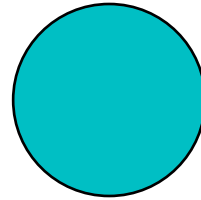
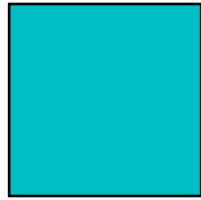
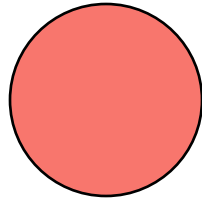
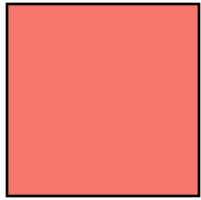
Natural

Hatchery

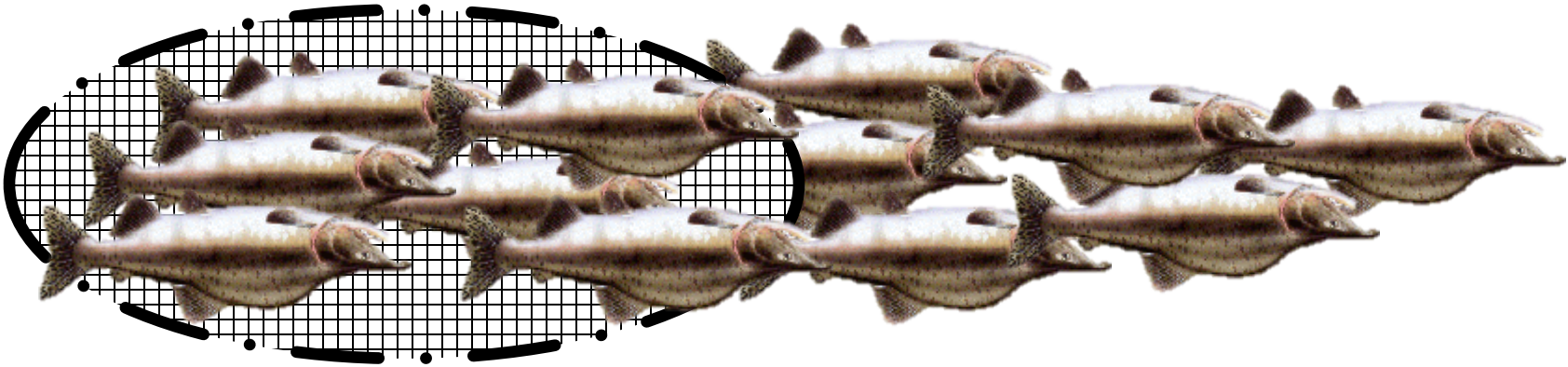


Measuring Reproductive Success

P

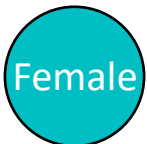
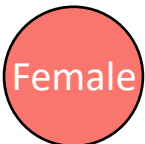


O



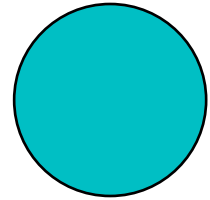
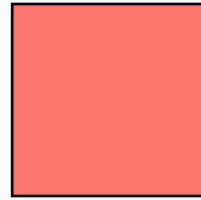
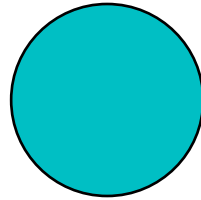
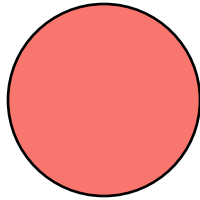
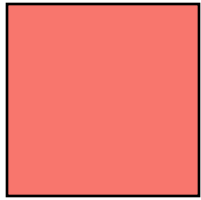
Natural

Hatchery

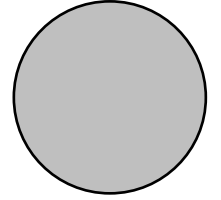
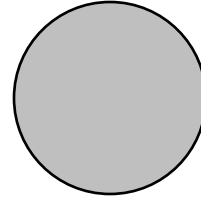
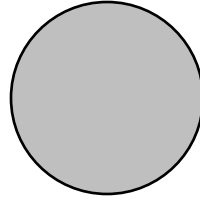
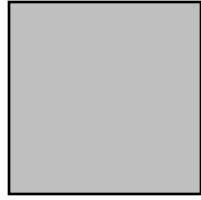
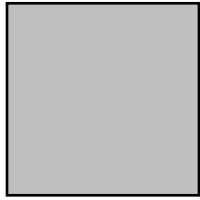
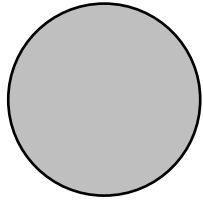


Measuring Reproductive Success

P

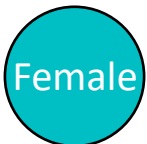
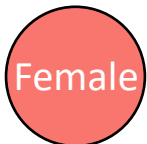
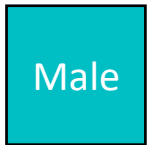


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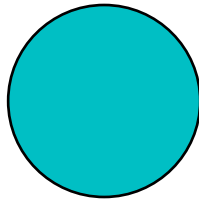
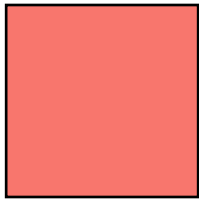
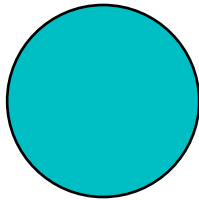
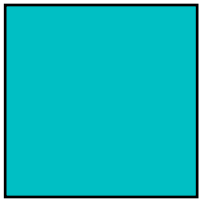
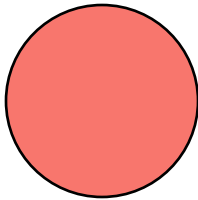
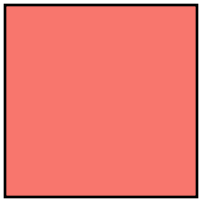
Natural

Hatchery

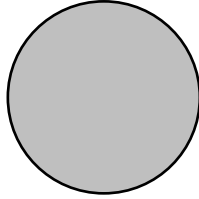
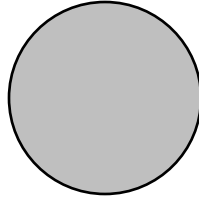
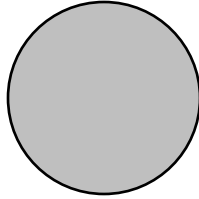
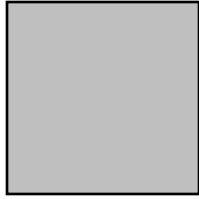
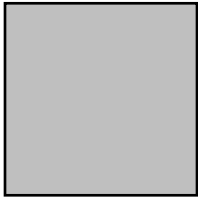
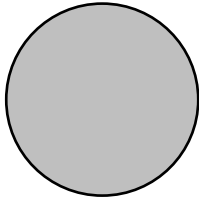


Measuring Reproductive Success

P

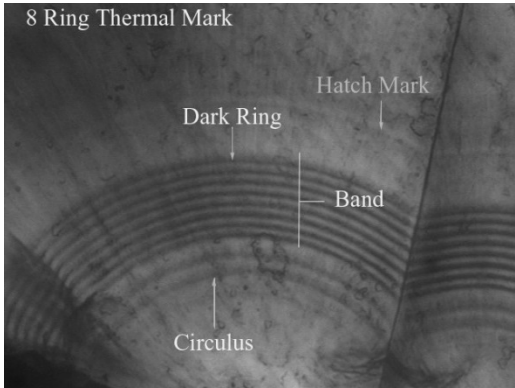
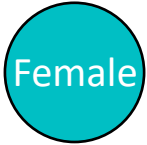
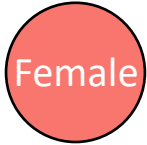
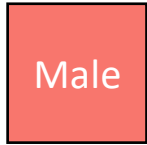


O



Natural

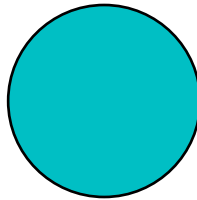
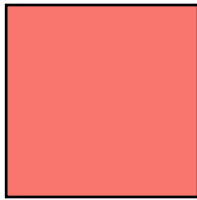
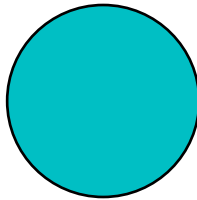
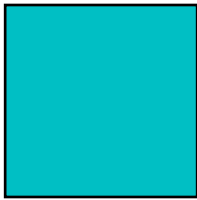
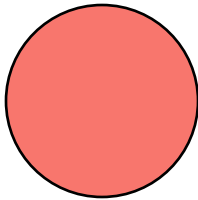
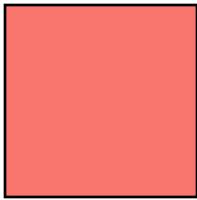
Hatchery



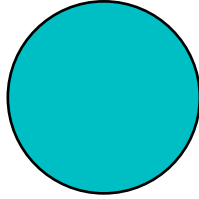
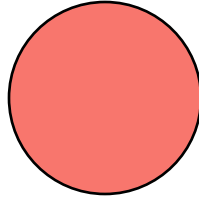
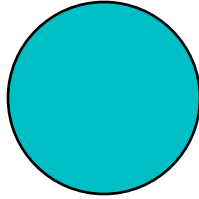
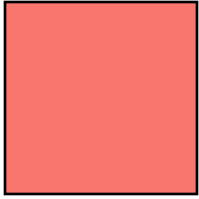
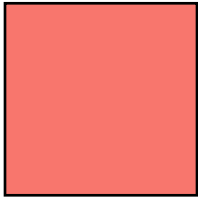
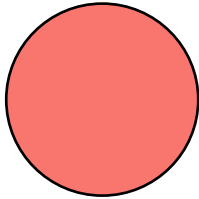
Hatchery-origin

Measuring Reproductive Success

P

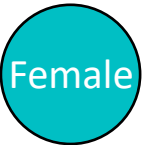
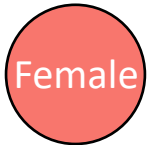
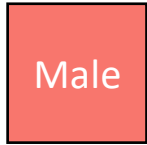


O

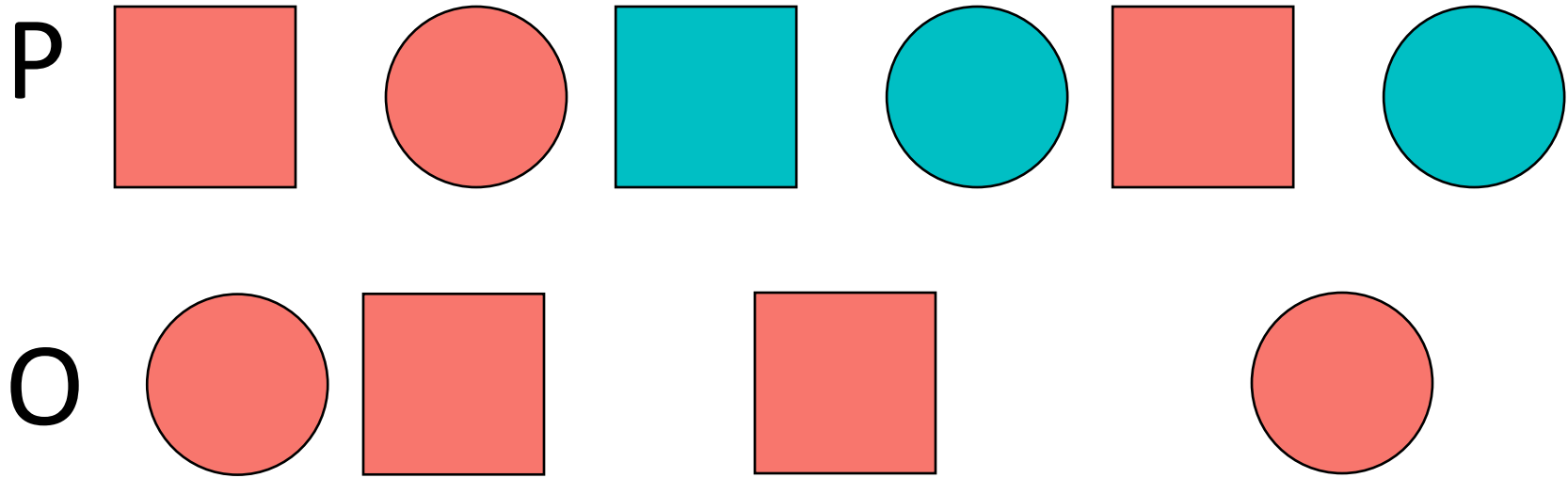


Natural

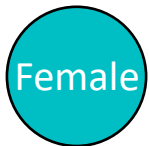
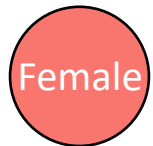
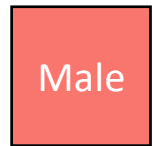
Hatchery



Measuring Reproductive Success

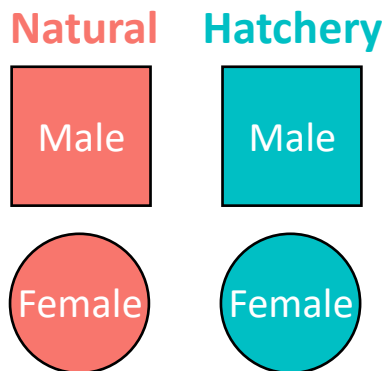
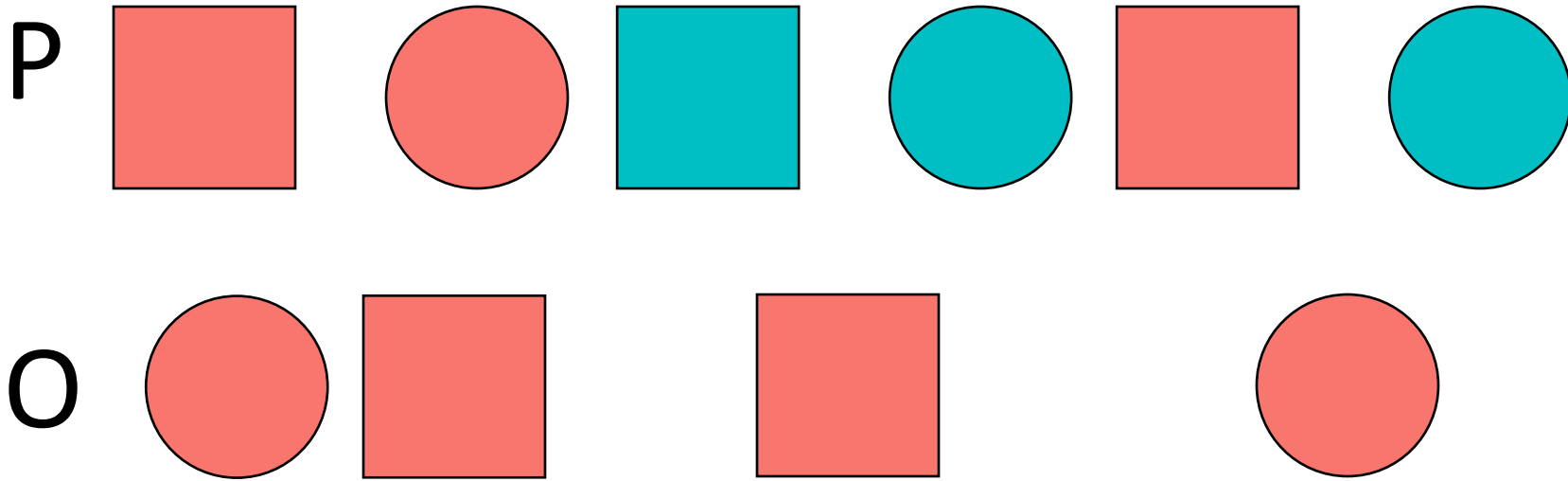


Natural **Hatchery**



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

Measuring Reproductive Success



298
markers

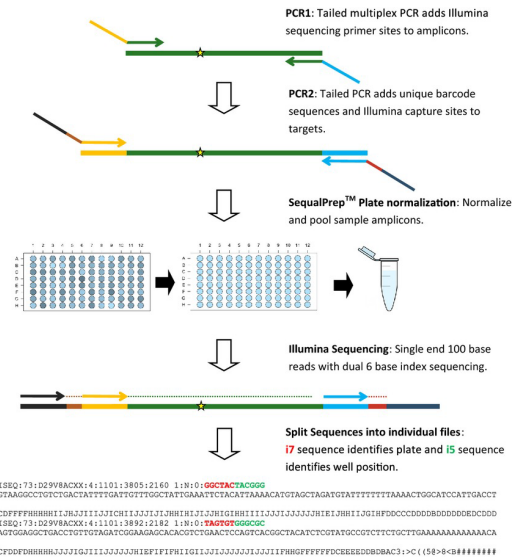


Figure 1 – Campbell et al. 2015

Riester et al. 2009

Genetic Parentage Analysis



CTATGTA**T**AAATGTTAATAATAACTAGCTAACC
CTATGTA**A**AAATGTTAATAATAACTAGCTAACC

T allele
A allele



CTATGTA**A**AAATGTTAATAATAACTAGCTAACC
CTATGTA**A**AAATGTTAATAATAACTAGCTAACC

A allele
A allele



CTATGTA**A**AAATGTTAATAATAACTAGCTAACC
CTATGTA**T**AAATGTTAATAATAACTAGCTAACC

A allele
T allele



CTATGTA**T**AAATGTTAATAATAACTAGCTAACC
CTATGTA**T**AAATGTTAATAATAACTAGCTAACC

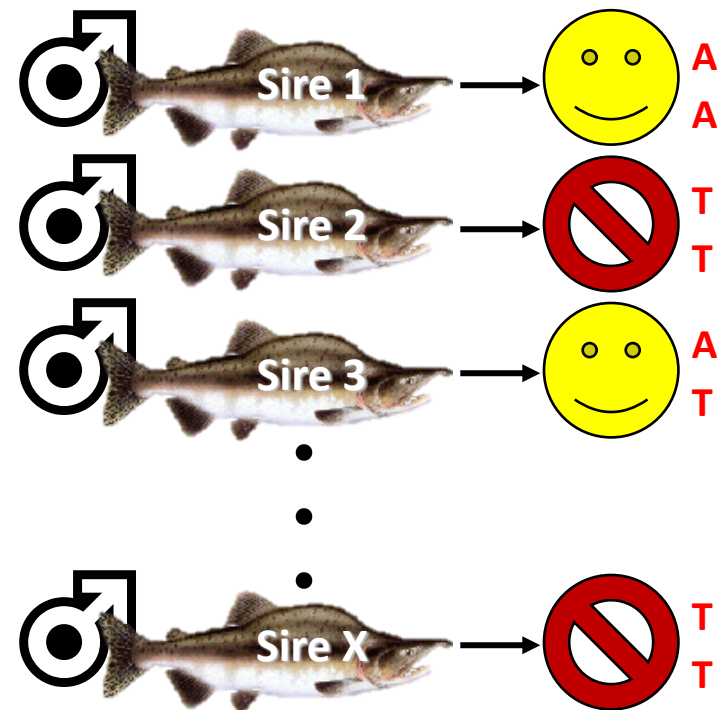
T allele
T allele

Genetic Parentage Analysis

Markers

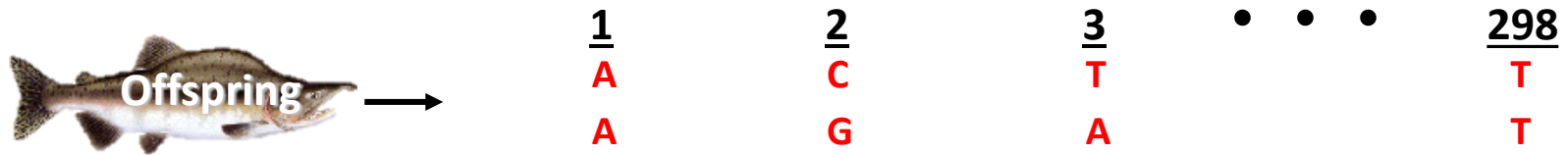


Potential sires (♂)

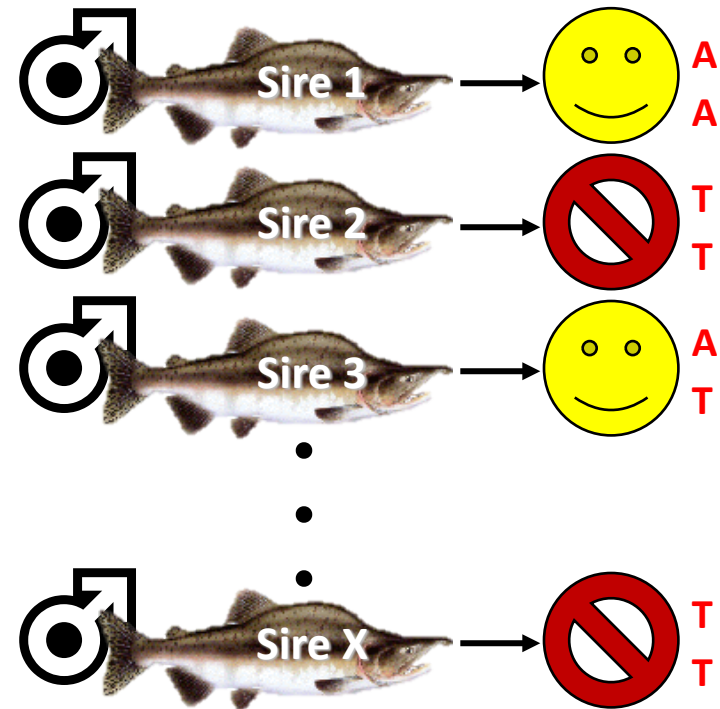


Genetic Parentage Analysis

Markers

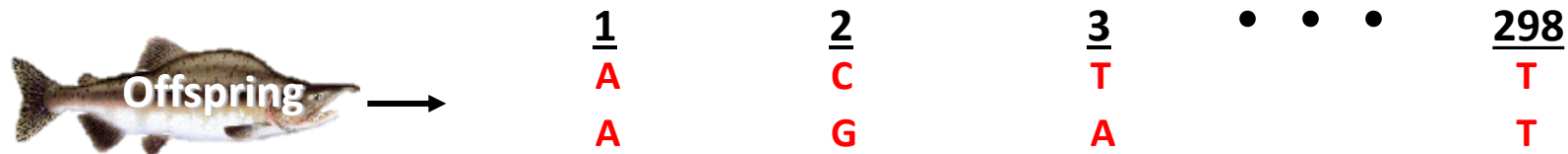


Potential sires (♂)

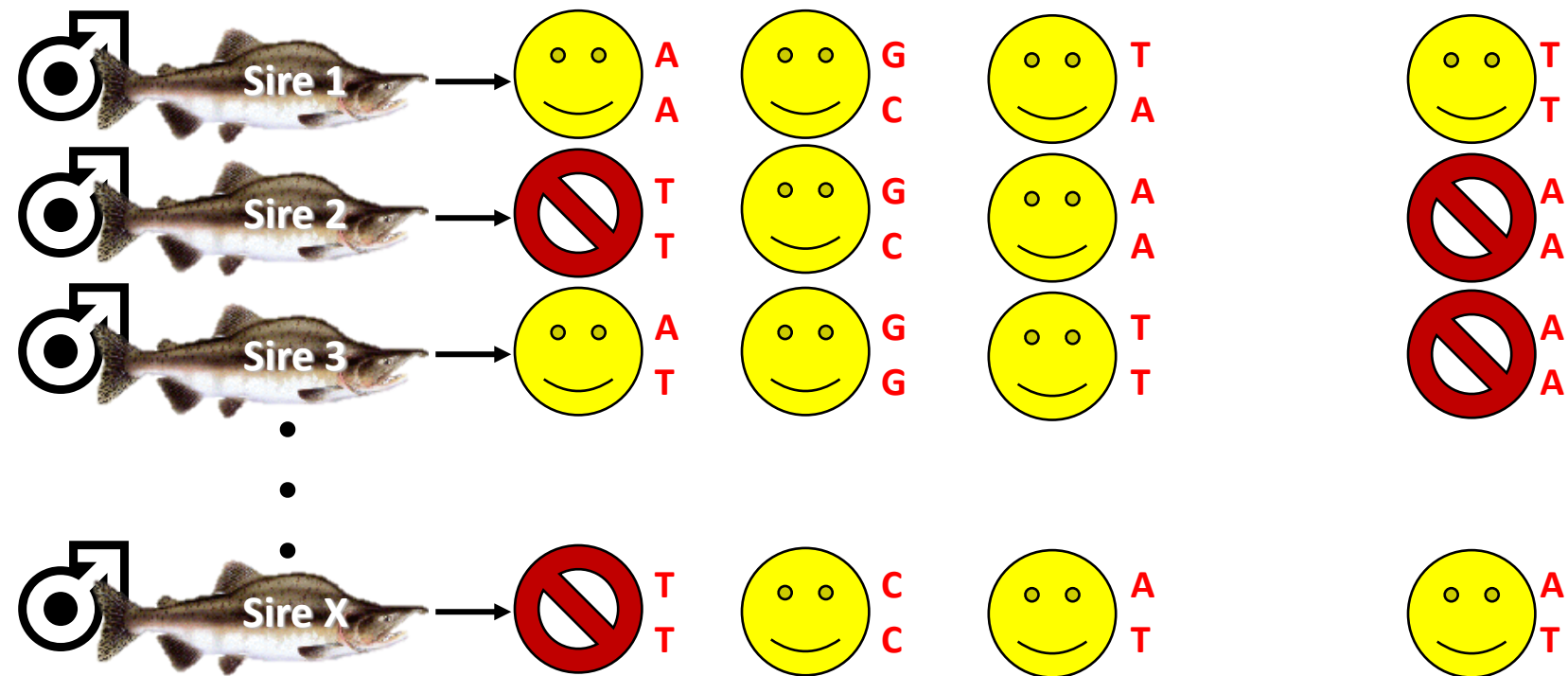


Genetic Parentage Analysis

Markers

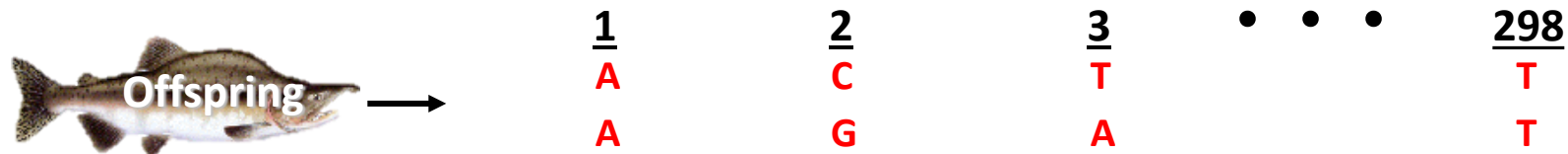


Potential sires (♂)

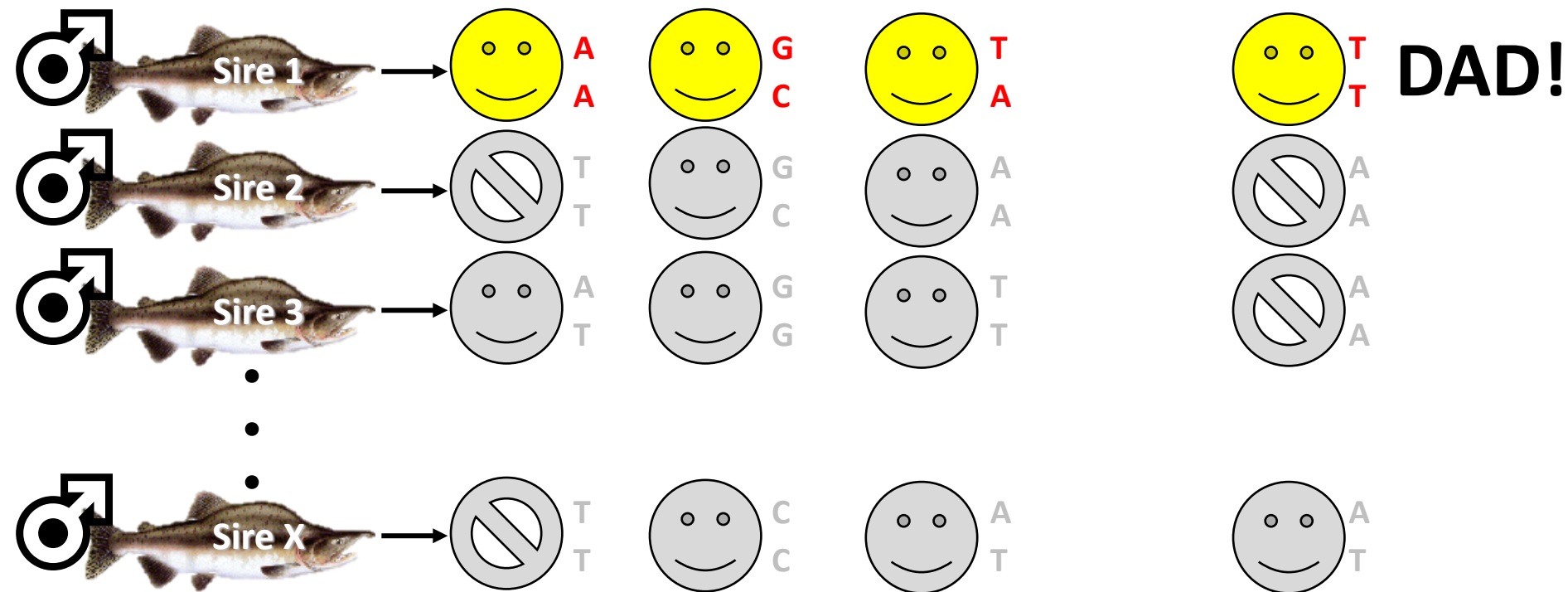


Genetic Parentage Analysis

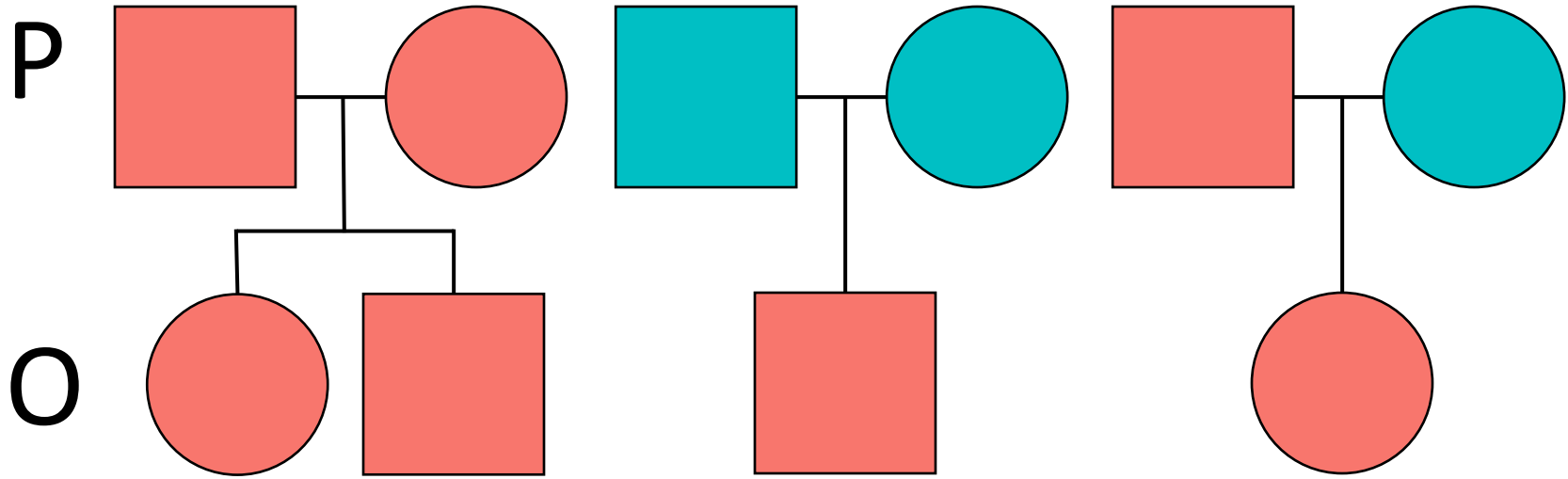
Markers



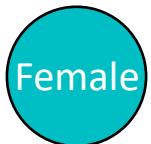
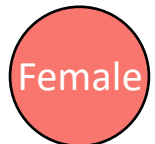
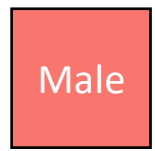
Potential sires (♂)



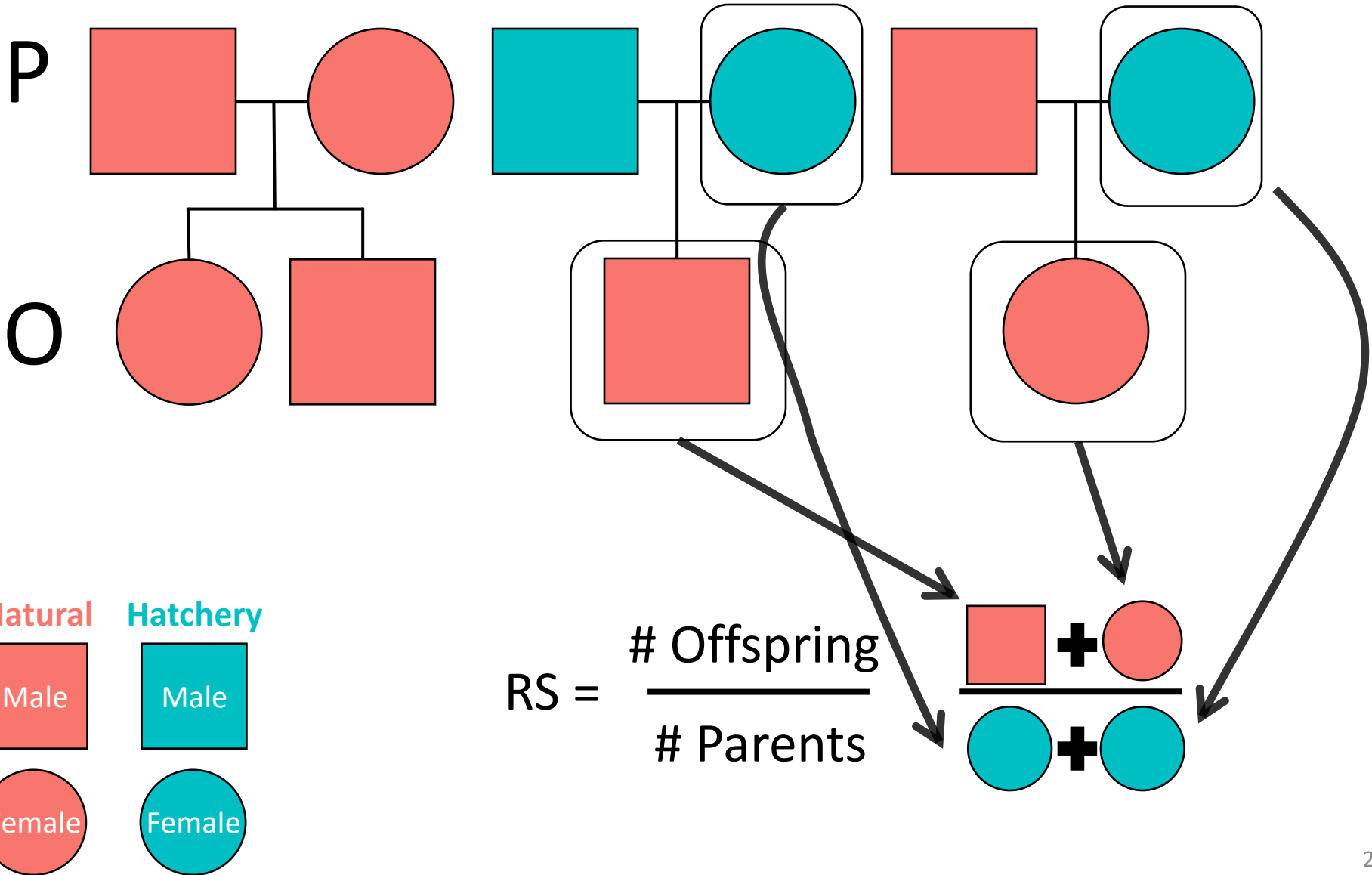
Measuring Reproductive Success



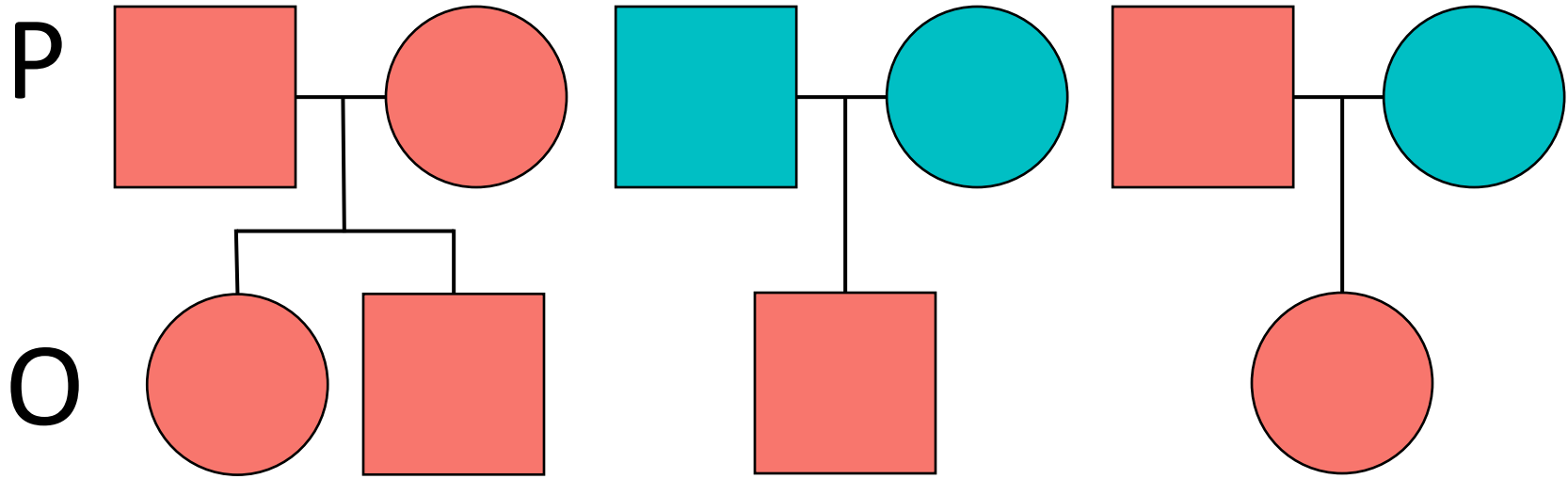
Natural Hatchery



Measuring Reproductive Success

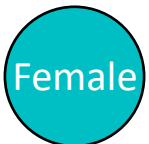
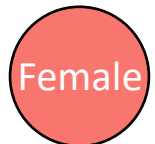
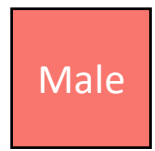


Measuring Reproductive Success

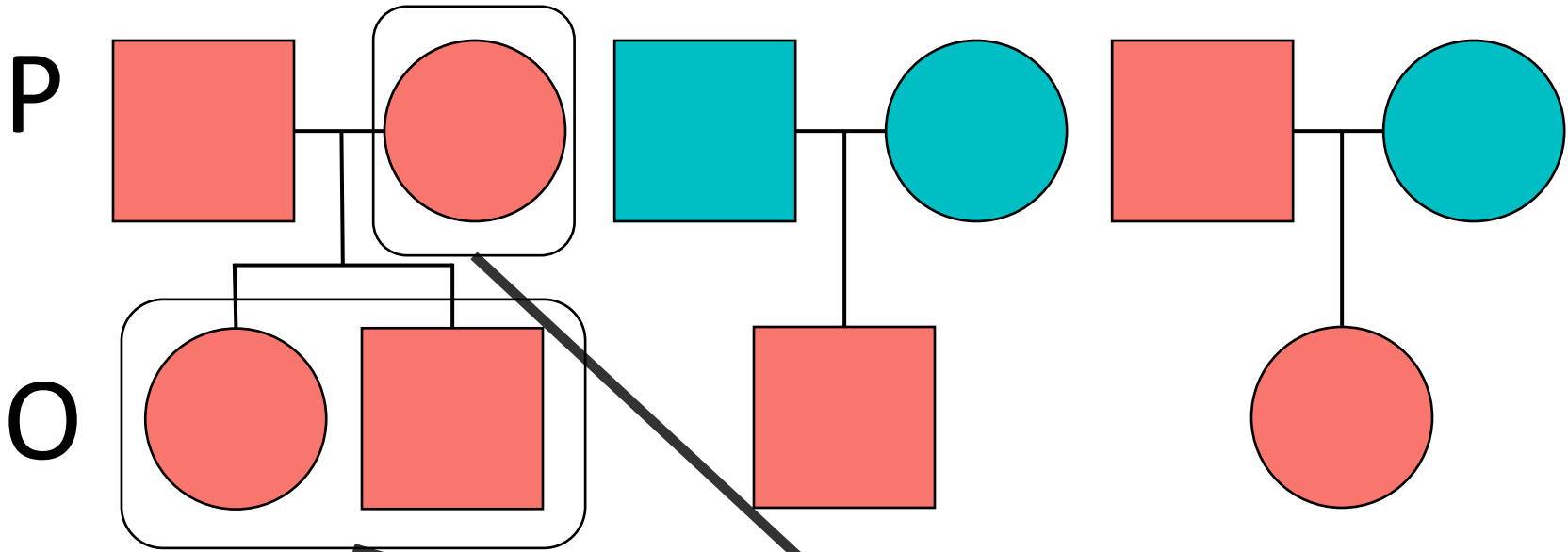


$$RS_{H \text{ Female}} = 1$$

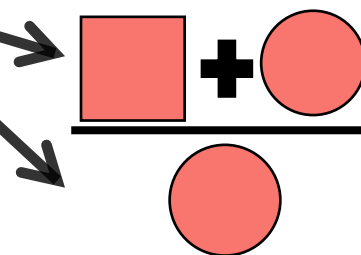
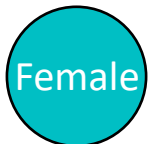
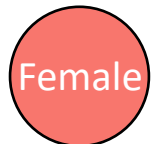
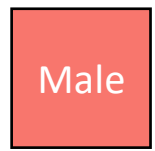
Natural Hatchery



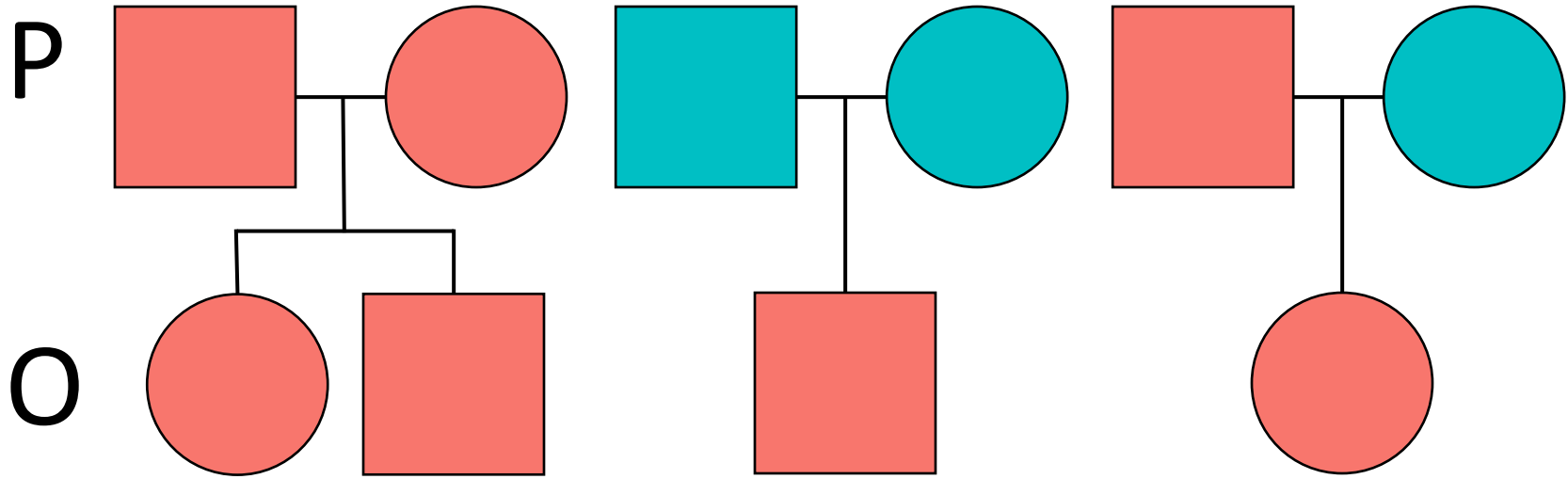
Measuring Reproductive Success



Natural Hatchery



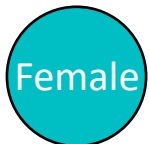
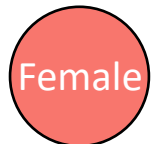
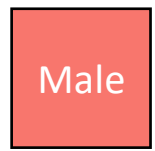
Measuring Reproductive Success



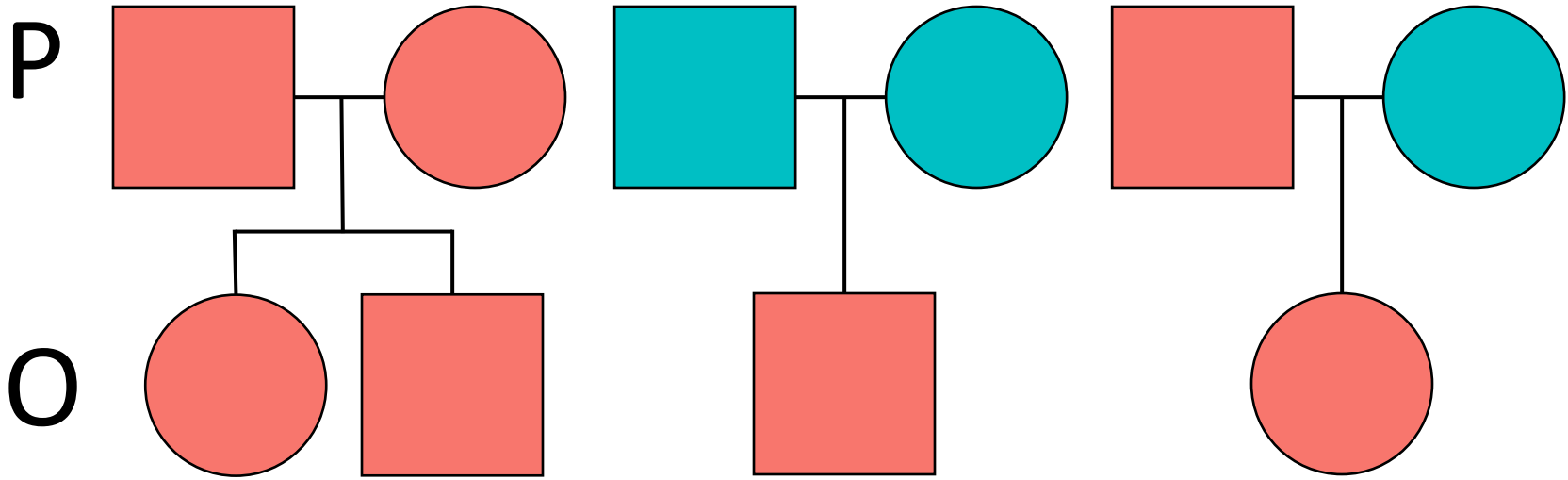
$$RS_{N \text{ Female}} = 2$$

$$RS_{H \text{ Female}} = 1$$

Natural Hatchery



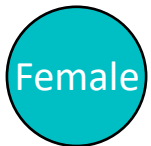
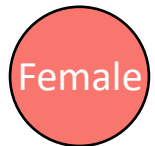
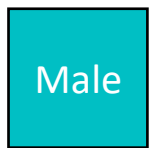
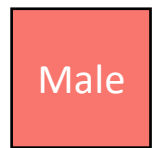
Measuring Reproductive Success



$$RS_{N \text{ Female}} = 2$$

$$RS_{H \text{ Female}} = 1$$

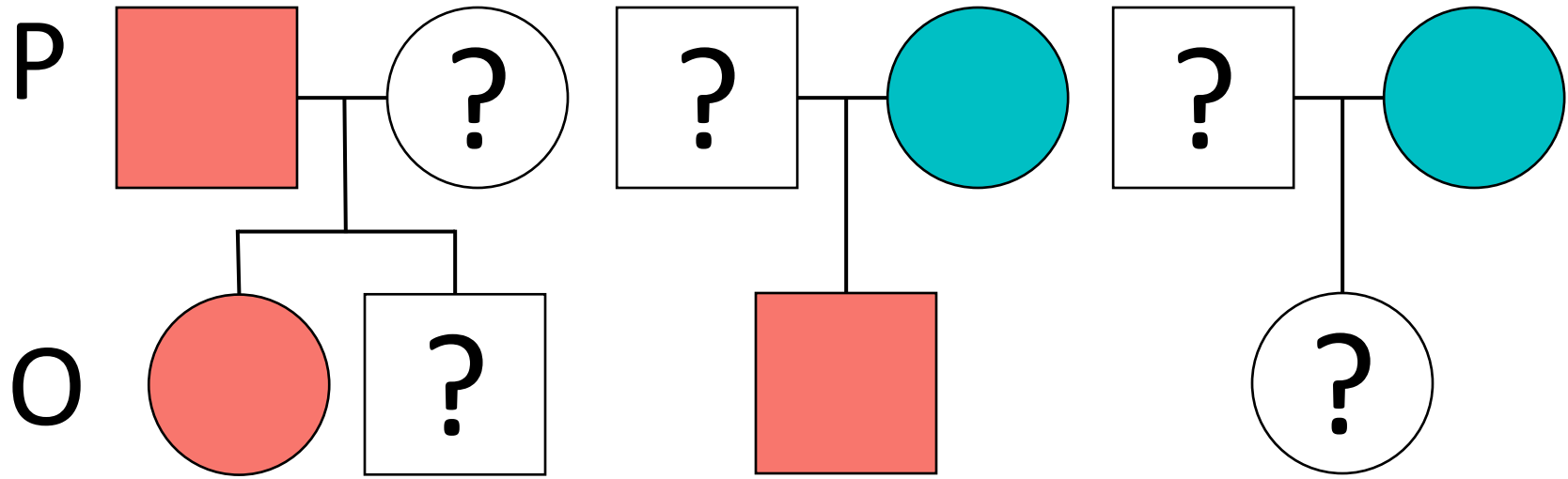
Natural Hatchery



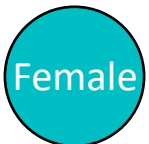
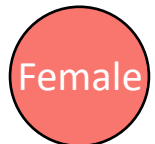
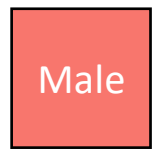
Relative Reproductive Success (RRS)

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

Measuring Reproductive Success



Natural Hatchery



Relative Reproductive Success (RRS)

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

AHRP Streams in PWS

| Stream | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|--------|------|------|------|------|-------|------|------|
| Hogan | P | P | P,O | P,O | P,O,G | O,G | O,G |

P – parents

O – offspring

G – grand-offspring

Odd-lineage

Even-lineage

AHRP Streams in PWS

| Stream | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|--------|------|------|------|------|-------|------|------|
| Hogan | P | P | P,O | P,O | P,O,G | O,G | O,G |

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| Stream | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|-----------|------|------|------|------|-------|-------|------|------|
| Hogan | P | P | P,O | P,O | P,O,G | O,G | O,G | |
| Stockdale | P | P | P,O | P,O | P,O,G | O,G | O,G | |
| Gilmour | | P | P | P,O | P,O | O,G | O,G | |
| Paddy | P | P | P,O | P,O | O,G | P,O,G | | O,G |
| Erb | P | P | P,O | P,O | O,G | P,O,G | | O,G |

P – parents

O – offspring

G – grand-offspring

Odd-lineage

Even-lineage

>235K samples!

AHRP Streams in PWS

Presented 2019

| Stream | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|-----------|------|------|------|------|-------|-------|------|------|
| Hogan | P | P | P,O | P,O | P,O,G | O,G | O,G | |
| Stockdale | P | P | P,O | P,O | P,O,G | O,G | O,G | |
| Gilmour | | P | P | P,O | P,O | O,G | O,G | |
| Paddy | P | P | P,O | P,O | O,G | P,O,G | | O,G |
| Erb | P | P | P,O | P,O | O,G | P,O,G | | O,G |

P – parents

O – offspring

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Odd-lineage

Even-lineage

>235K samples!

AHRP Streams in PWS

Presented 2020

| Stream | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|-----------|------|------|------|------|-------|-------|------|------|
| Hogan | P | P | P,O | P,O | P,O,G | O,G | O,G | |
| Stockdale | P | P | P,O | P,O | P,O,G | O,G | O,G | |
| Gilmour | | P | P | P,O | P,O | O,G | O,G | |
| Paddy | P | P | P,O | P,O | O,G | P,O,G | | O,G |
| Erb | P | P | P,O | P,O | O,G | P,O,G | | O,G |

P – parents

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AHRP Streams in PWS

Presented 2020

| Stream | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|-----------|------|------|------|------|-------|------|------|------|
| Hogan | P | P | P,O | P,O | P,O,G | O,G | O,G | |
| Stockdale | P | P | P,O | P,O | P,O,G | O,G | O,G | |
| | | | | | | | | |

Shedd, K.R., Lescak, E.A., Habicht, C., Knudsen, E.E., Dann, T.H., Hoyt, H.A., Prince, D.J. and Templin, W.D. 2022. Reduced relative fitness in hatchery-origin Pink Salmon in two streams in Prince William Sound, Alaska. *Evolutionary Applications*.

<https://doi.org/10.1111/eva.13356>

G – grand-offspring

Even image

AHRP Streams in PWS

Presenting 2022

| Stream | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|-----------|------|------|------|------|-------|-------|------|------|
| Hogan | P | P | P,O | P,O | P,O,G | O,G | O,G | |
| Stockdale | P | P | P,O | P,O | P,O,G | O,G | O,G | |
| Gilmour | | P | P | P,O | P,O | O,G | O,G | |
| Paddy | P | P | P,O | P,O | O,G | P,O,G | | O,G |
| Erb | P | P | P,O | P,O | O,G | P,O,G | | O,G |

P – parents

O – offspring

G – grand-offspring

Odd-lineage

Even-lineage

>235K samples!

A large group of salmon are captured in mid-air, jumping out of the water onto a rocky shore. The fish are in various stages of their jump, with some having their mouths wide open. The water is dark and turbulent, and the rocks are dark and wet. The scene is dynamic and energetic.

Questions?