Pink Salmon pedigree analyses and remaining work

Kyle Shedd
Gene Conservation Laboratory
Alaska Department of Fish and Game
AHRP Informational Meeting
March 6, 2020

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 <u>fitness</u> (productivity) of natural pink and chum stocks due to straying hatchery pink and chum salmon?

Hatchery/Natural Fitness

Steelhead

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

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

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

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

Hitoshi Araki, Becky Cooper and Michael S. Blouin

Transactions of the American Fisheries Society

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

Ewann A. Berntson, Richard W. Carmichael, Michael W. Flesher, Eric J. Ward & Paul Moran

PNAS

Genetic adaptation to captivity can occur in a single generation

Mark R. Christie, Melanie L. Marine, Rod A. French, and Michael S. Blouin

Chinook

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

Jason Baumsteiger, David M. Hand and Douglas E. Olson, Robert Spateholts and Geoff FitzGerald, William R. Ardren

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

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

ORIGINAL ARTICLE

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

Joseph H. Anderson, Paul L. Faulds, William I. Atlas and Thomas P. Quinn

Coho

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

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

Chum

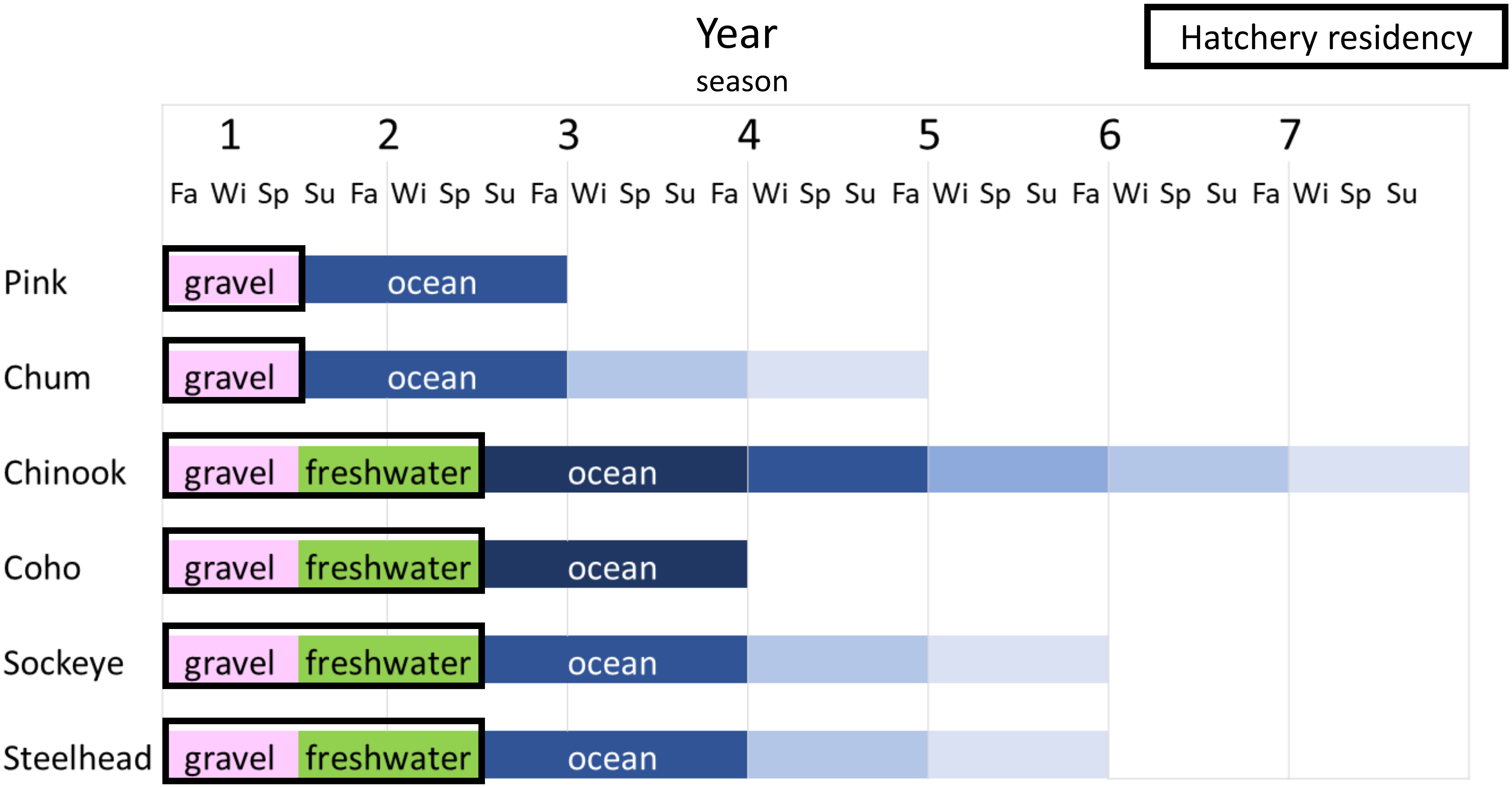
Reproductive behavior and relative reproductive success of natural- and hatchery-origin Hood Canal summer chum salmon (*Oncorhynchus keta*)

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

Hatchery/Natural Fitness

- No pinks and only one chum study

Hatchery/Natural Fitness

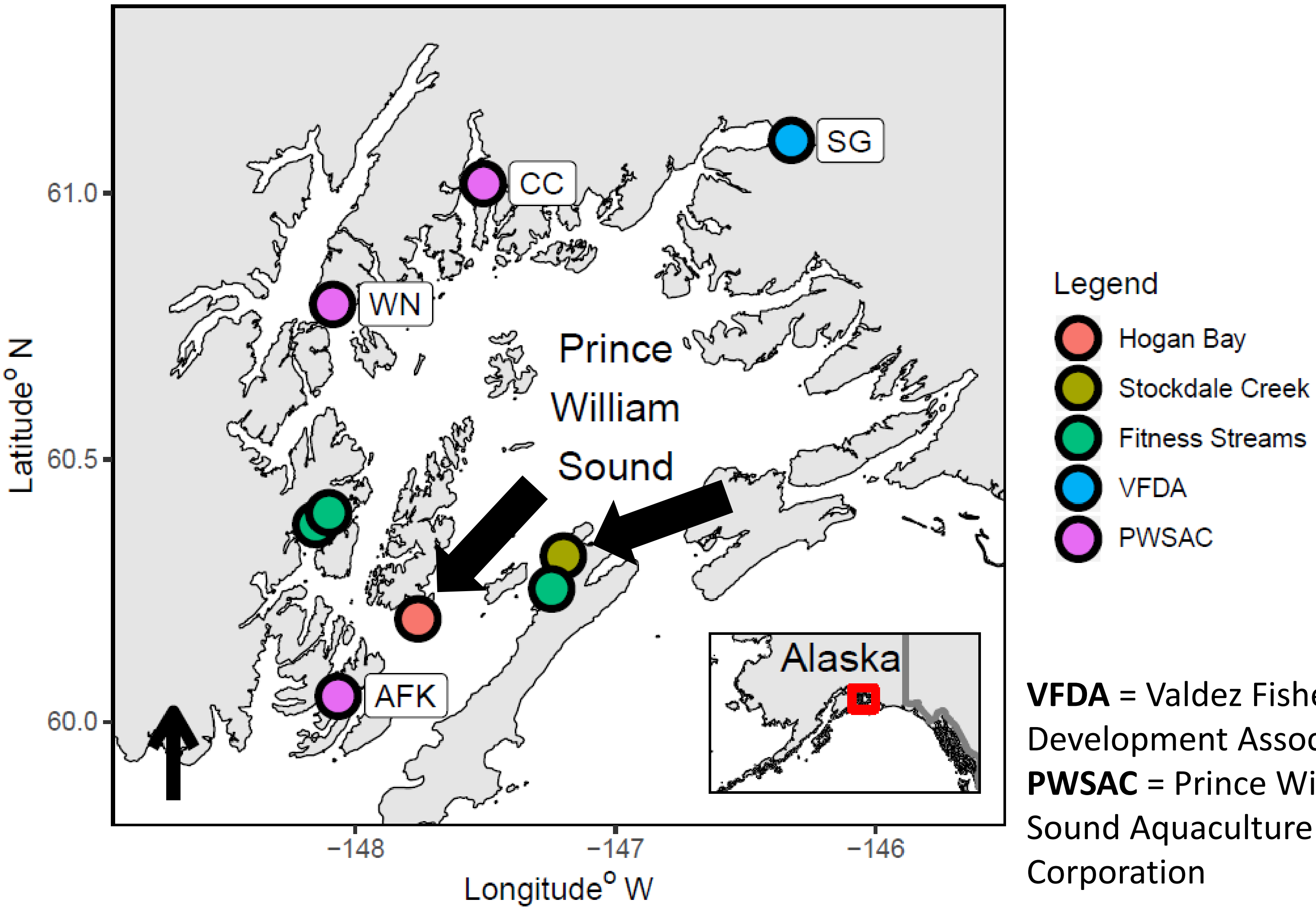


Hatchery/Natural Fitness

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

AHRP Fitness Study: PWS Pink Salmon

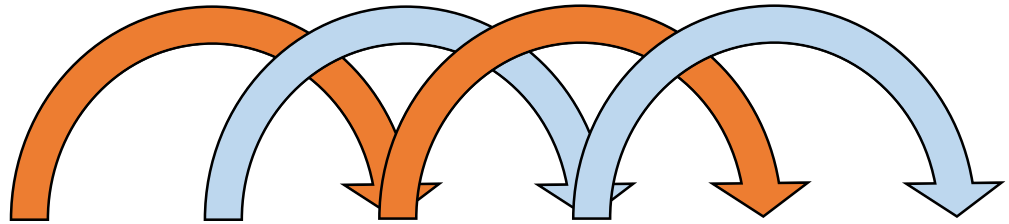
AHRP Streams in PWS



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

Figure 1 – Lescak et al. *in submission*

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
Stockdale	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

Presented last year

Stream	2013	2014	2015	2016	2017	2018	2019
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

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
Stockdale	P	P	P,O	P,O	P,O,G	O,G	O,G

P – parents

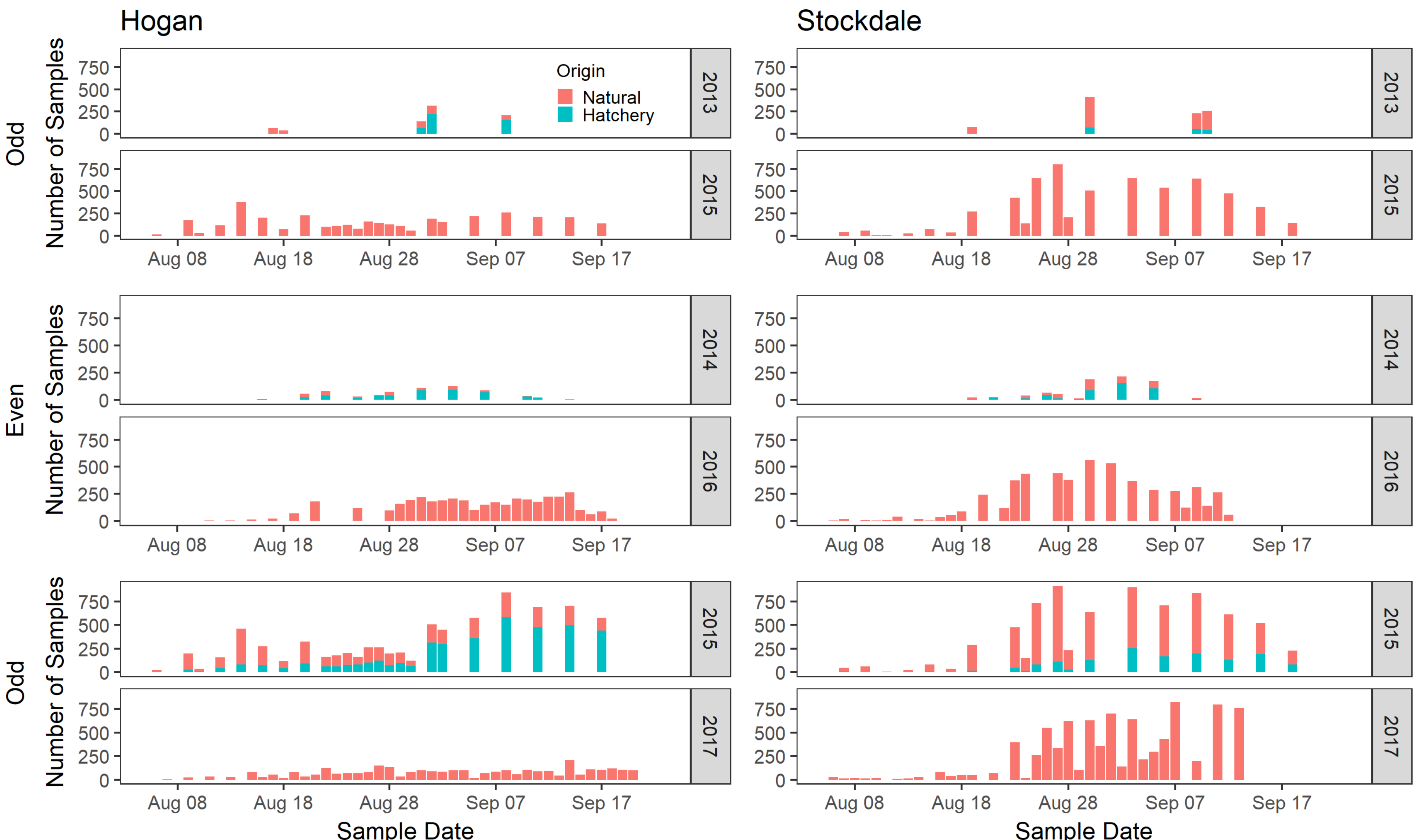
O – offspring

G – grand-offspring

Odd-lineage

Even-lineage

Samples



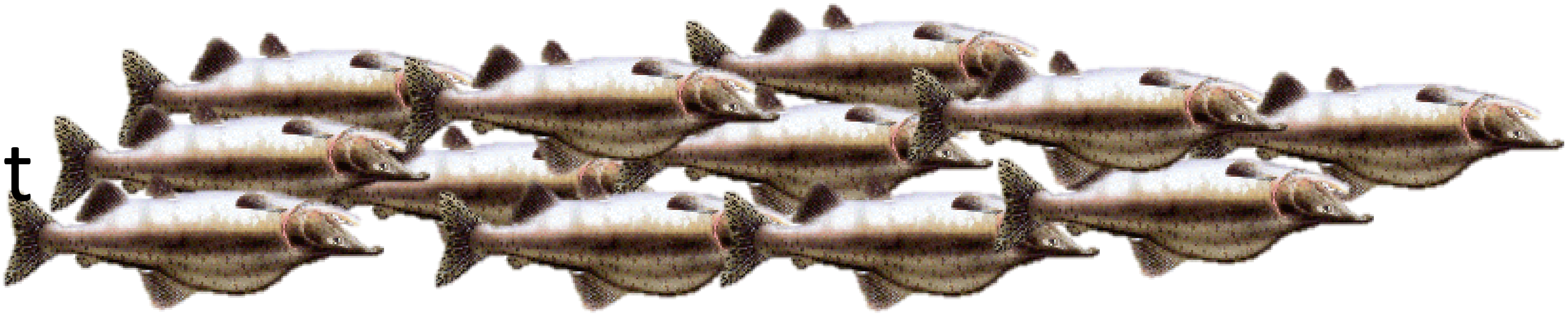
Hogan
Stockdale
Origin
Natural
Hatchery
Odd
Even
Odd
Number of Samples
2013
2015
2014
2016
2015
2017
0
250
500
750
Aug 08
Aug 18
Aug 28
Sep 07
Sep 17
Sample Date

Fitness = Reproductive Success

Parent

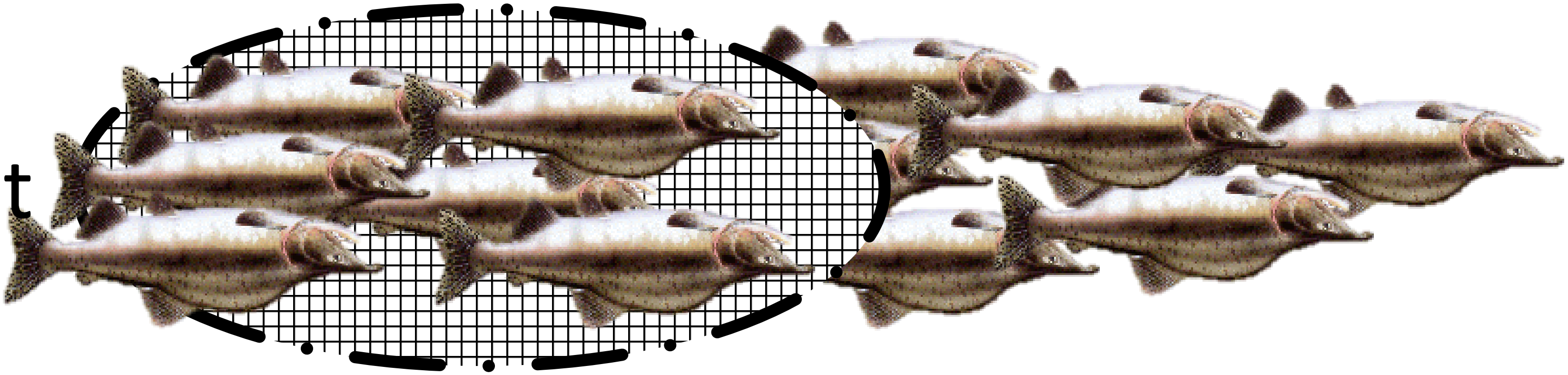
Measuring Reproductive Success

Parent



Measuring Reproductive Success

Parent

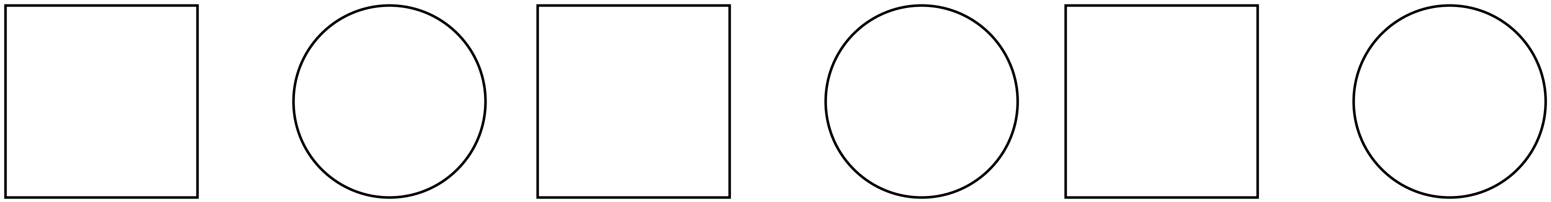


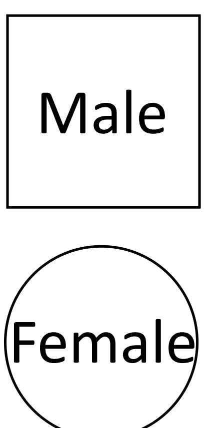
Measuring Reproductive Success

Parent 

Measuring Reproductive Success

P





Measuring Reproductive Success

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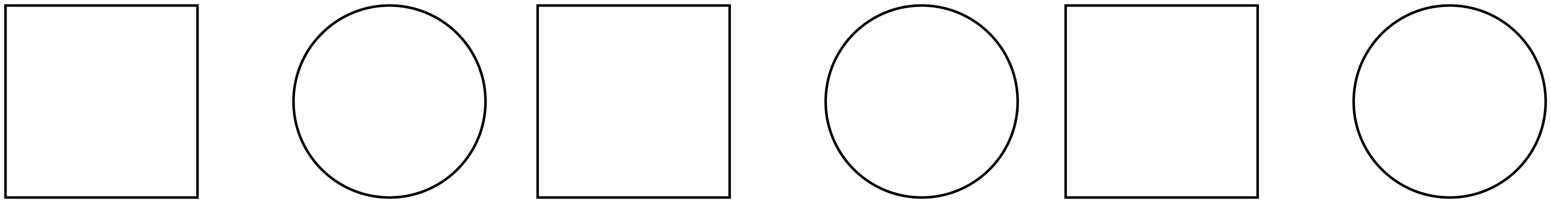
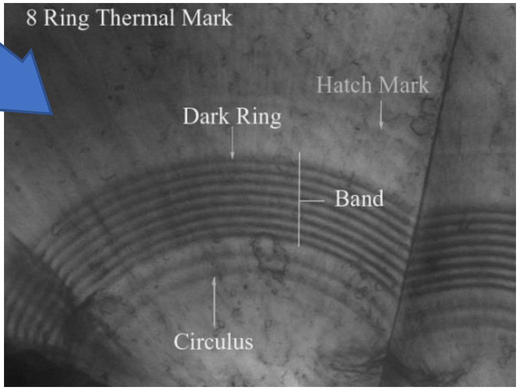


Male

Female

Measuring Reproductive Success

P

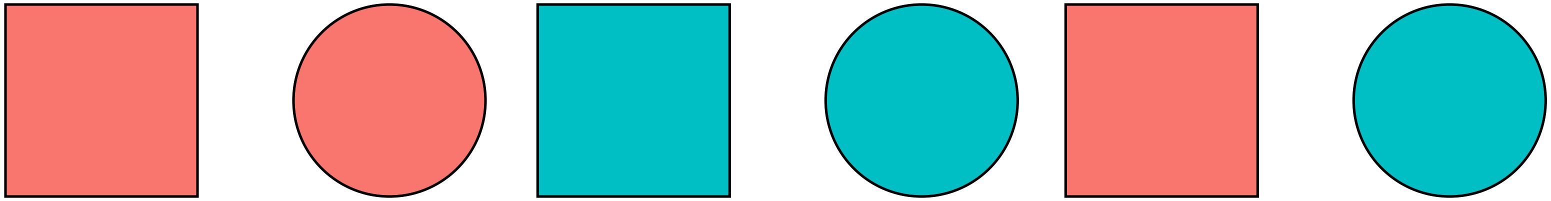


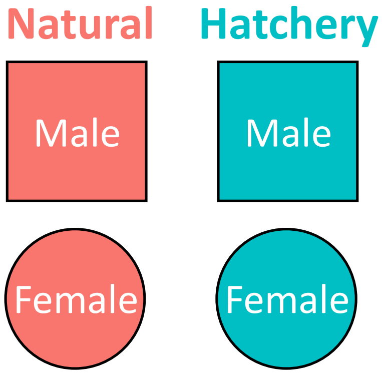
Hatchery-origin

Male

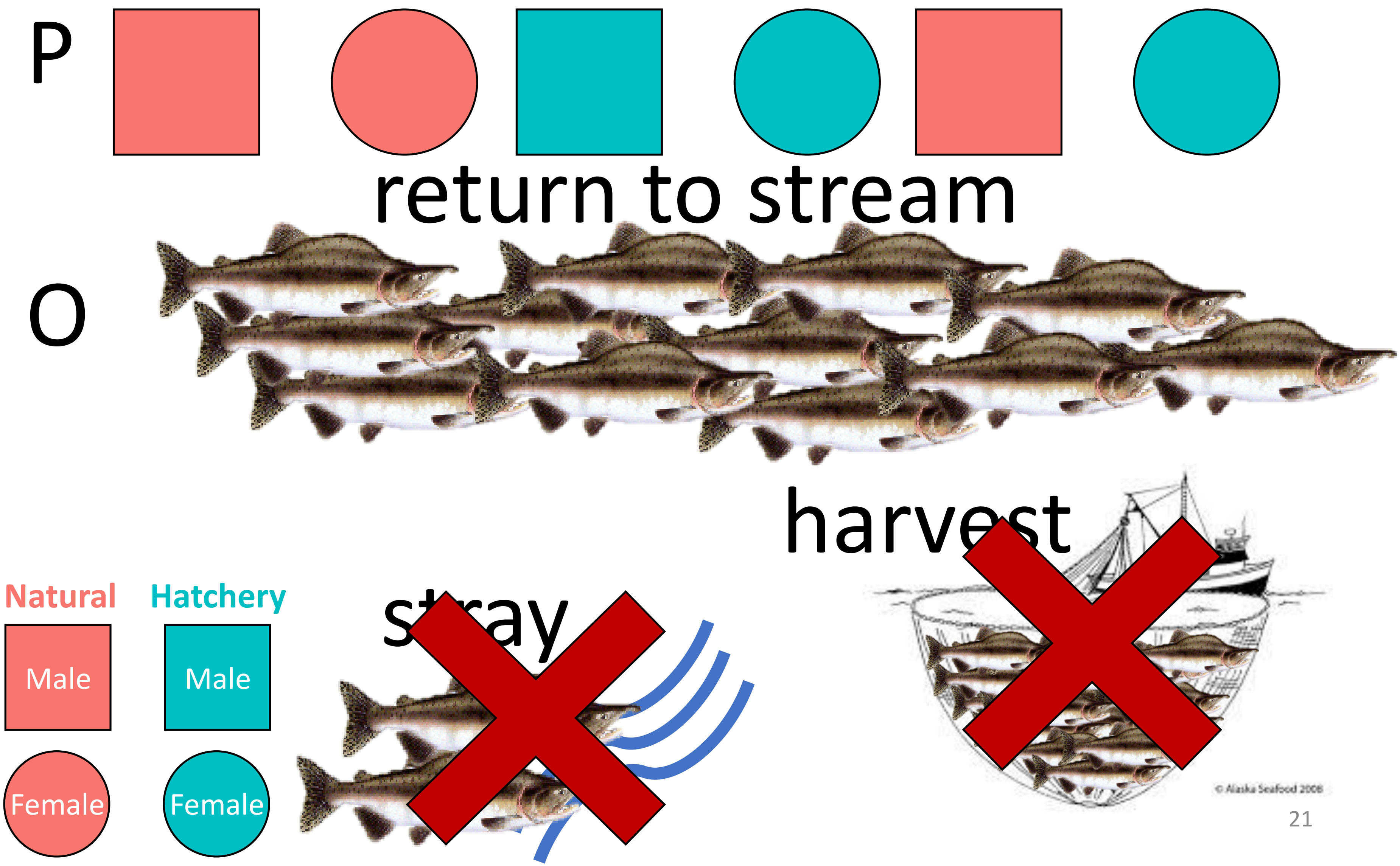
Female

Measuring Reproductive Success

P 



Measuring Reproductive Success



Measuring Reproductive Success

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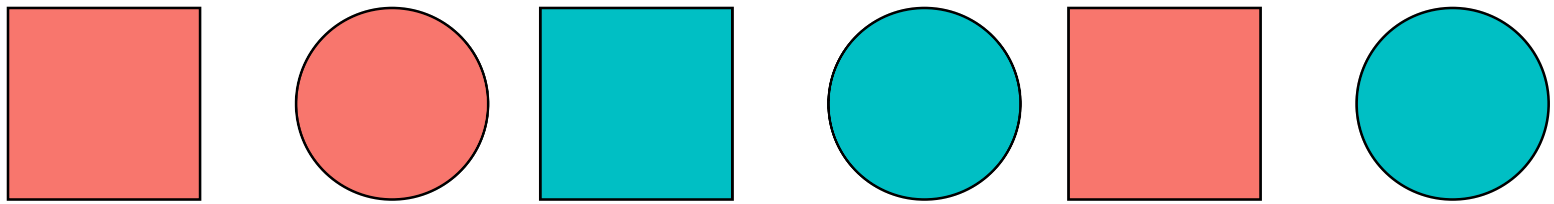

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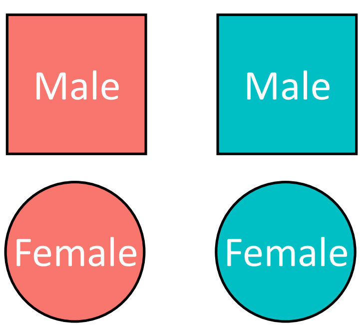
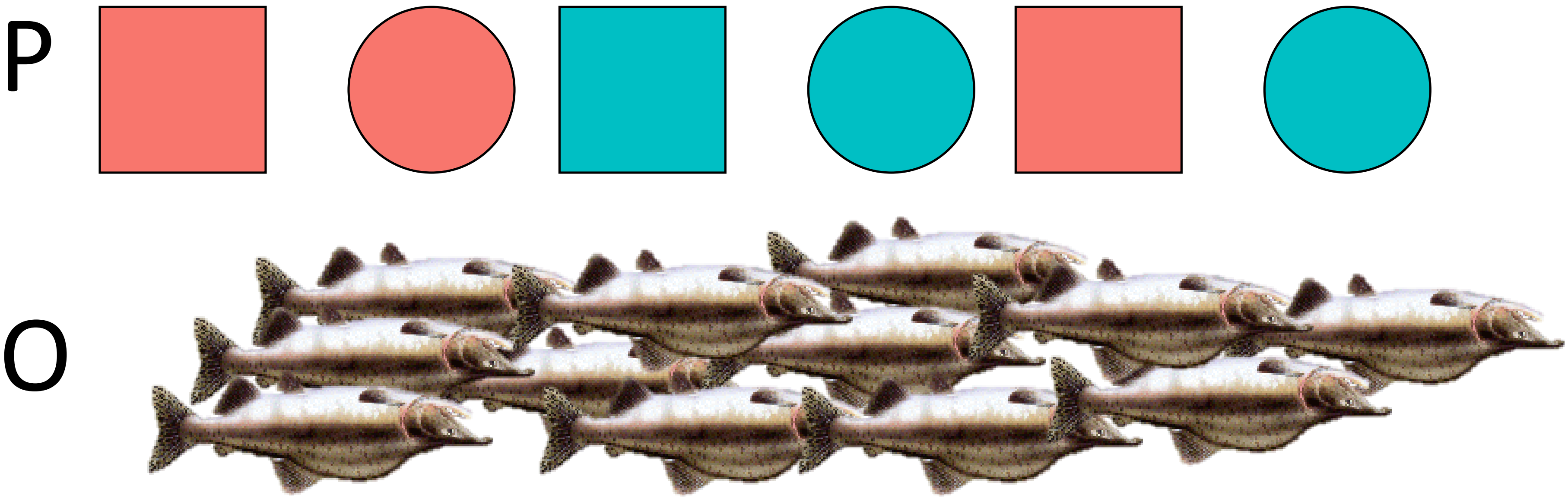
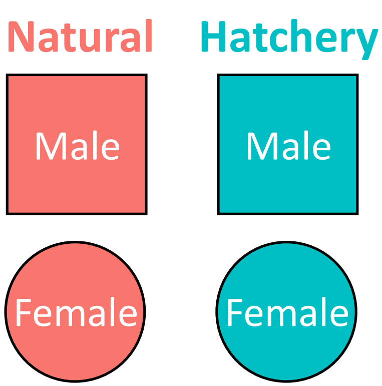
Natural Hatchery

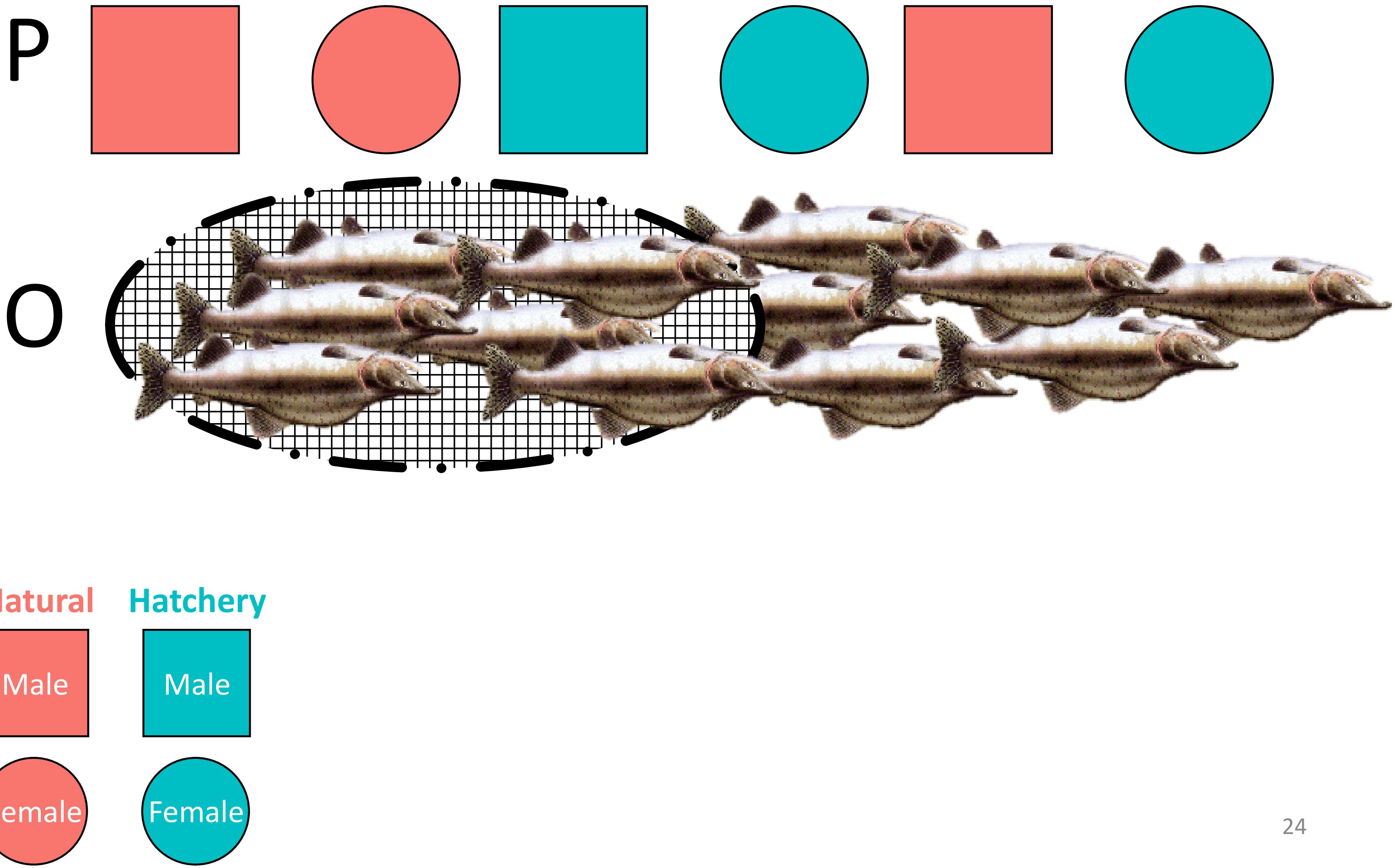


Measuring Reproductive Success

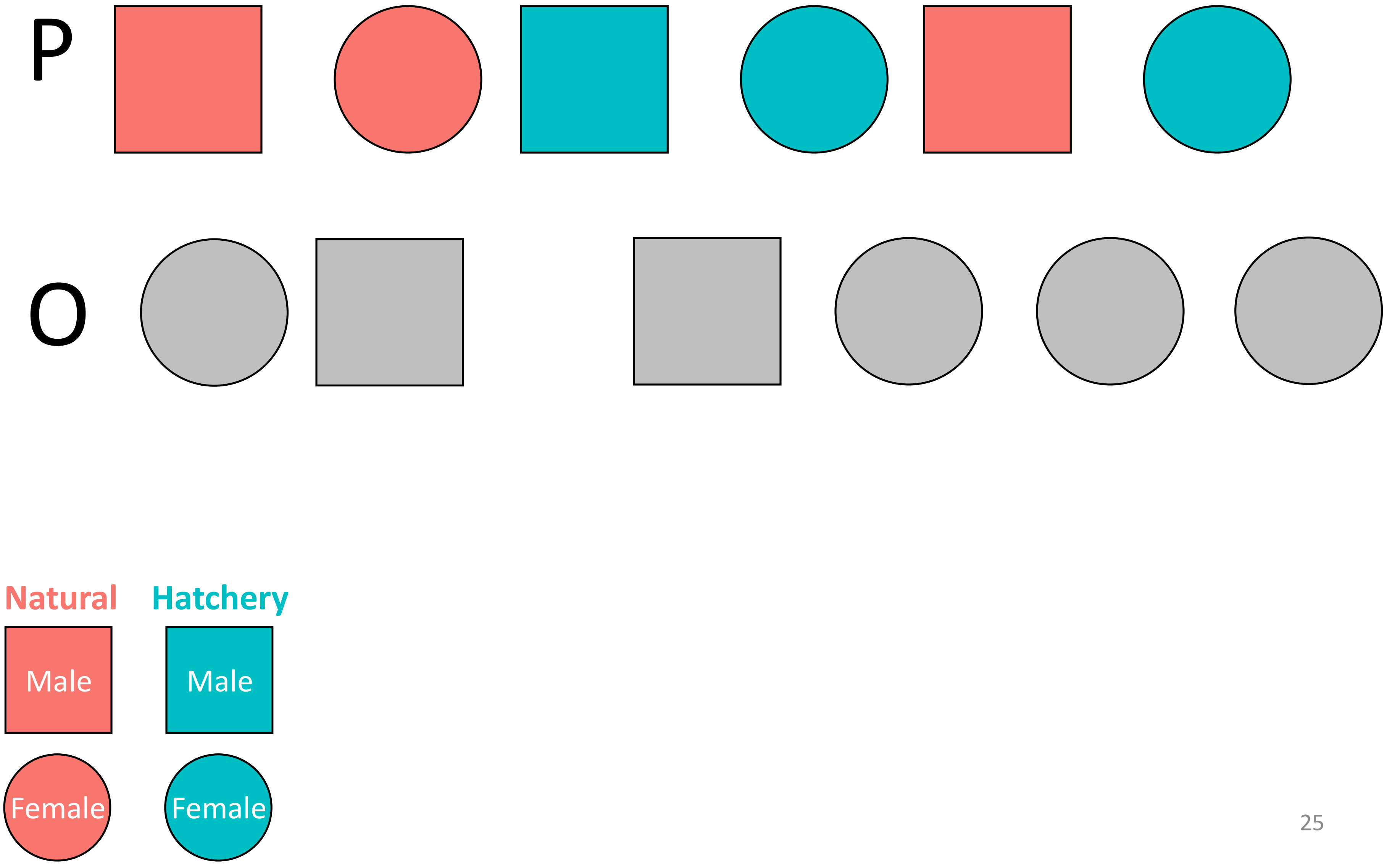




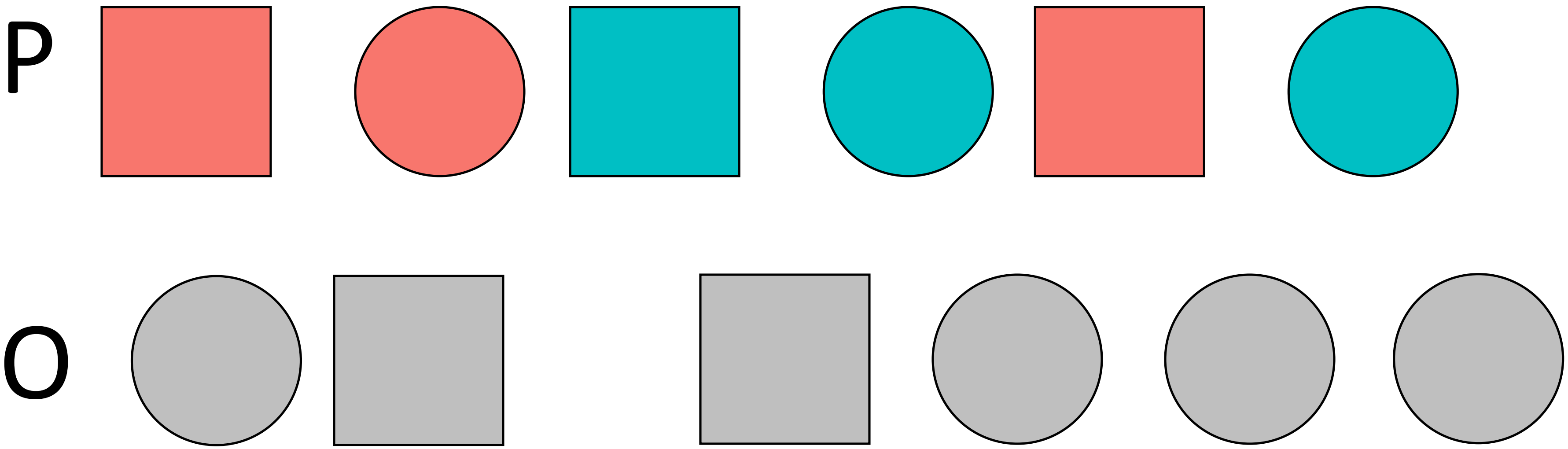
Measuring Reproductive Success

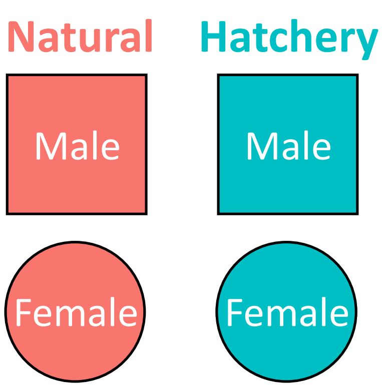


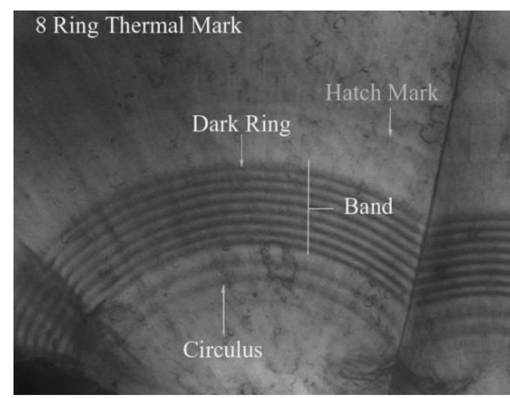
Measuring Reproductive Success



Measuring Reproductive Success

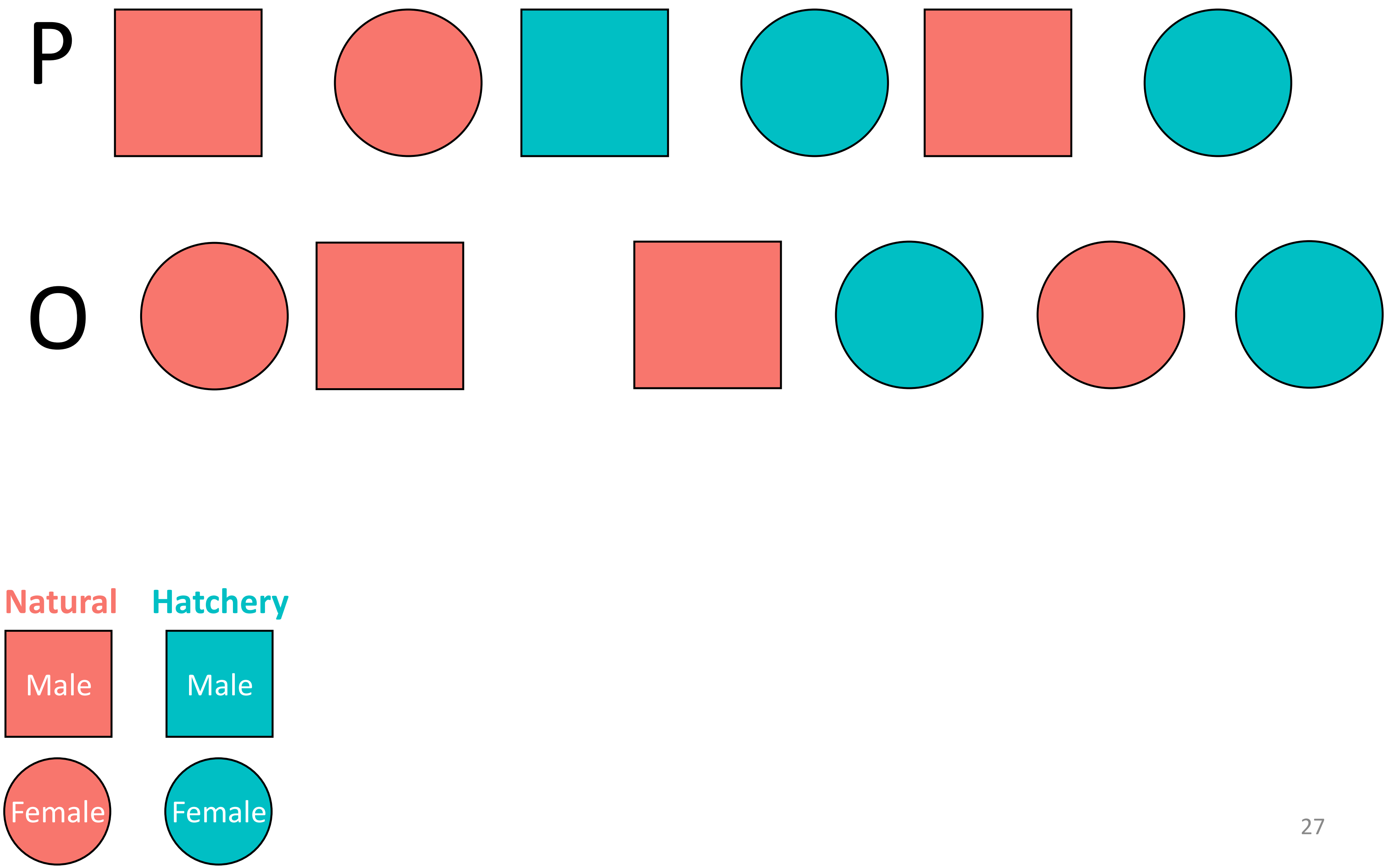




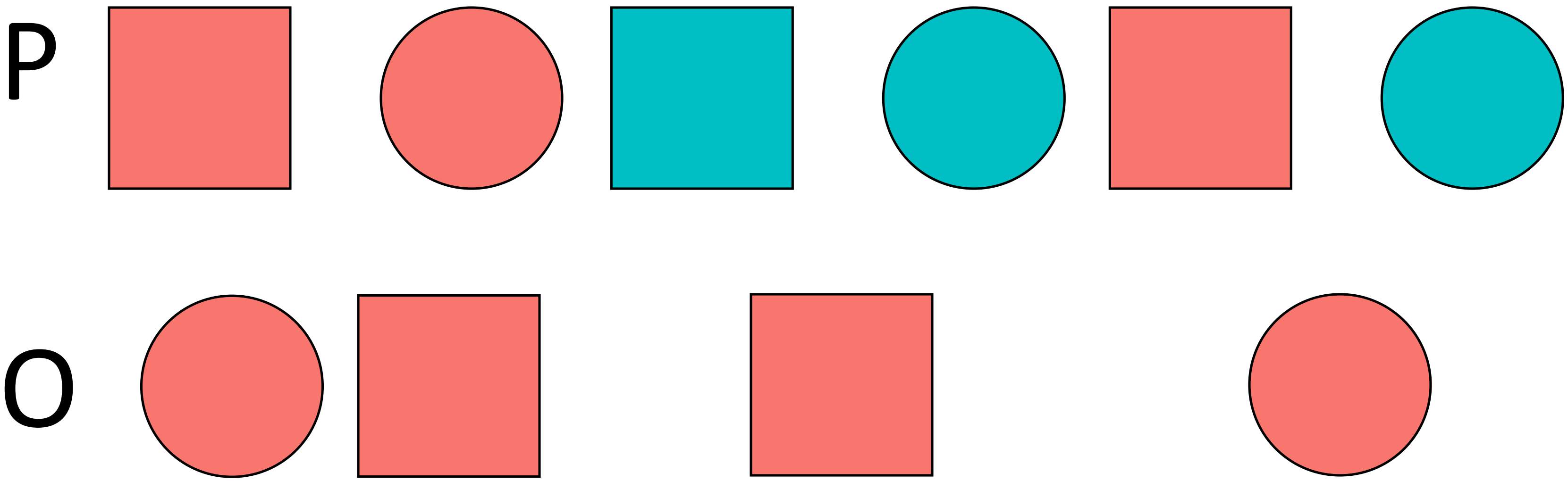


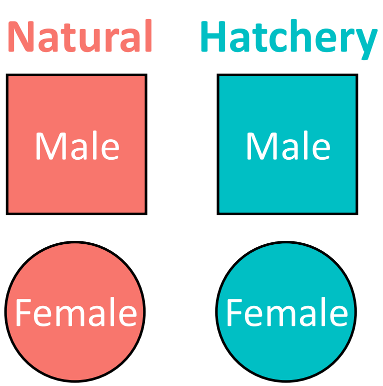
Hatchery-origin

Measuring Reproductive Success



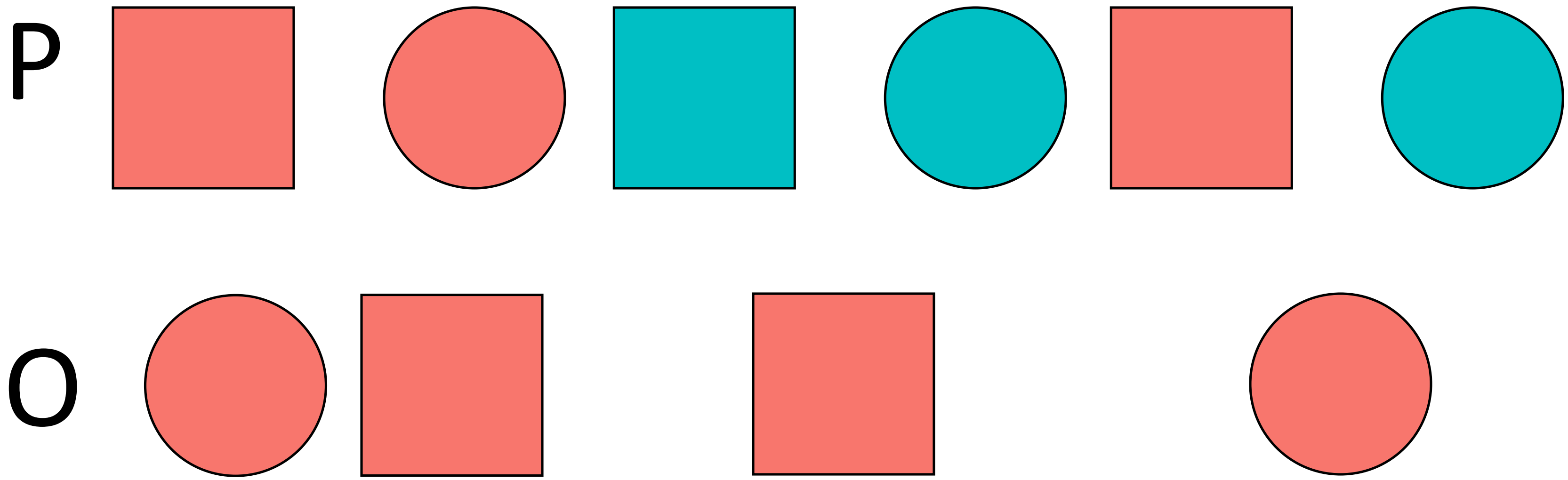
Measuring Reproductive Success

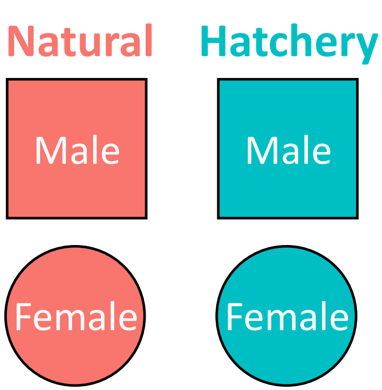




Hatchery-origin fish are not genotyped in the offspring generation because they have a known origin.

Measuring Reproductive Success





298 markers

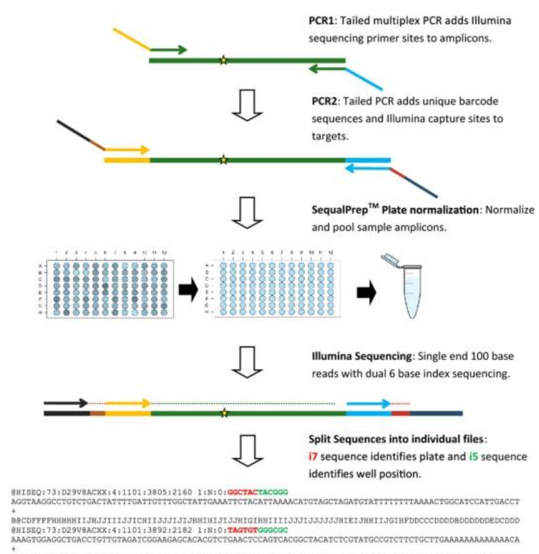


Figure 1 – Campbell et al. 2015

Measuring Reproductive Success

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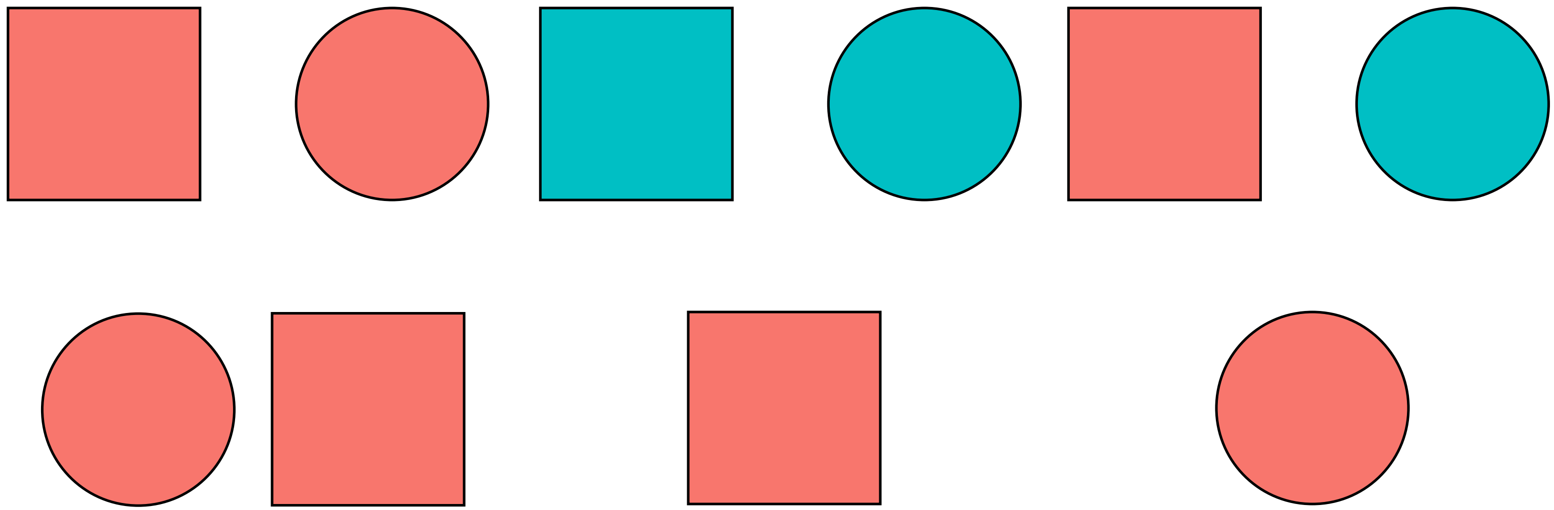
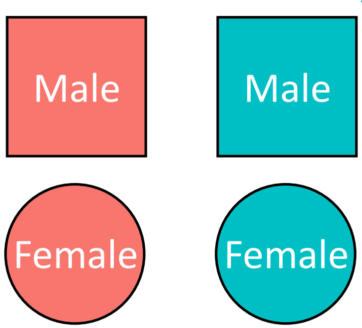


Natural Hatchery



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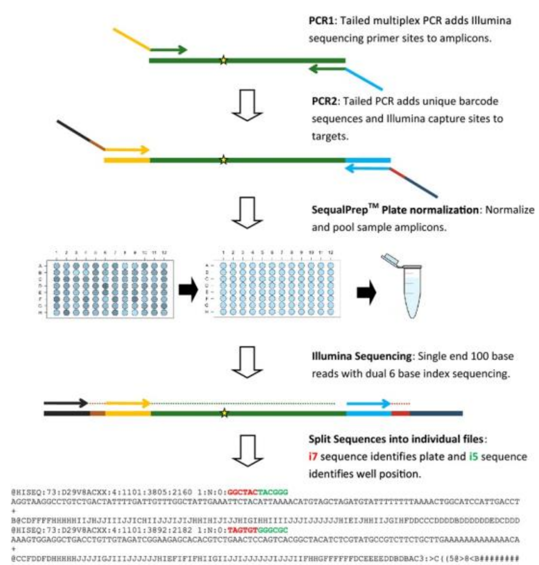


Figure 1 – Campbell et al. 2015

Riester et al. 2009

Genetic Parentage Analysis

CTATGTATTAAATGTTAATAATAATAACTAGCTAACC *T allele*

CTATGTAATAAATGTTAATAATAATAACTAGCTAACC *A allele*

CTATGTAATAAATGTTAATAATAATAACTAGCTAACC *A allele*

CTATGTAATAAATGTTAATAATAATAACTAGCTAACC *A allele*

CTATGTAATAAATGTTAATAATAATAACTAGCTAACC *A allele*

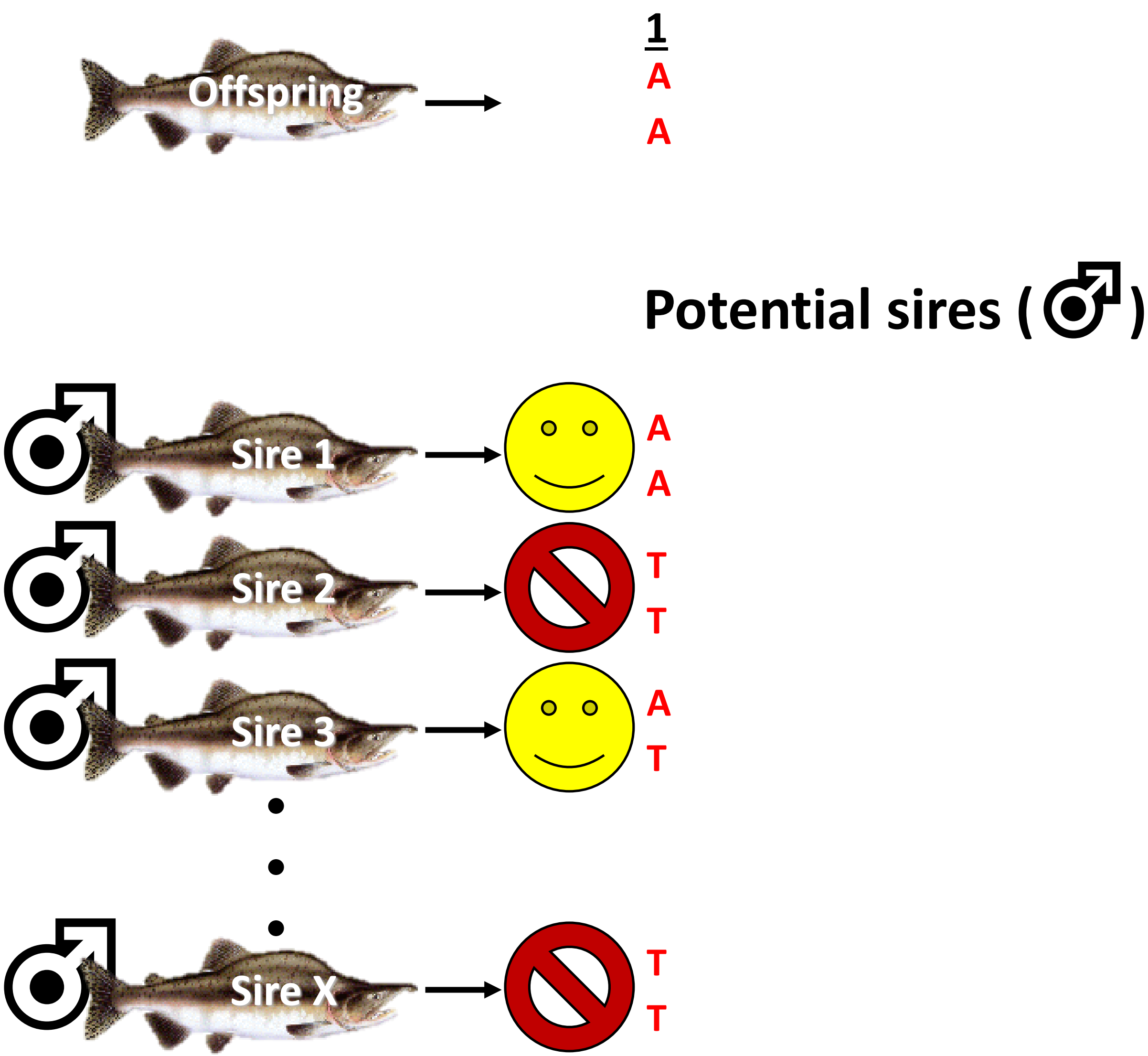
CTATGTATTAAATGTTAATAATAATAACTAGCTAACC *T allele*

CTATGTATTAAATGTTAATAATAATAACTAGCTAACC *T allele*

CTATGTATTAAATGTTAATAATAATAACTAGCTAACC *T allele*

Genetic Parentage Analysis

Markers



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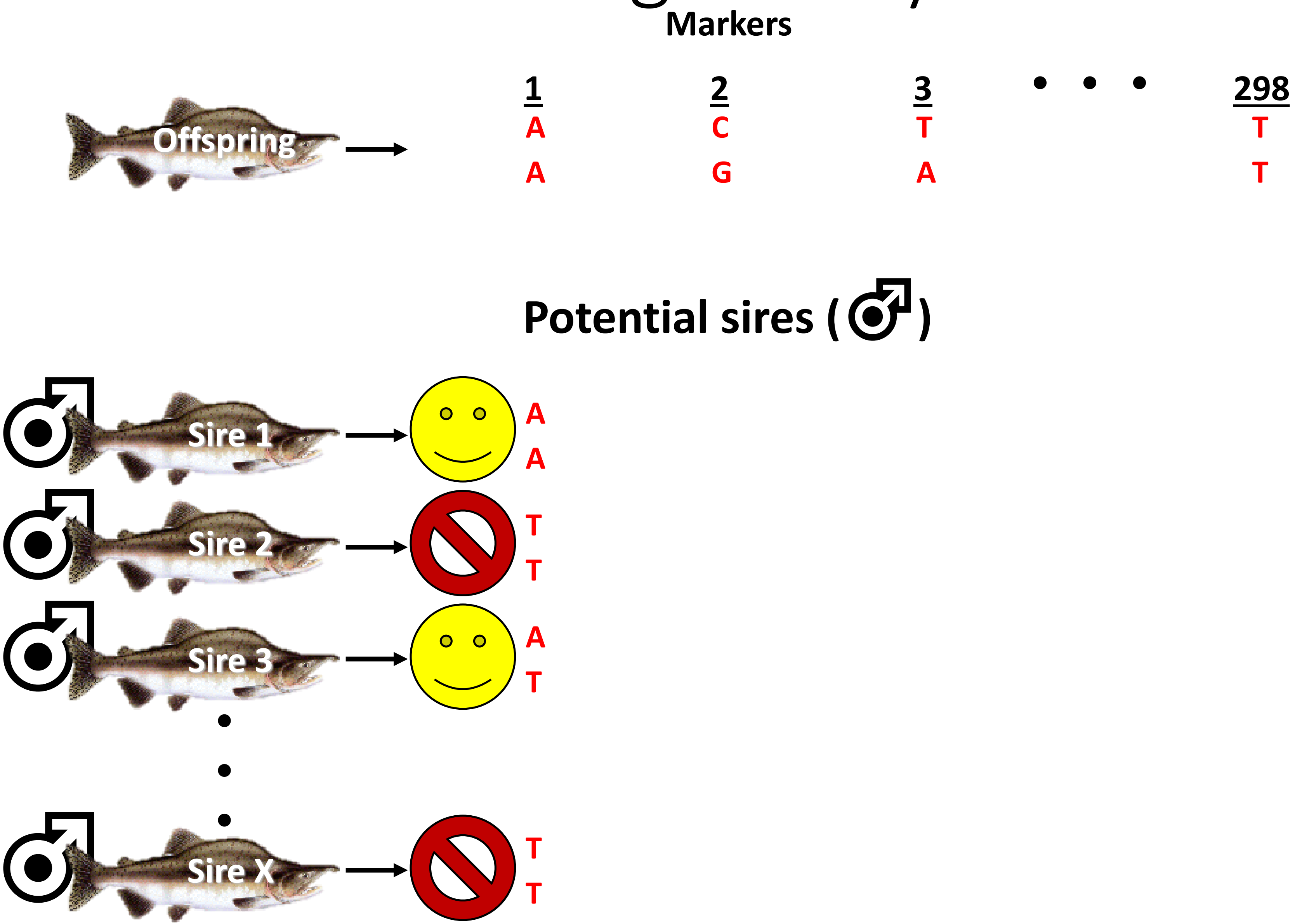

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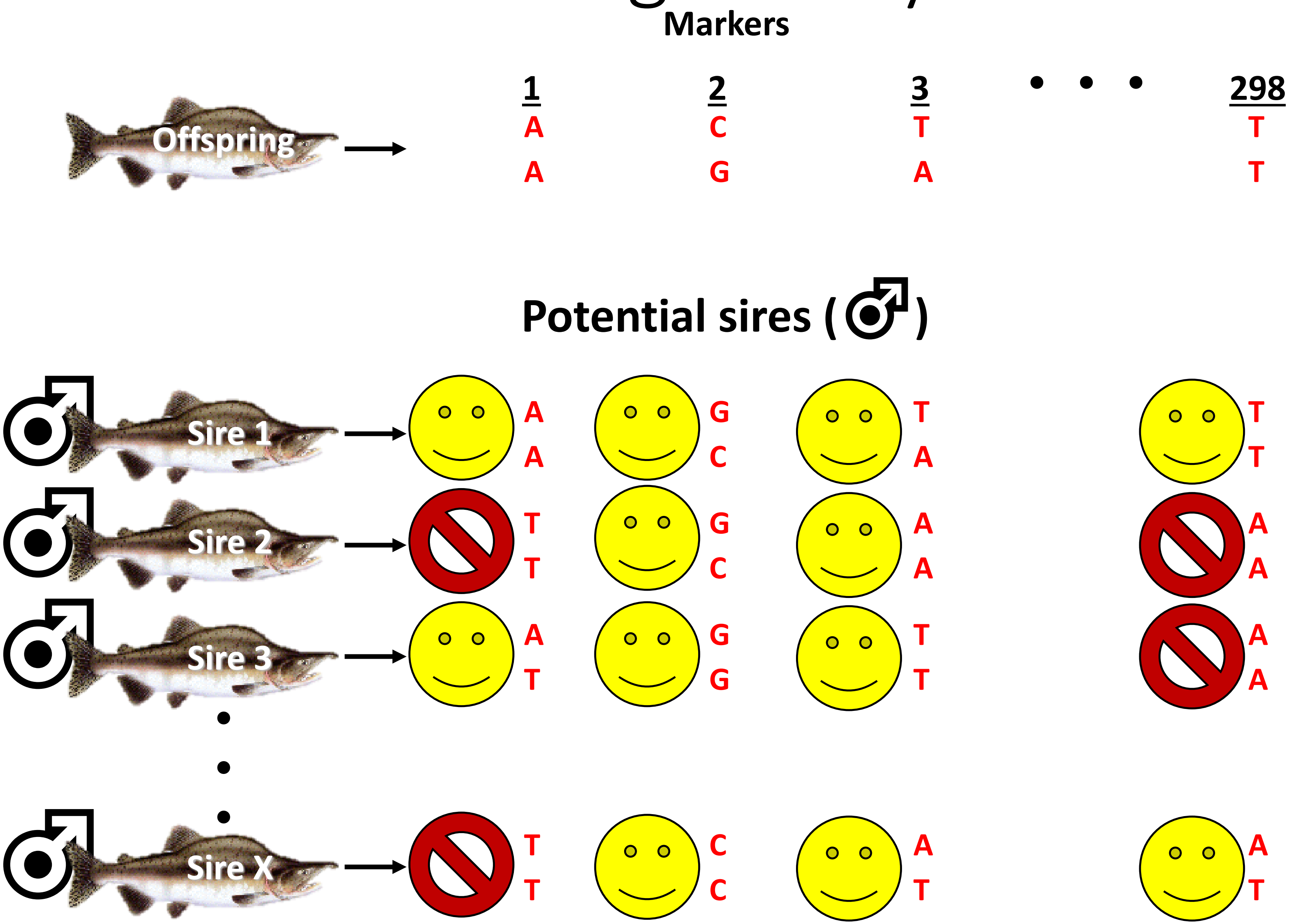
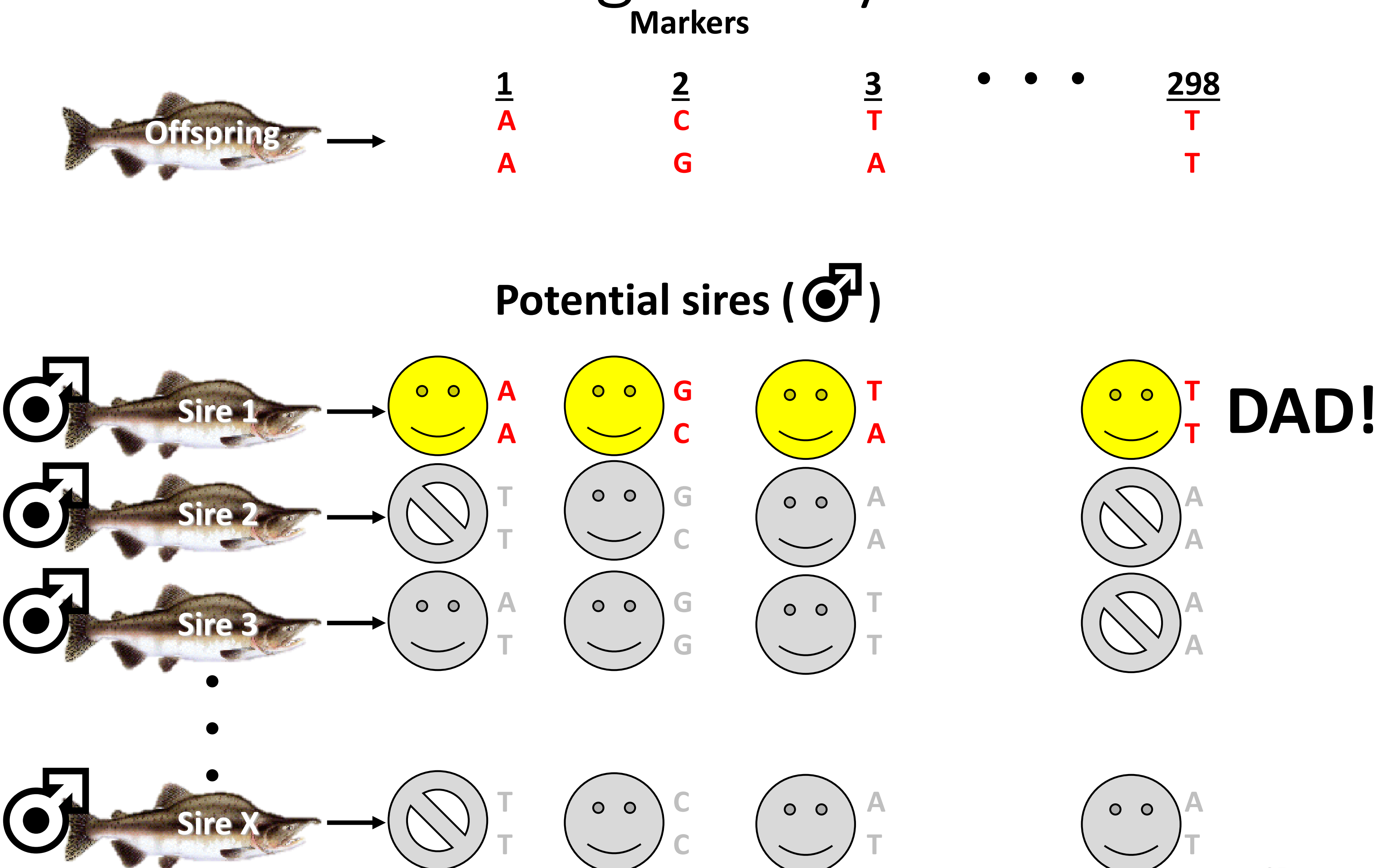
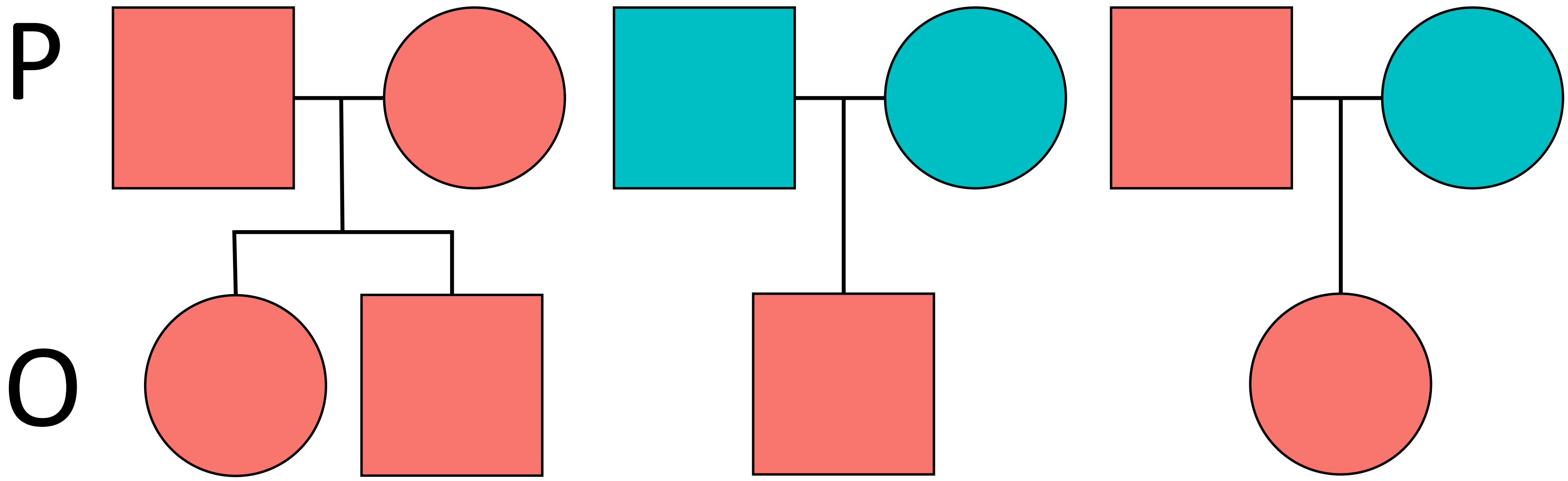
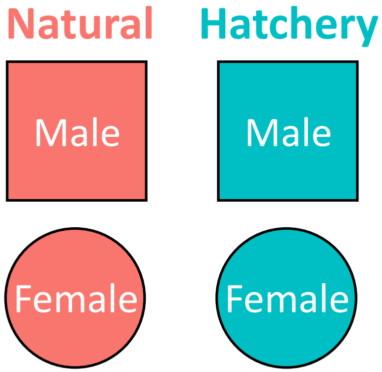


Genetic Parentage Analysis



Measuring Reproductive Success





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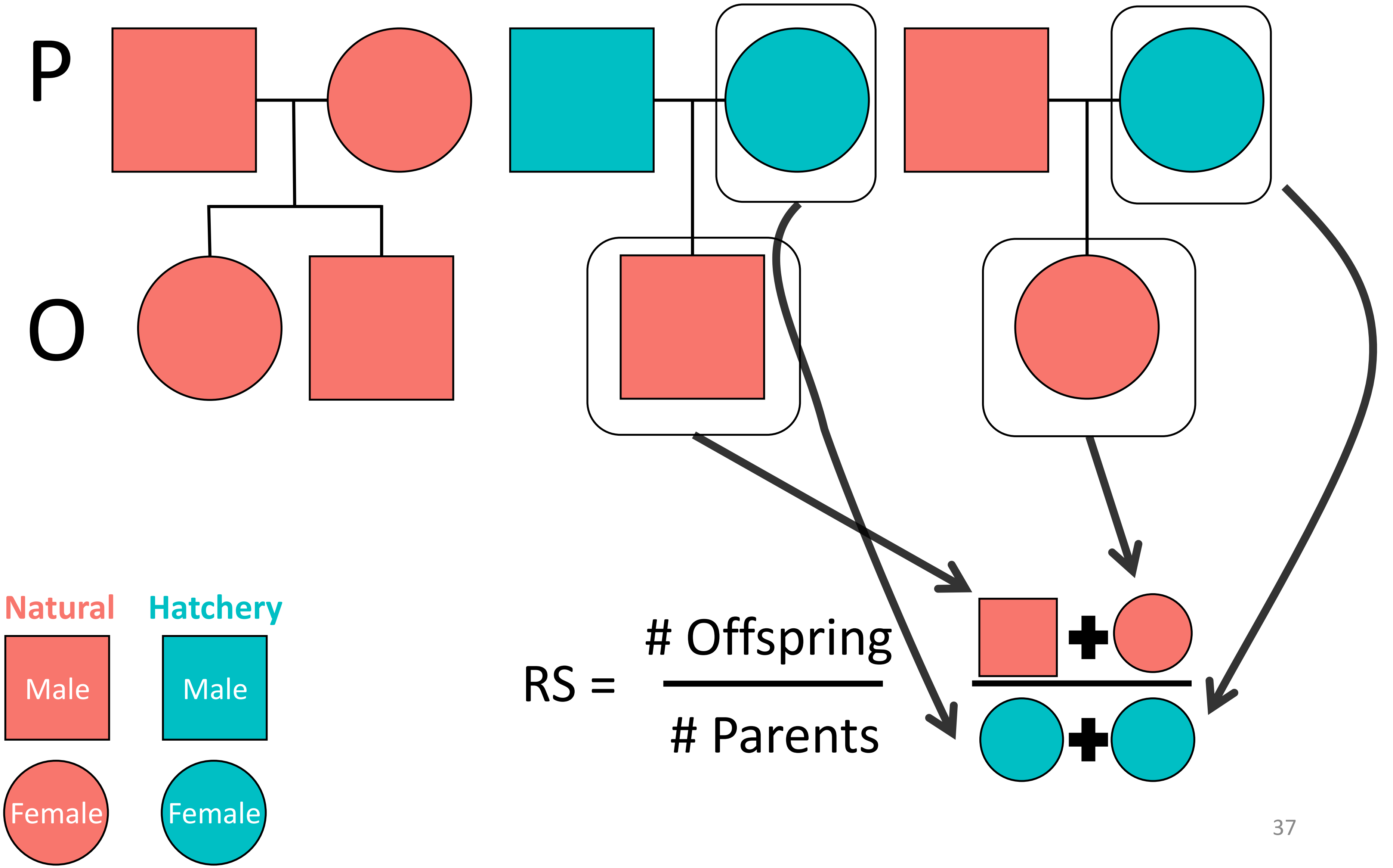
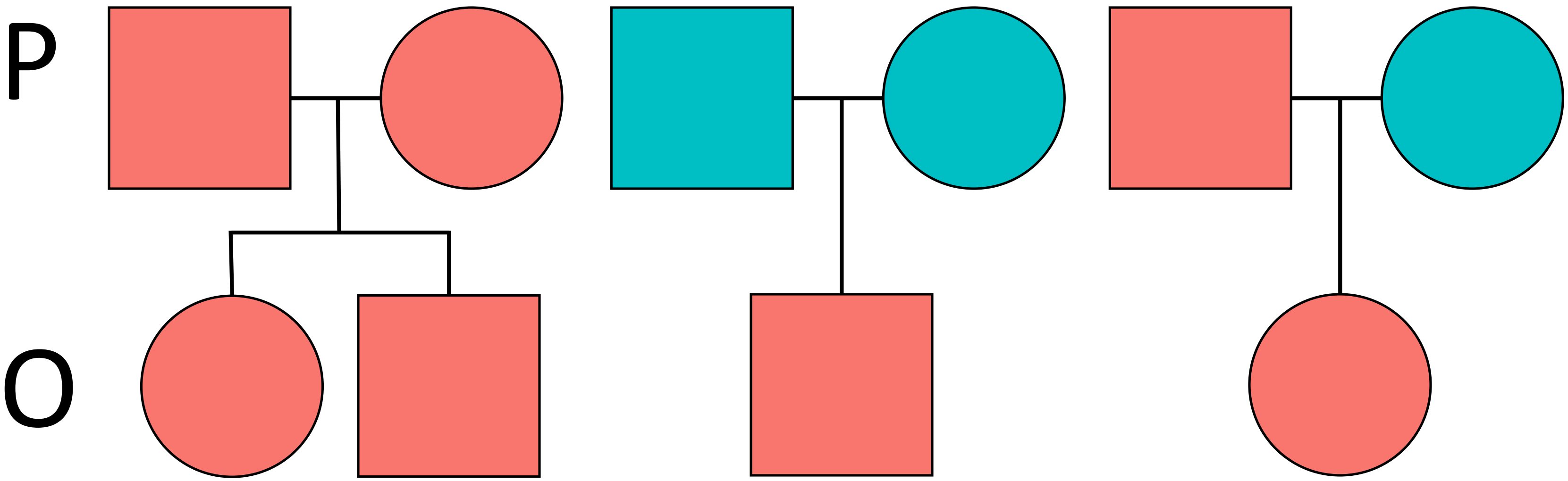
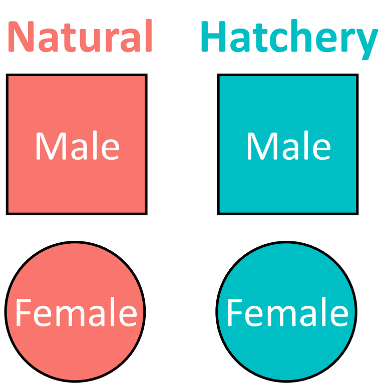


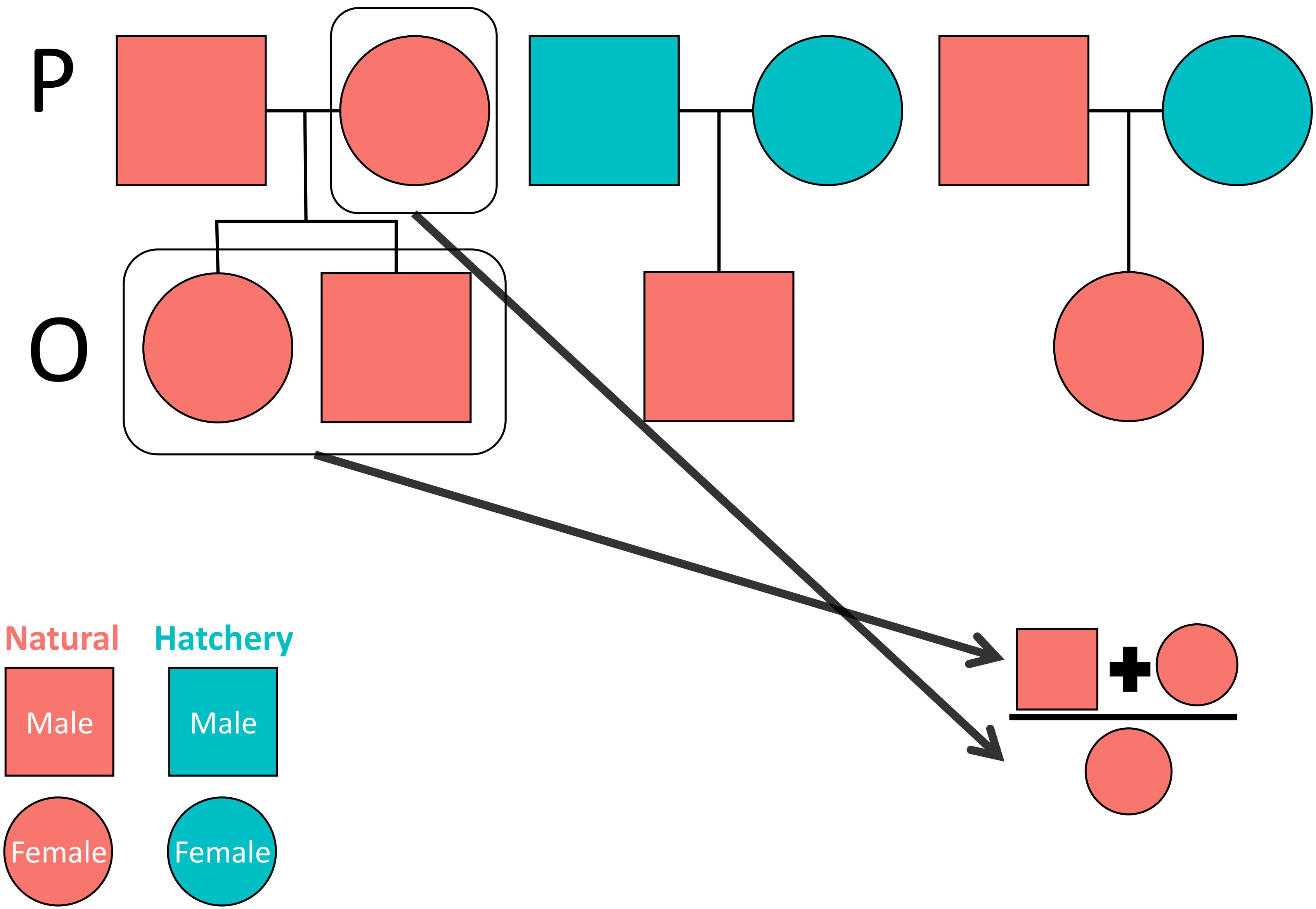
Measuring Reproductive Success



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



Measuring Reproductive Success



Measuring Reproductive Success

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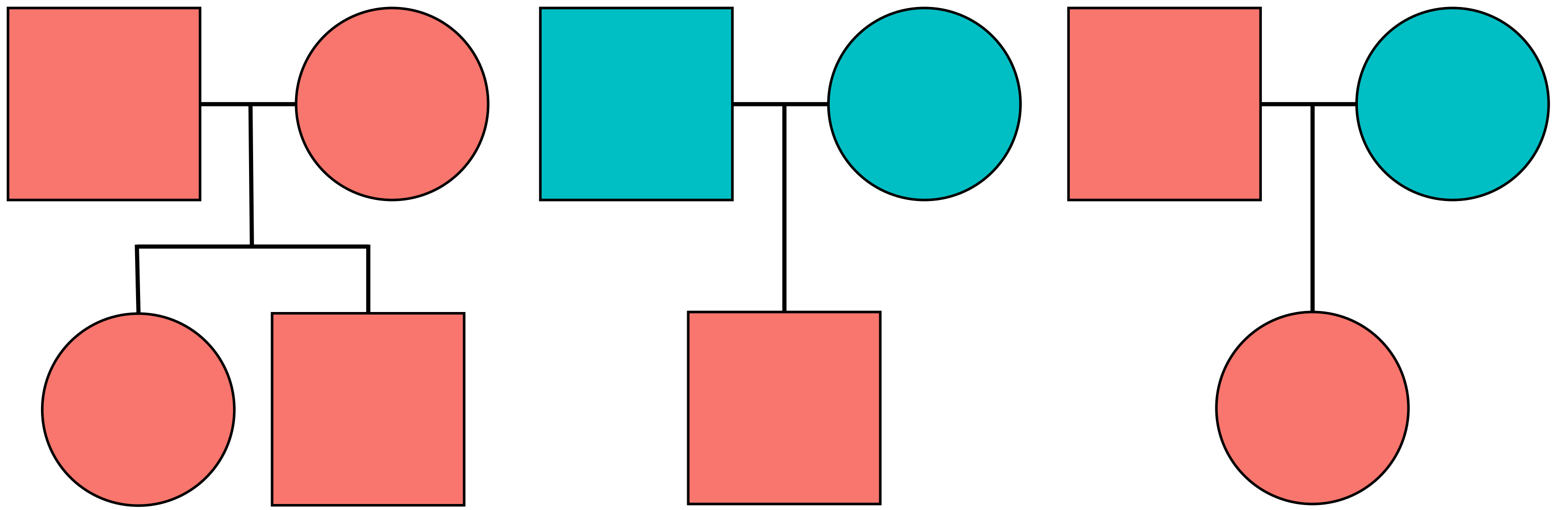
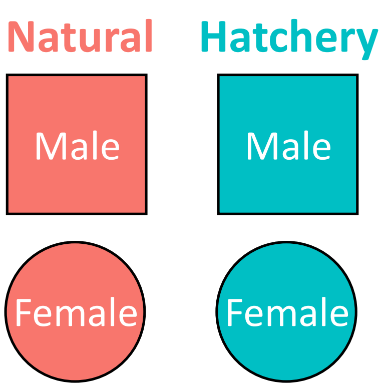


$RS_{N\ \mathrm{Female}} = 2$ $RS_{H\ \mathrm{Female}} = 1$



Measuring Reproductive Success

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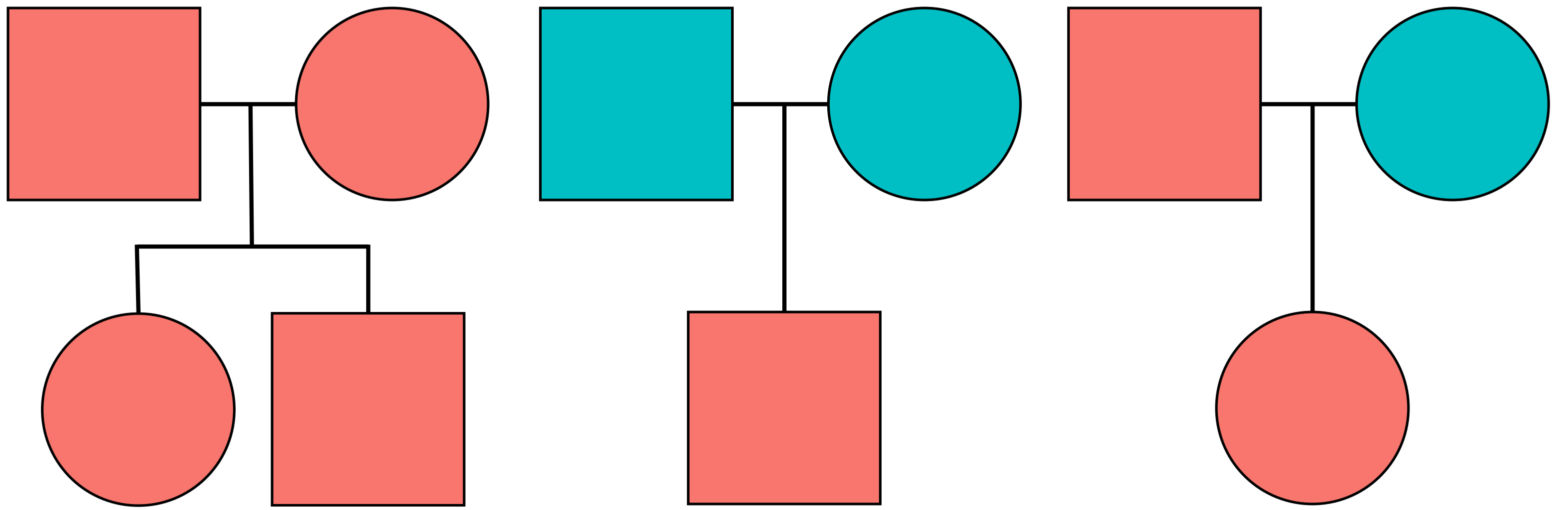
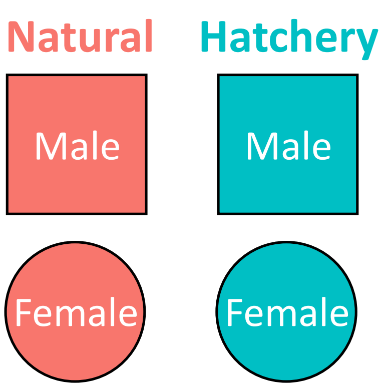


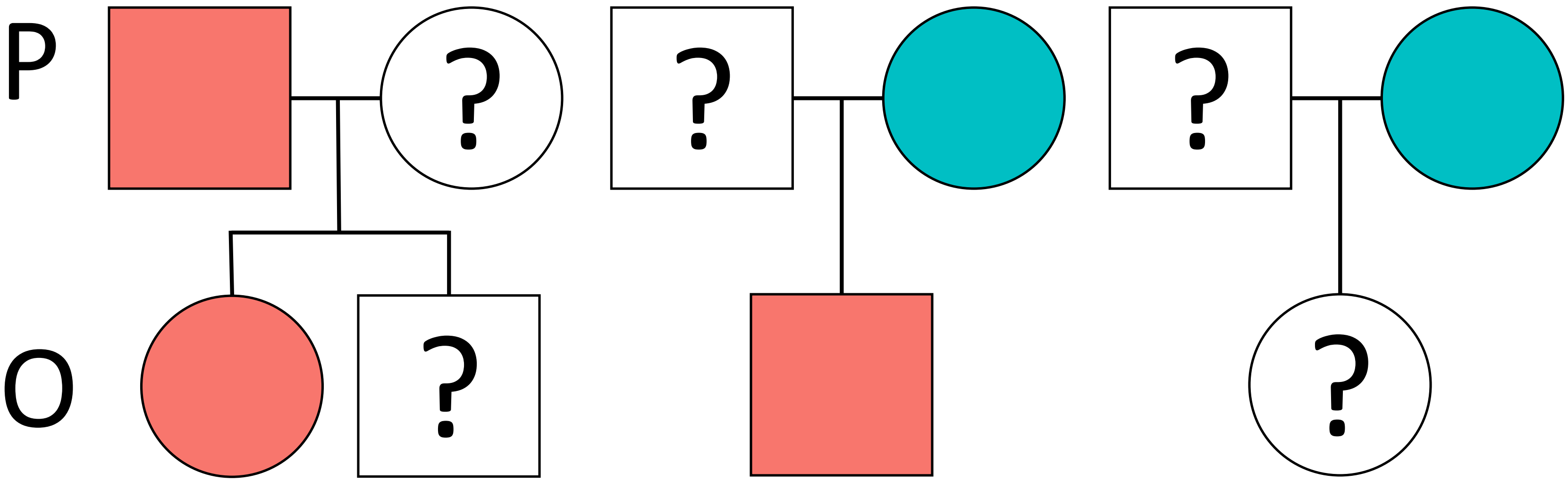
$RS_{N\ Female} = 2$ $RS_{H\ Female} = 1$

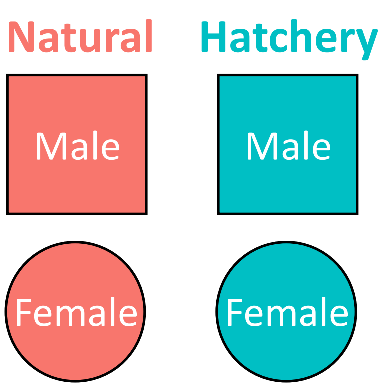


Relative Reproductive Success (RRS)

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

Measuring Reproductive Success





Relative Reproductive Success (RRS)

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

Average Reproductive Success

Stockdale 2014/2016

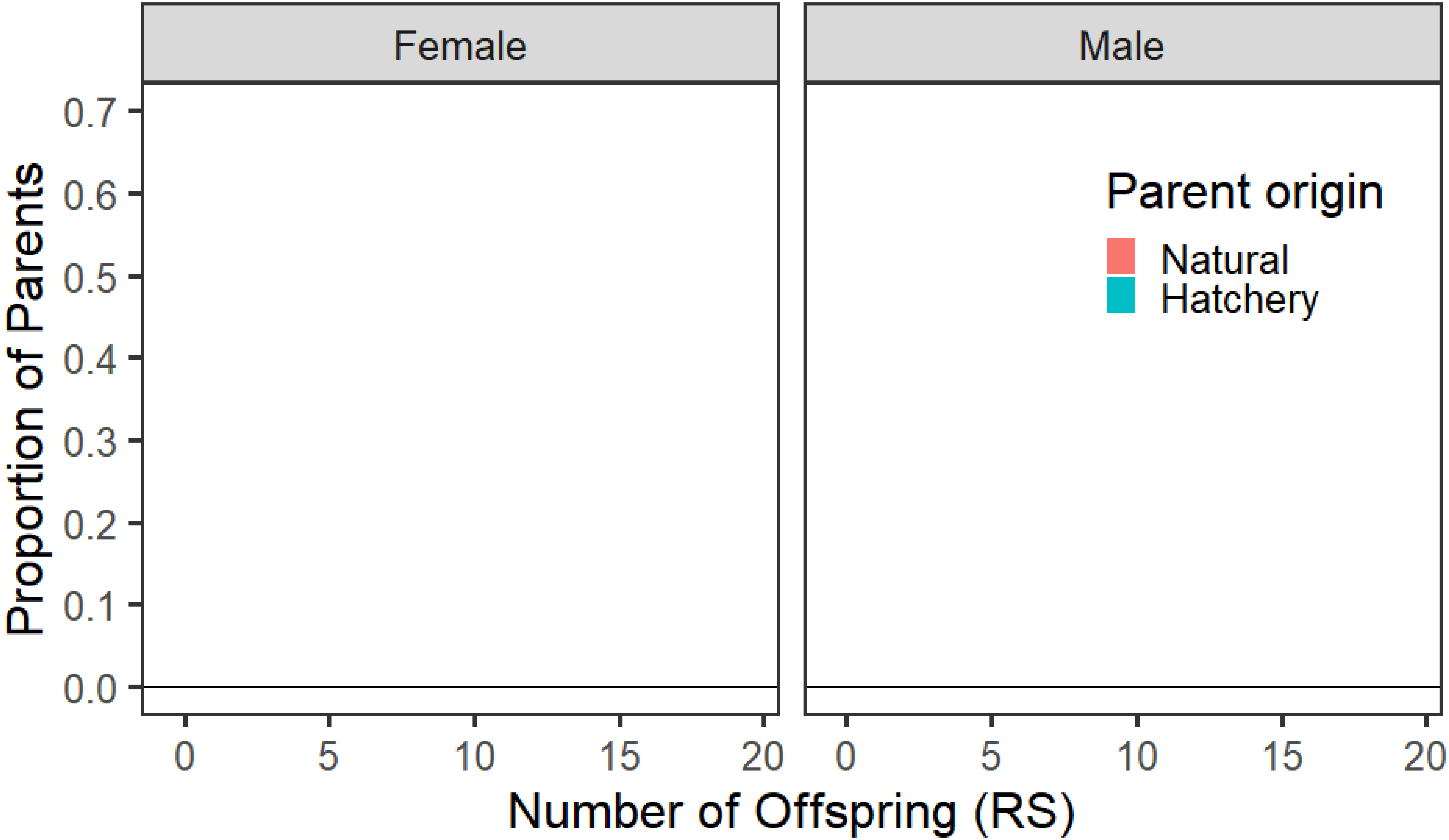
Female	2014 Parents	2016 Offspring	Average RS
Hatchery	**230**	**196**	**0.85**
Natural	**221**	**448**	**2.03**

RRS = 0.42

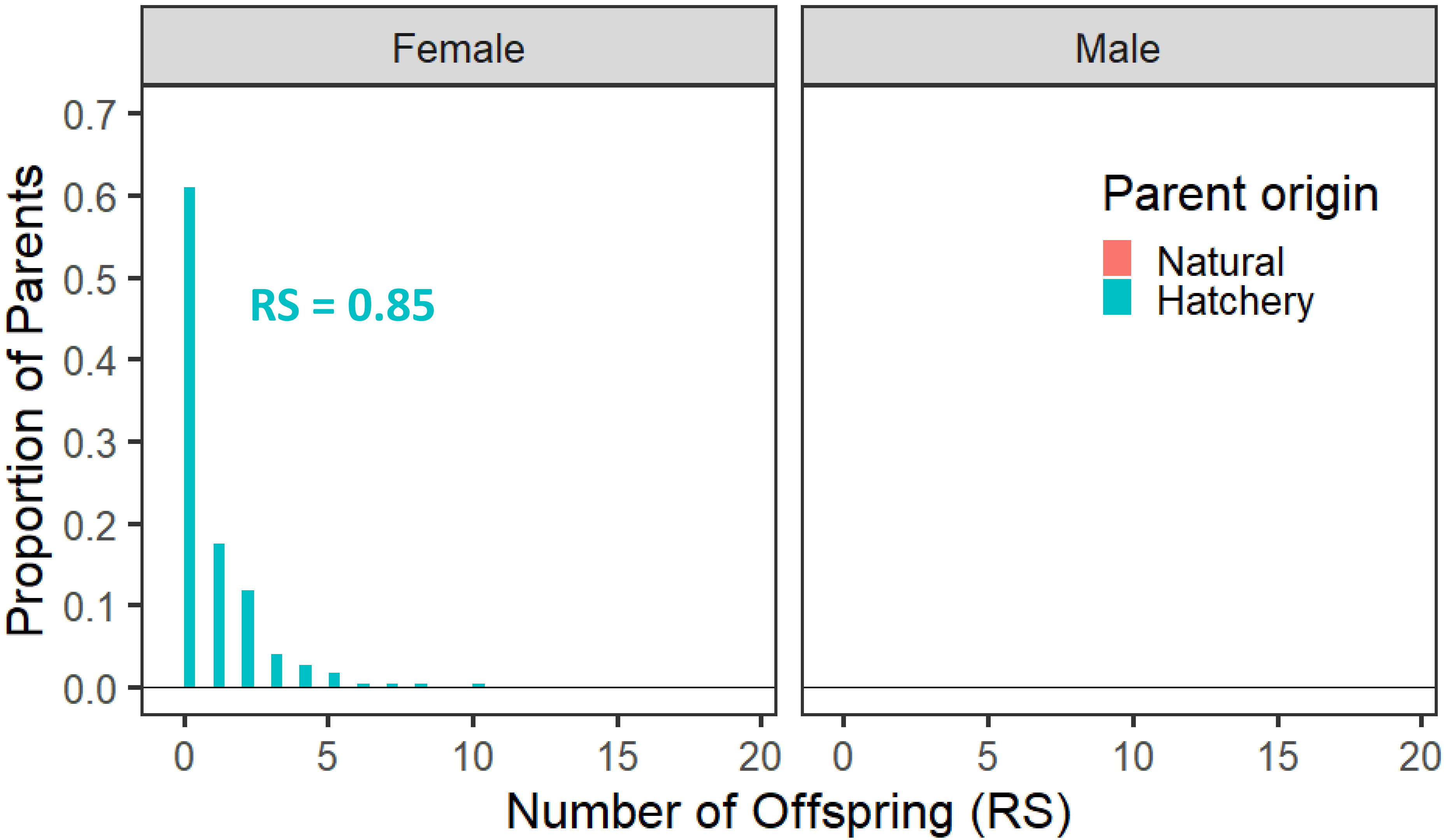
Male	2014 Parents	2016 Offspring	Average RS
Hatchery	**206**	**177**	**0.86**
Natural	**137**	**417**	**3.04**

RRS = 0.28

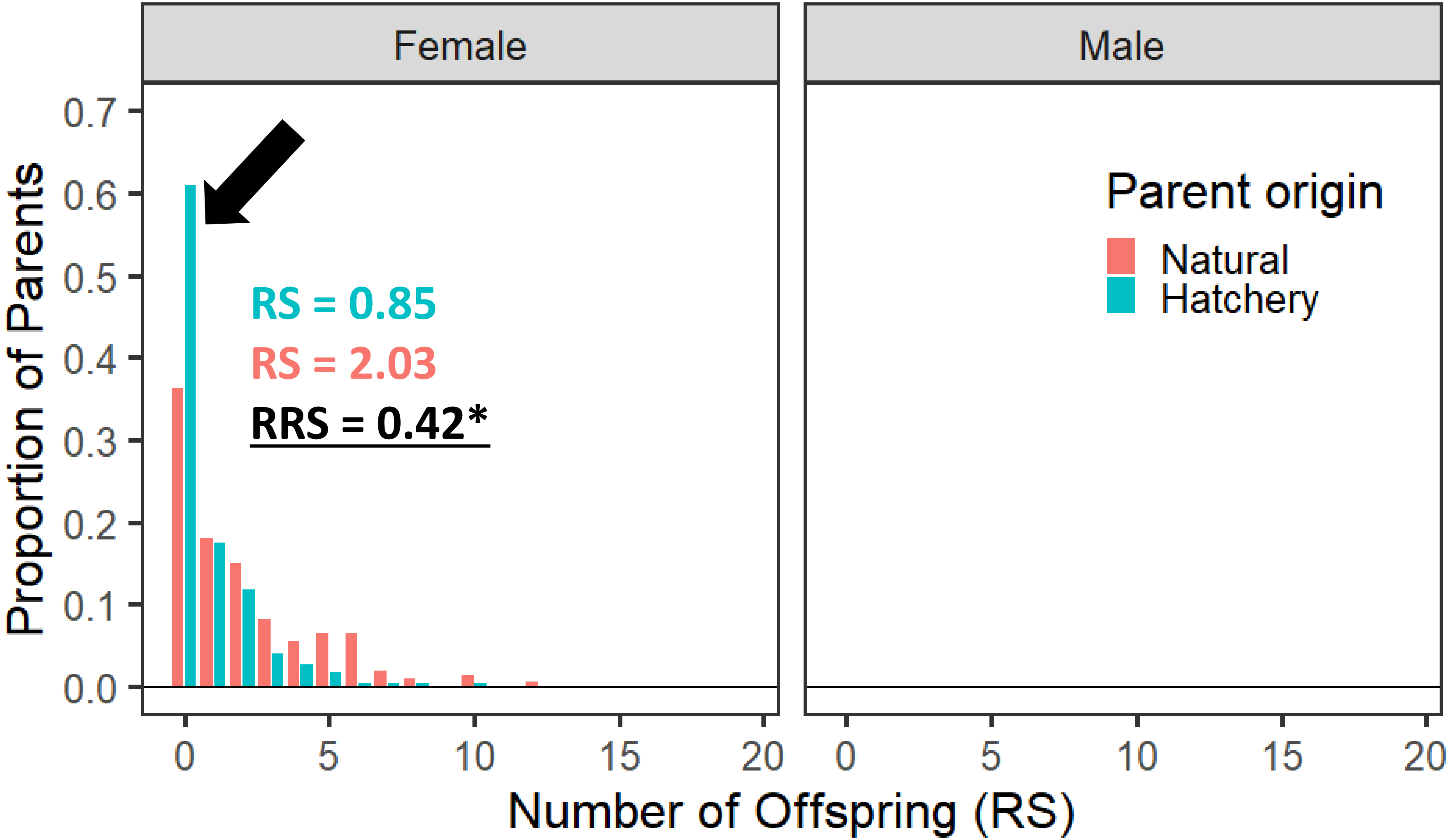
RS Distribution: Stockdale 2014/2016



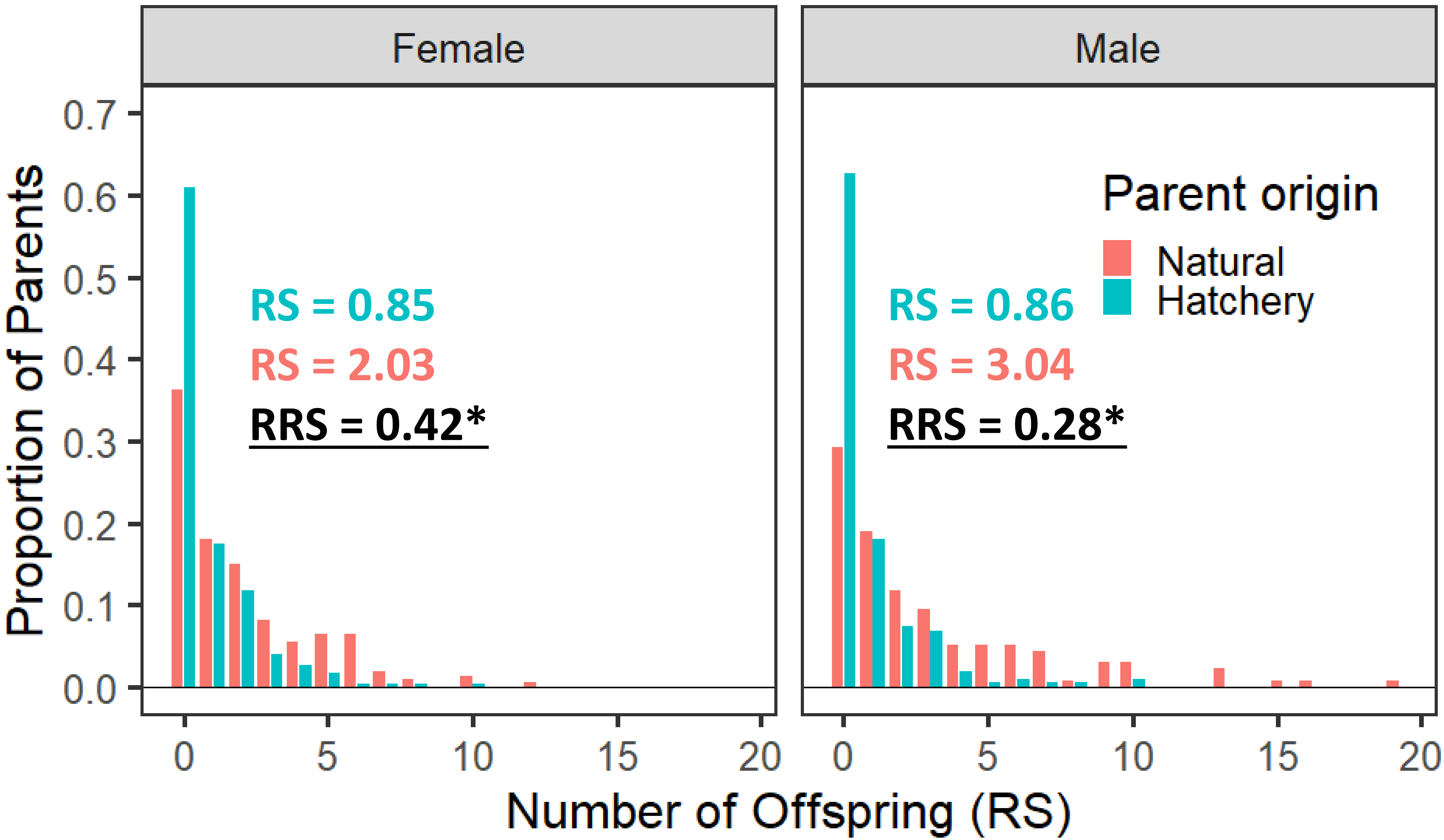
RS Distribution: Stockdale 2014/2016



RS Distribution: Stockdale 2014/2016



RS Distribution: Stockdale 2014/2016



Summary of RRS to Date

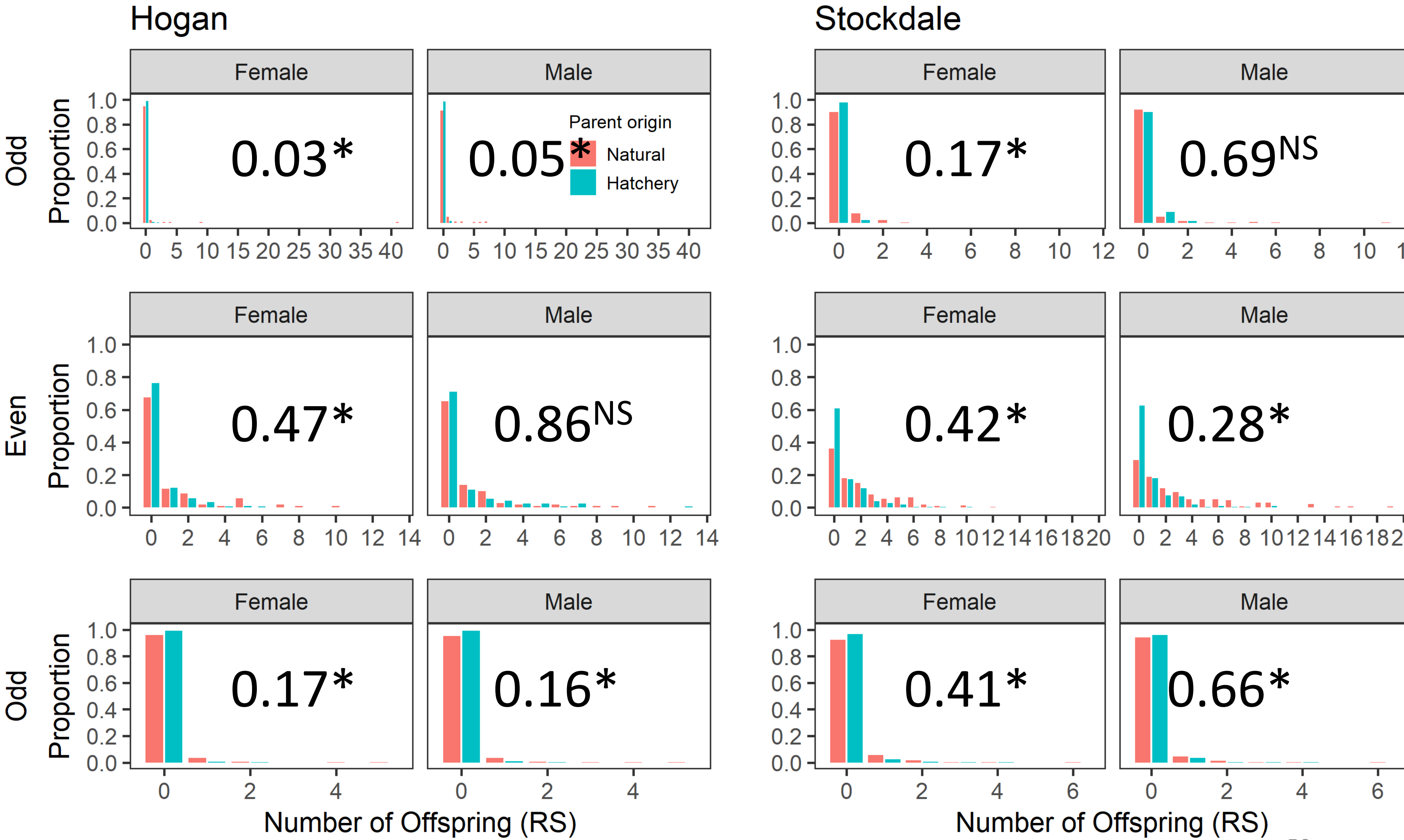
Hogan	RRS (95% CI) Hatchery / Natural	
Year	Male	Female
13/15	**0.05** (0.01-0.17)	**0.03** (0.01-0.08)
14/16	**0.86** (0.67-1.12)	**0.47** (0.37-0.62)

Summary of RRS to Date

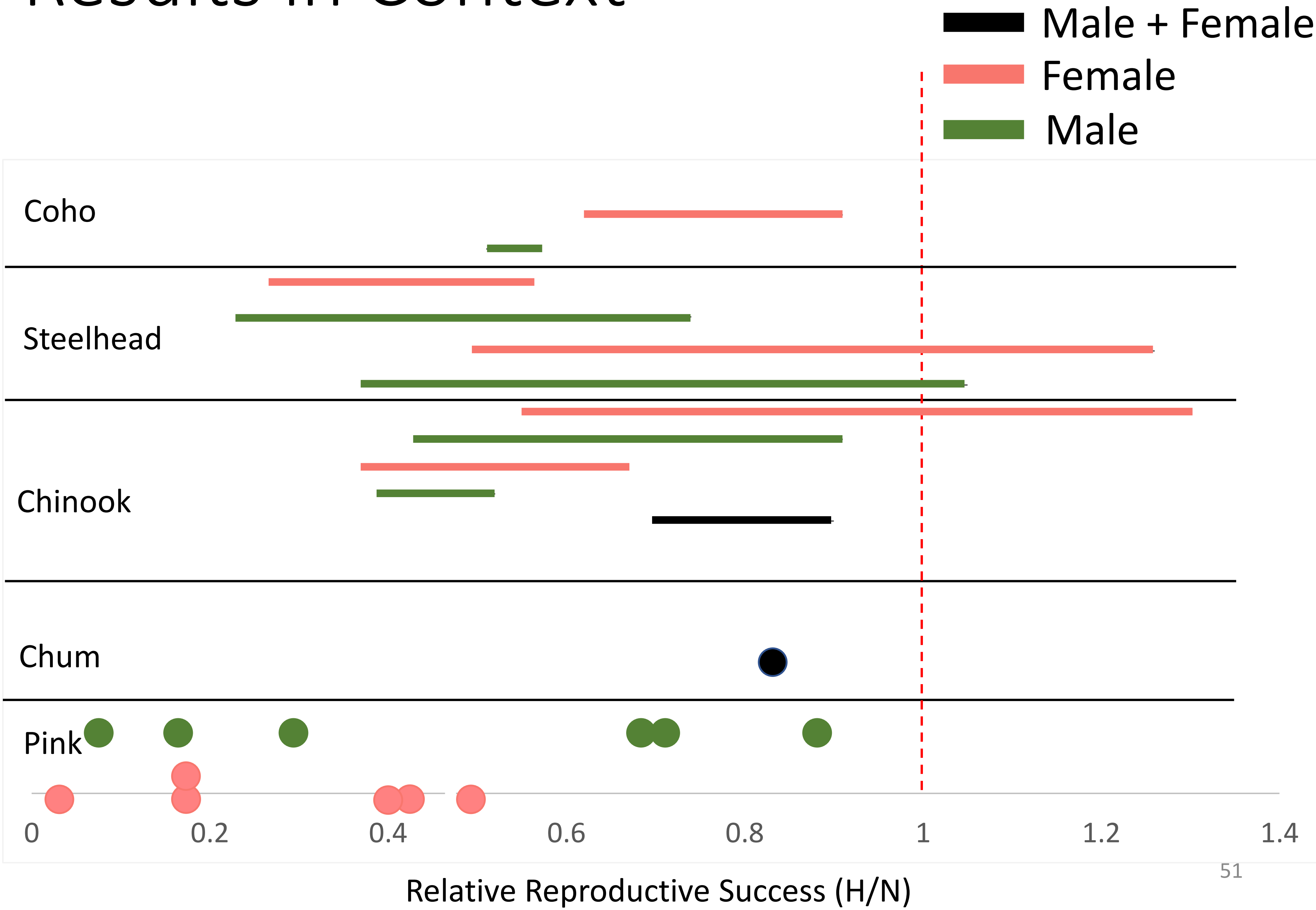
Hogan	RRS (95% CI) Hatchery / Natural			
Year	Male		Female	
13/15	**0.05**	(0.01-0.17)	**0.03**	(0.01-0.08)
14/16	**0.86**	(0.67-1.12)	**0.47**	(0.37-0.62)
15/17	**0.16**	(0.09-0.25)	**0.17**	(0.10-0.26)

Stockdale	RRS (95% CI) Hatchery / Natural			
Year	Male		Female	
13/15	**0.69**	(0.31-1.35)	**0.17**	(0.03-0.55)
14/16	**0.28**	(0.24-0.34)	**0.42**	(0.35-0.50)
15/17	**0.66**	(0.46-0.93)	**0.41**	(0.29-0.58)

RS Distributions: All



Results in Context



RS vs. Sample Date

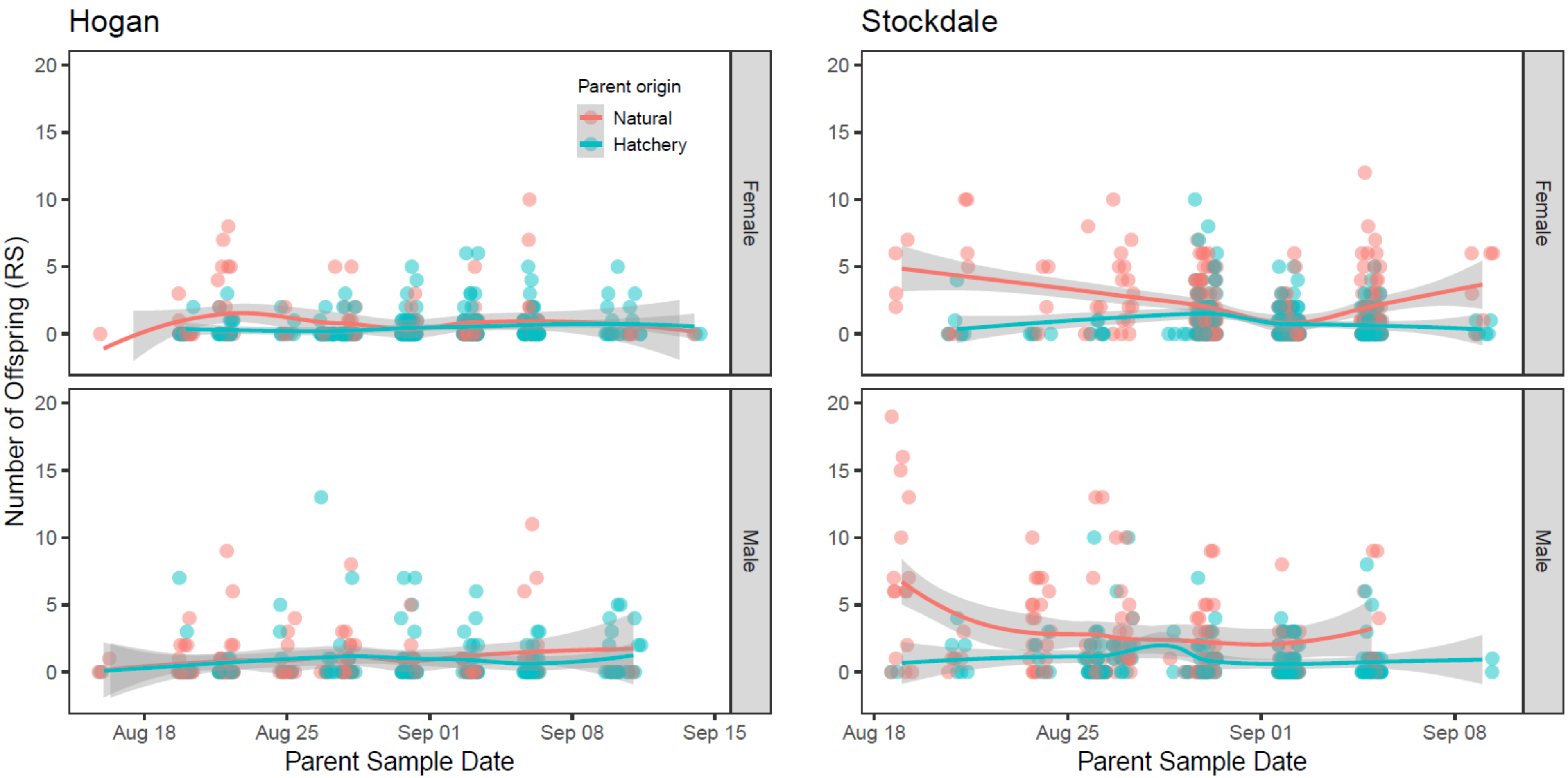


Figure 4 – Lescak et al. *in submission*

RS vs. Sample Location

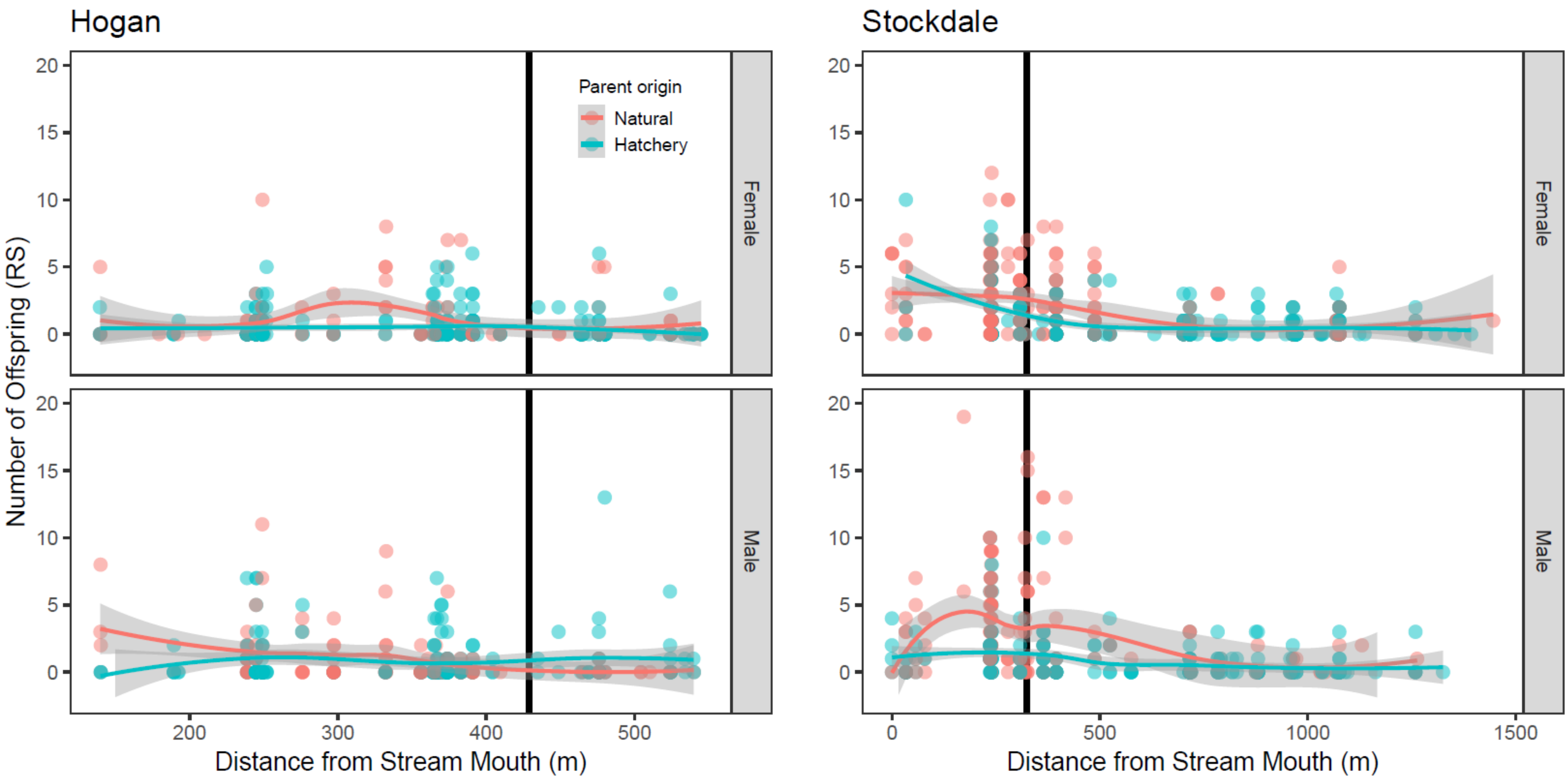


Figure 5 – Lescak et al. *in submission*

RS vs. Body Length

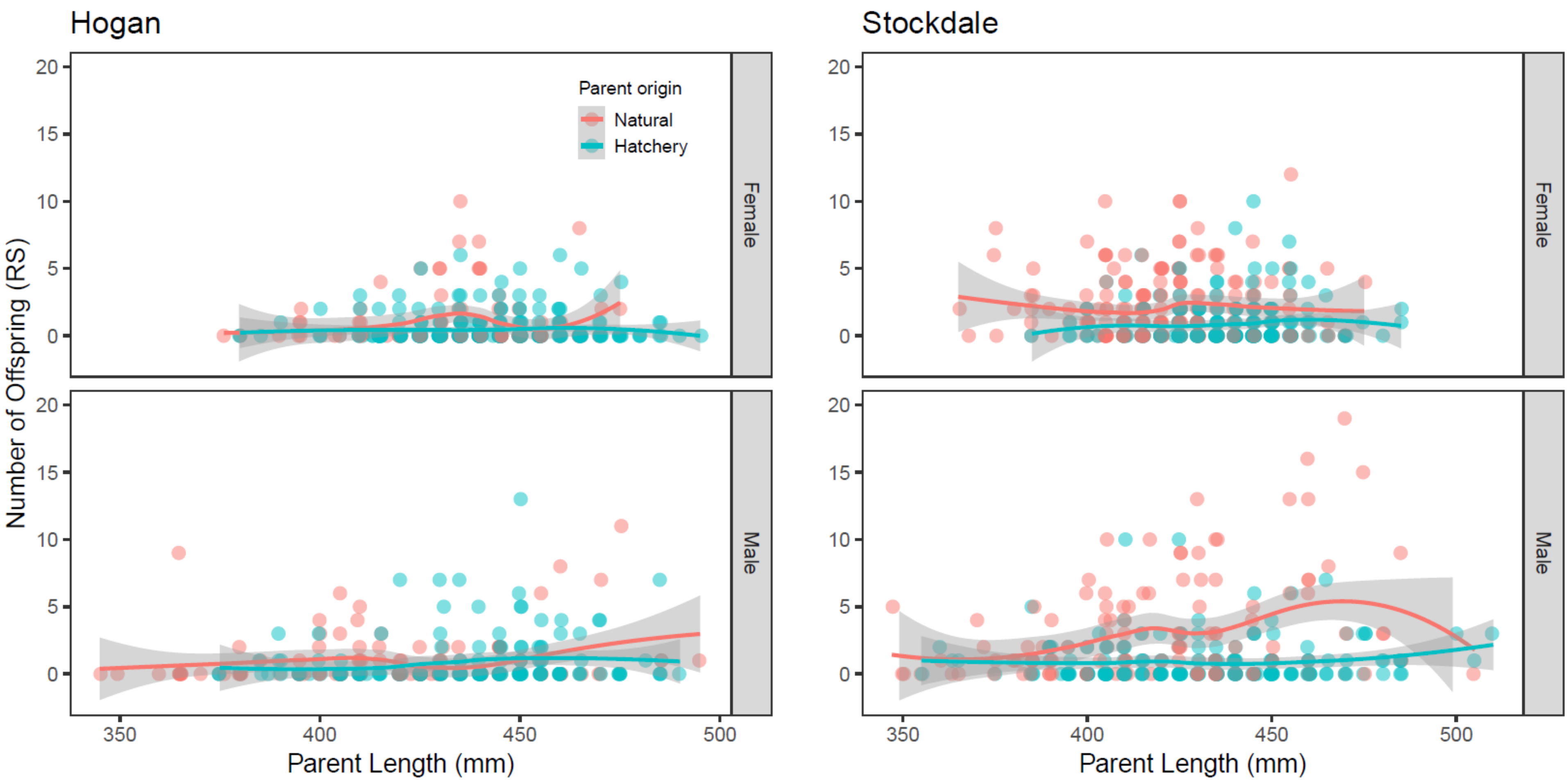
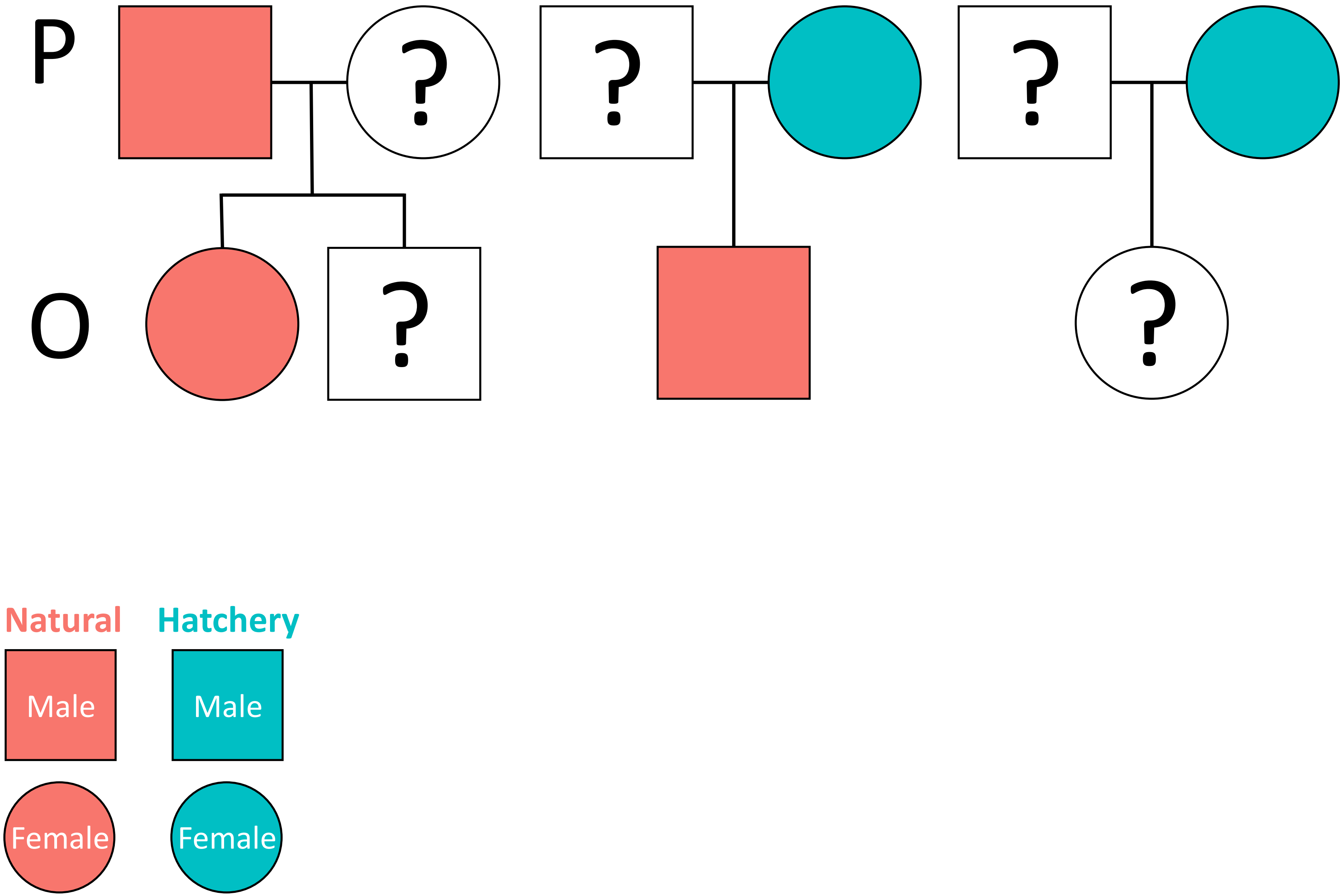


Figure 6 – Lescak et al. *in submission*

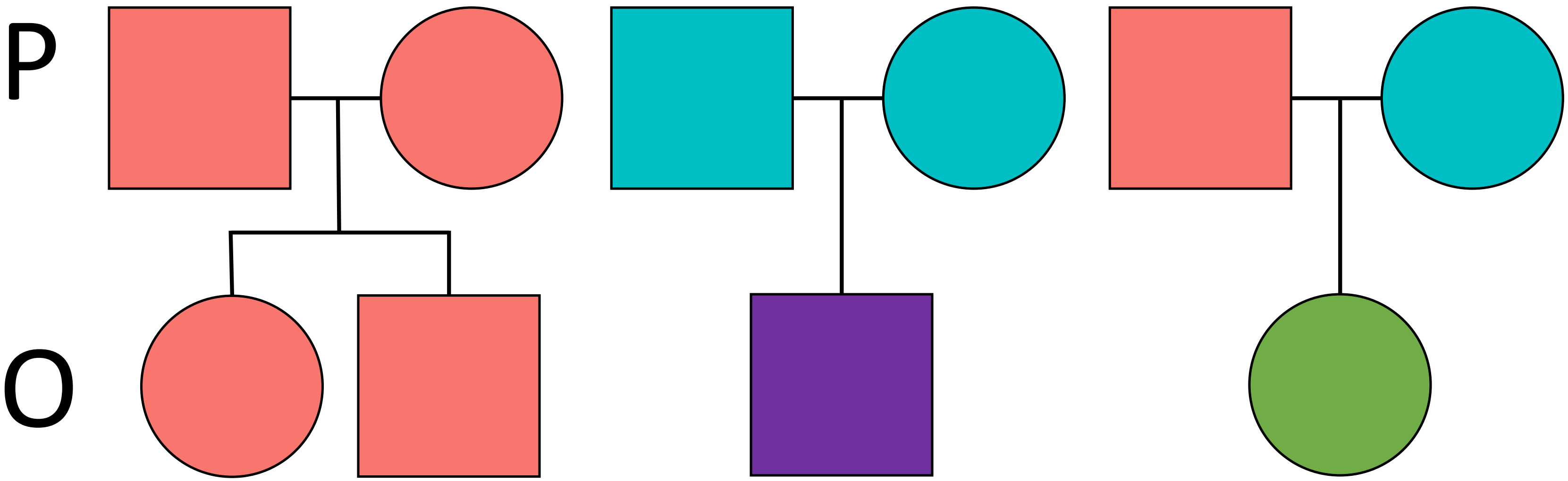
Accounting for Other Factors

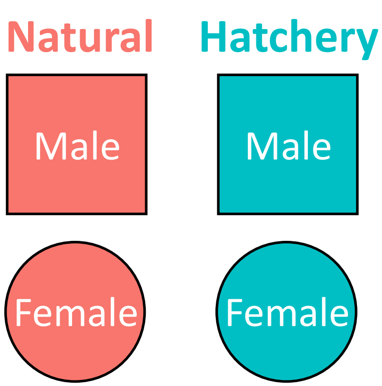
- Differences between hatchery/natural
  - Body length
  - Sample date
  - Sample location
- Correlated with number of offspring (RS)
- After accounting for these other factors (GLM), differences in RS remained (RRS ~ 42-60%)

Parent-Offspring Duos

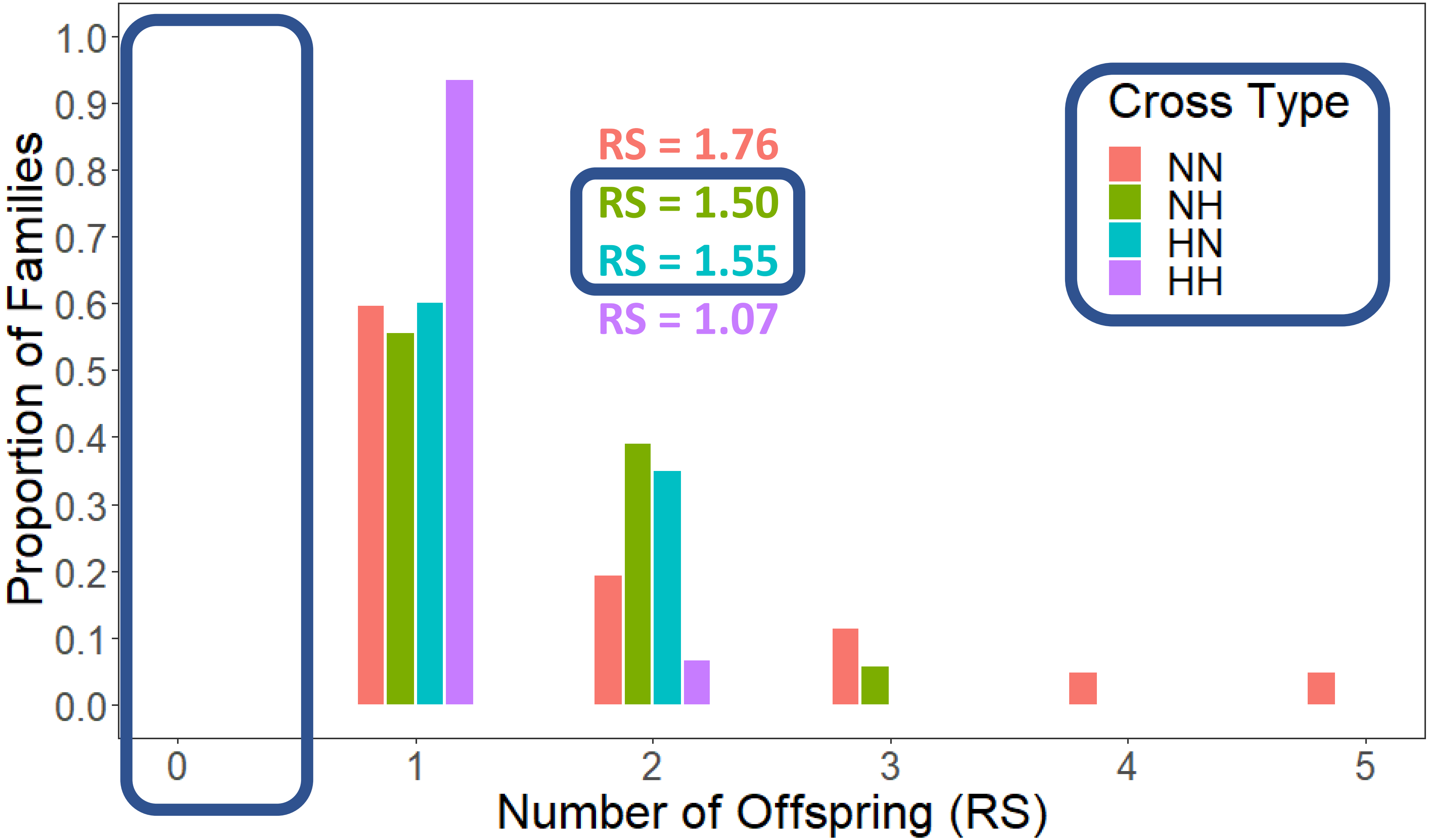


Parent-Pair-Offspring Trios





RS Distribution: Stockdale 2014/2016



Grandparentage: Hogan 13/15/17

	hatchery	natural
P, 2013	442	321
O, 2015	6	104
G, 2017	0	5

Grandparentage: Stockdale 13/15/17

	hatchery	natural
P, 2013	163	811
O, 2015	10	119
G, 2017	3	19

Takeaways

- On average, hatchery-origin pink salmon that stray into the two streams for BY 2013-2015 consistently produce fewer adult offspring that return to their natal streams
- High variability in RRS (streams, years, sexes)
- After accounting for other variables (length, timing, location), hatchery-origin fish produce fewer offspring, on average, than natural-origin fish
- Hybrids had intermediate RRS
- We found grand-offspring!!!
- Submitted for peer reviewed publication at *Evolutionary Applications* on 1/27/20

Remaining Questions

- Are observed reductions in hatchery-origin fitness an artifact of the study design?
  - Returning adults that are harvested?
  - Returning adults that stray to other streams?
- Are results consistent in other streams and years?
- Do hatchery/natural hybrids consistently produce fewer offspring than two natural-origin pink salmon?
- Are reductions in fitness persistent across generations (F_2 and beyond)?

Remaining Work

Stream	2013	2014	2015	2016	2017	2018	2019
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

P – parents

O – offspring

G – grand-offspring

Odd-lineage

Even-lineage

Remaining Work

Stream	2013	2014	2015	2016	2017	2018	2019
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

							2019
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

P – parents
O – offspring
G – grand-offspring

Odd-lineage
Even-lineage

Remaining Work

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

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- Alaska Hatchery Research Program
  - State of Alaska
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  - Funding for Stockdale analyses (2014/2016)
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  - Field collection
- ADF&G Cordova Otolith Lab
- University of Washington - Seeb Lab
- ADF&G Gene Conservation Laboratory


Questions?
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