Study question 3: Update on pink and chum salmon hatchery/wild relative fitness

Kyle Shedd
Gene Conservation Laboratory
Alaska Department of Fish and Game

Alaska Board of Fisheries Hatchery Committee

March 7, 2020

Tab 6

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

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,*[1] 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
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, Richard W. Carmichael, Michael W. Flesher, Eric J. Ward & Paul Moran

Genetic adaptation to captivity can occur in a single generation

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

PNAS

Chinook

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

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
Evolutionary Applications ISSN 1752-4571

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

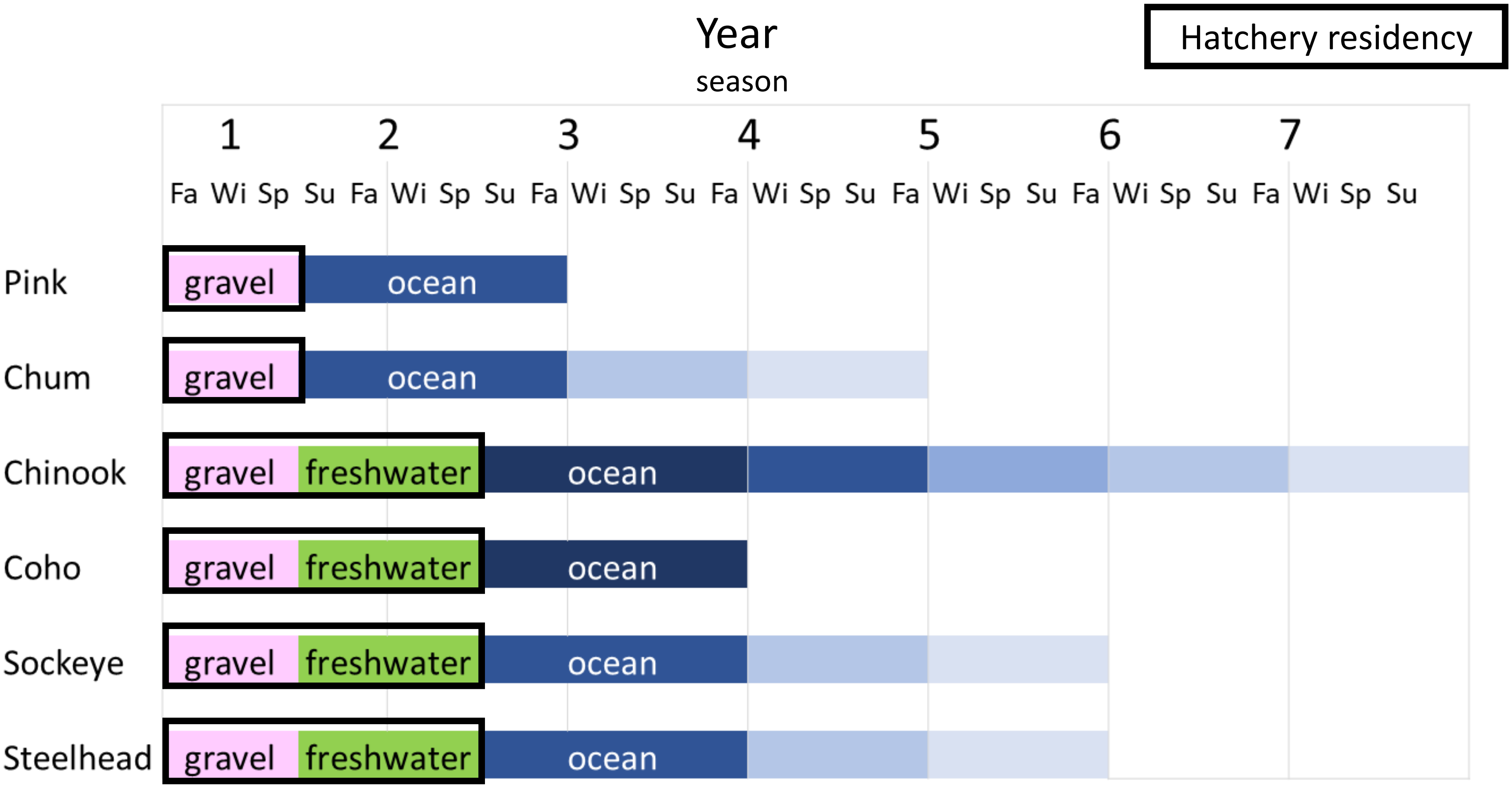
VÉRONIQUE THÉRIAULT,* GREGORY R. MOYER,*[1] LAURA S. JACKSON,† MICHAEL S. BLOUIN‡ and MICHAEL A. BANKS*

Chum

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

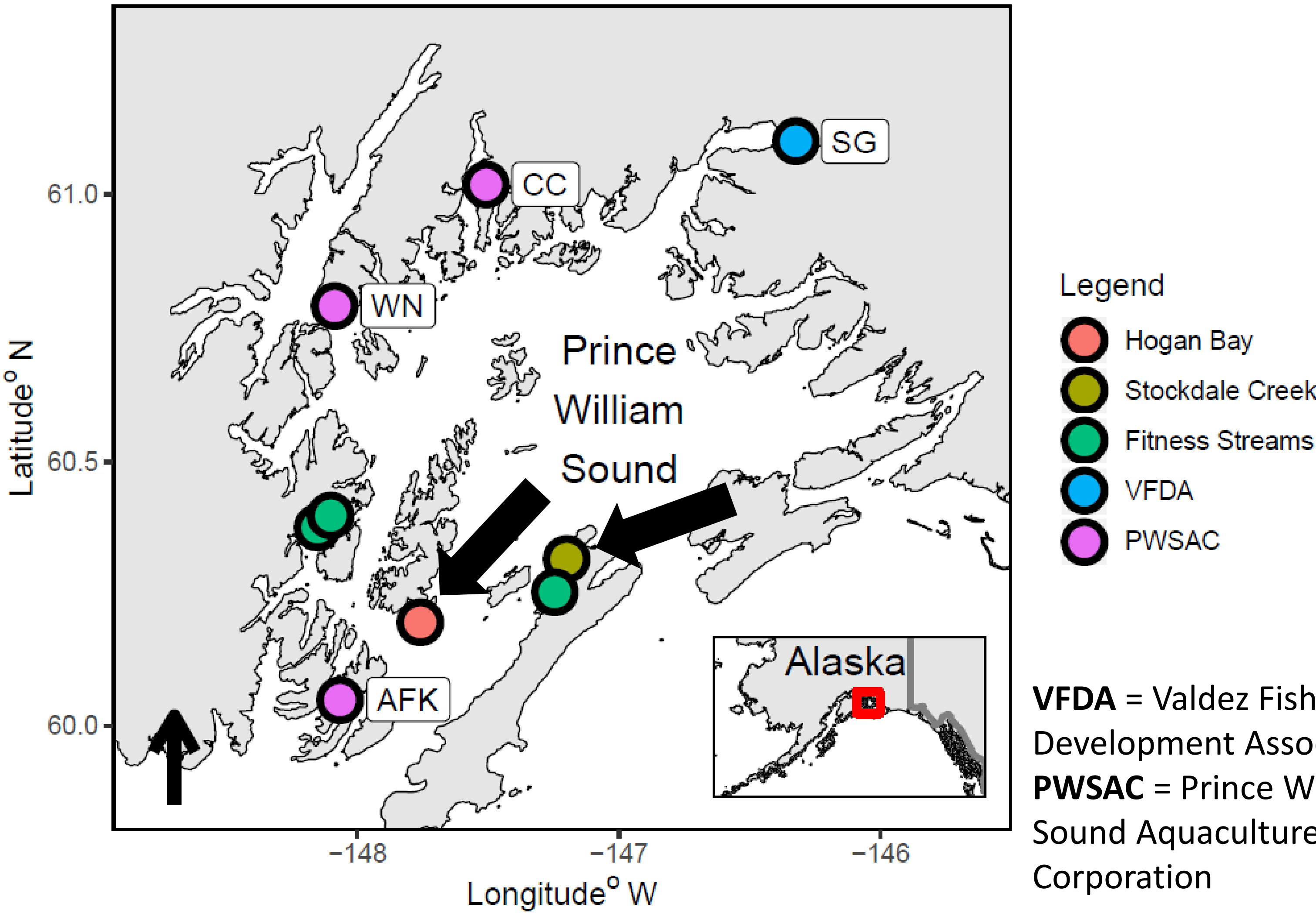
Barry A. Berejikian, Donald M. Van Doornik, Julie A. Scheurer, and Richard Bush

Hatchery/Natural Fitness



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

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

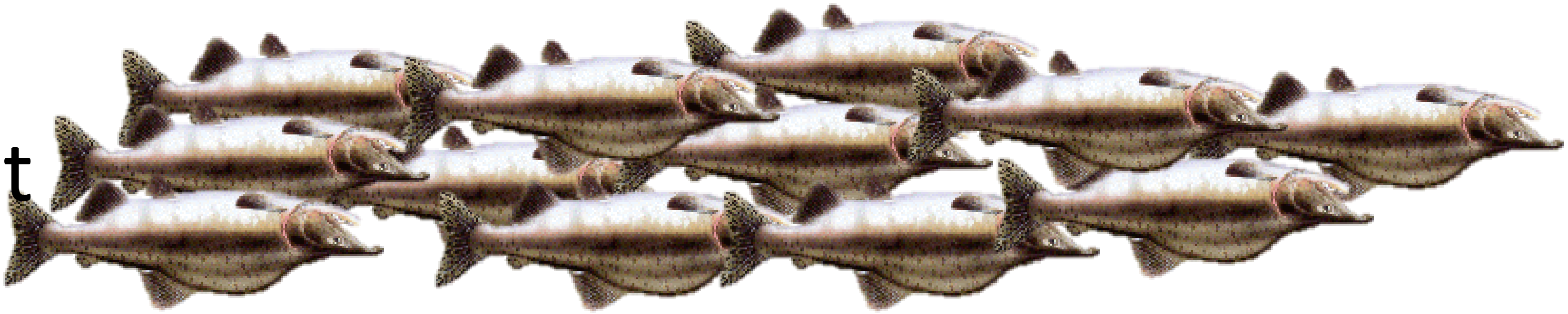
Even-lineage

Fitness = Reproductive Success

Parent

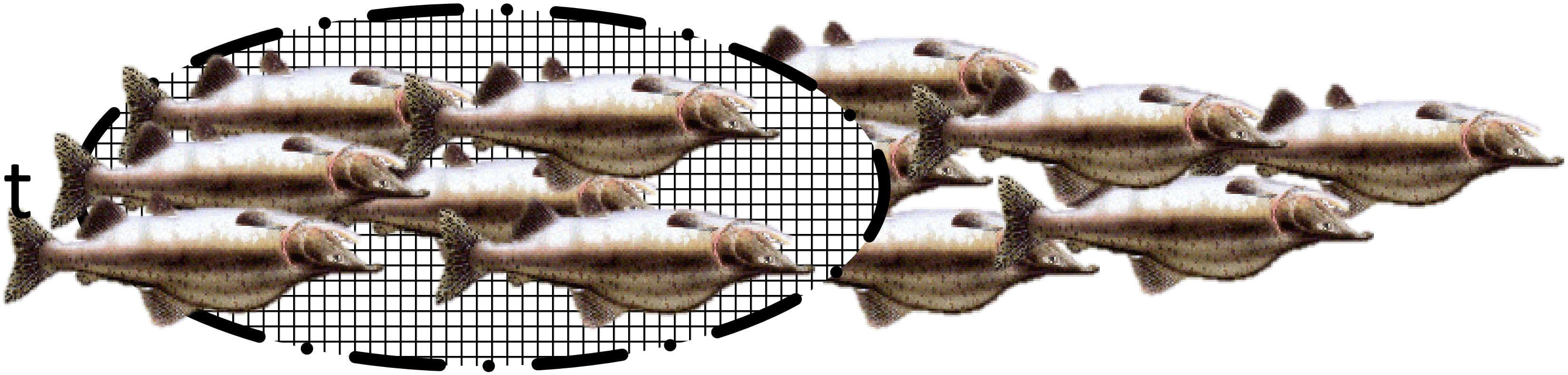
Measuring Reproductive Success

Parent



Measuring Reproductive Success

Parent

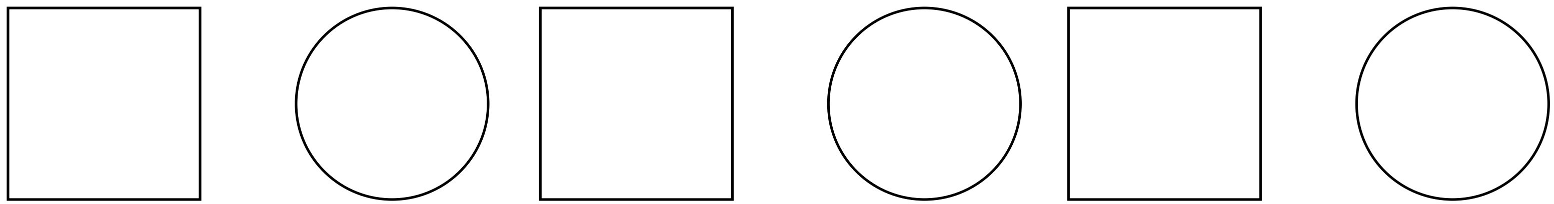


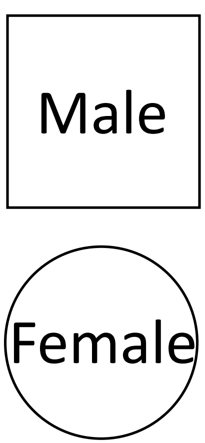
Measuring Reproductive Success

Parent 

Measuring Reproductive Success

P





Measuring Reproductive Success

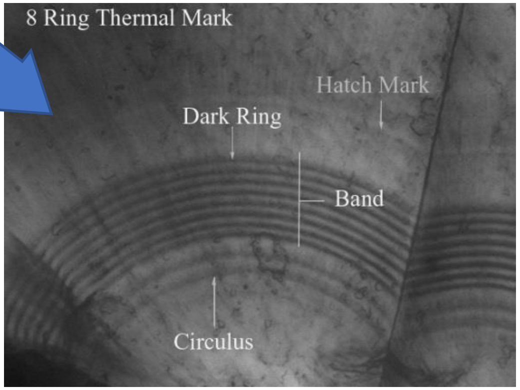
P

Male

Female

Measuring Reproductive Success

P



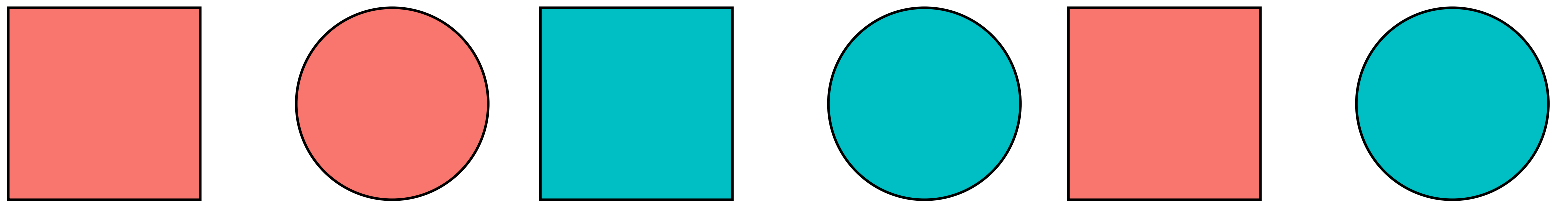
Hatchery-origin

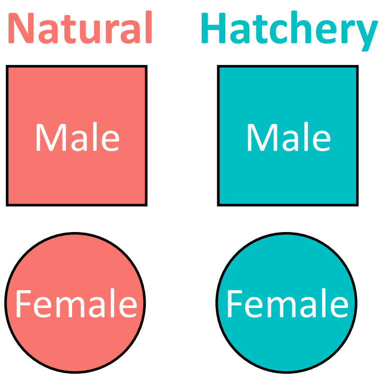
Male

Female

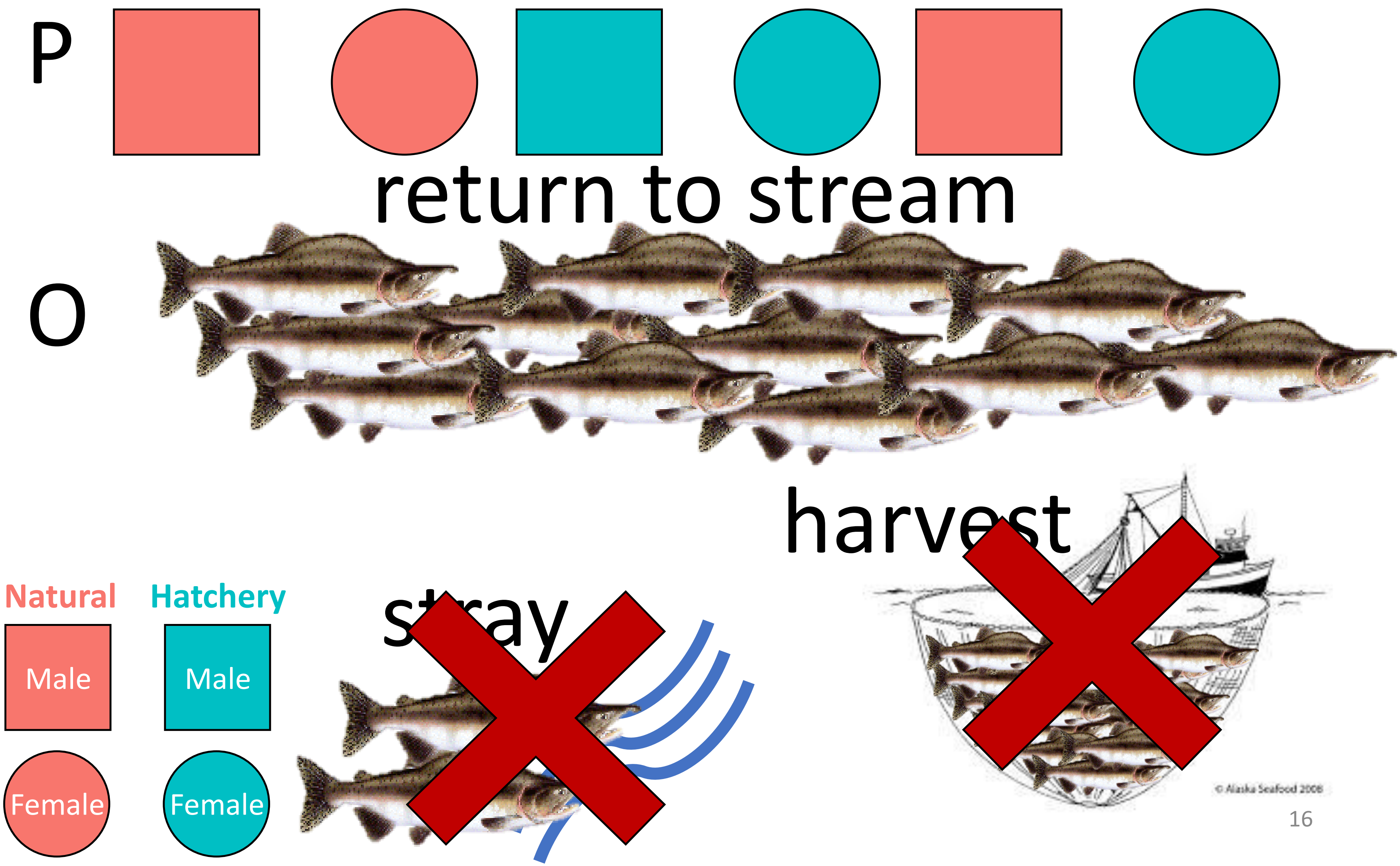
Measuring Reproductive Success

P





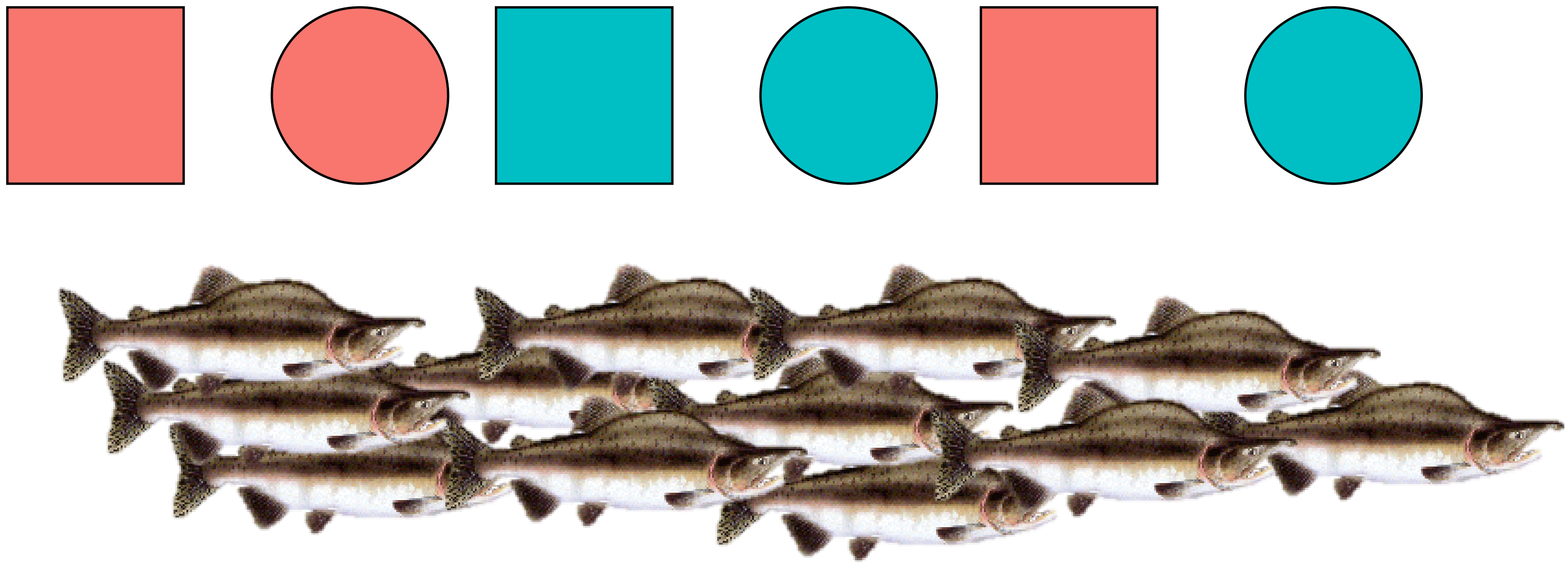
Measuring Reproductive Success

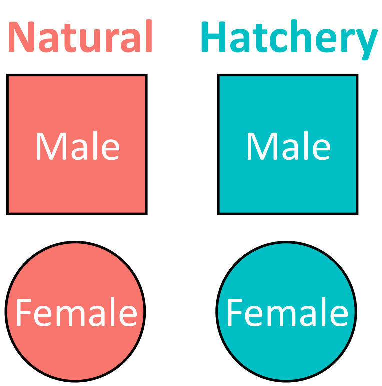


Measuring Reproductive Success

P

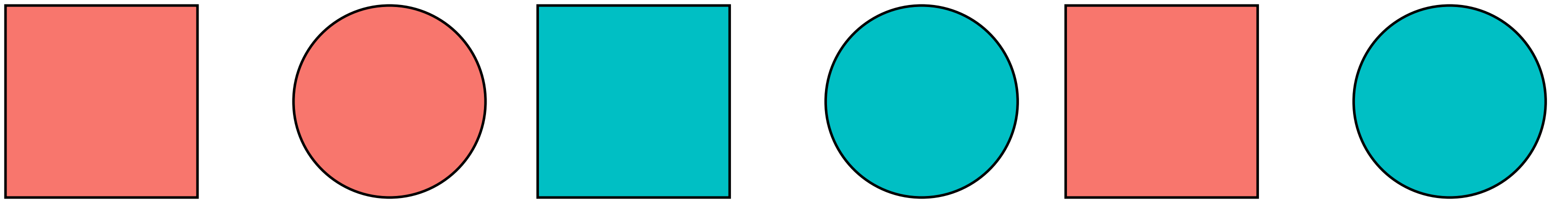
O





Measuring Reproductive Success

P



O

Natural

Male

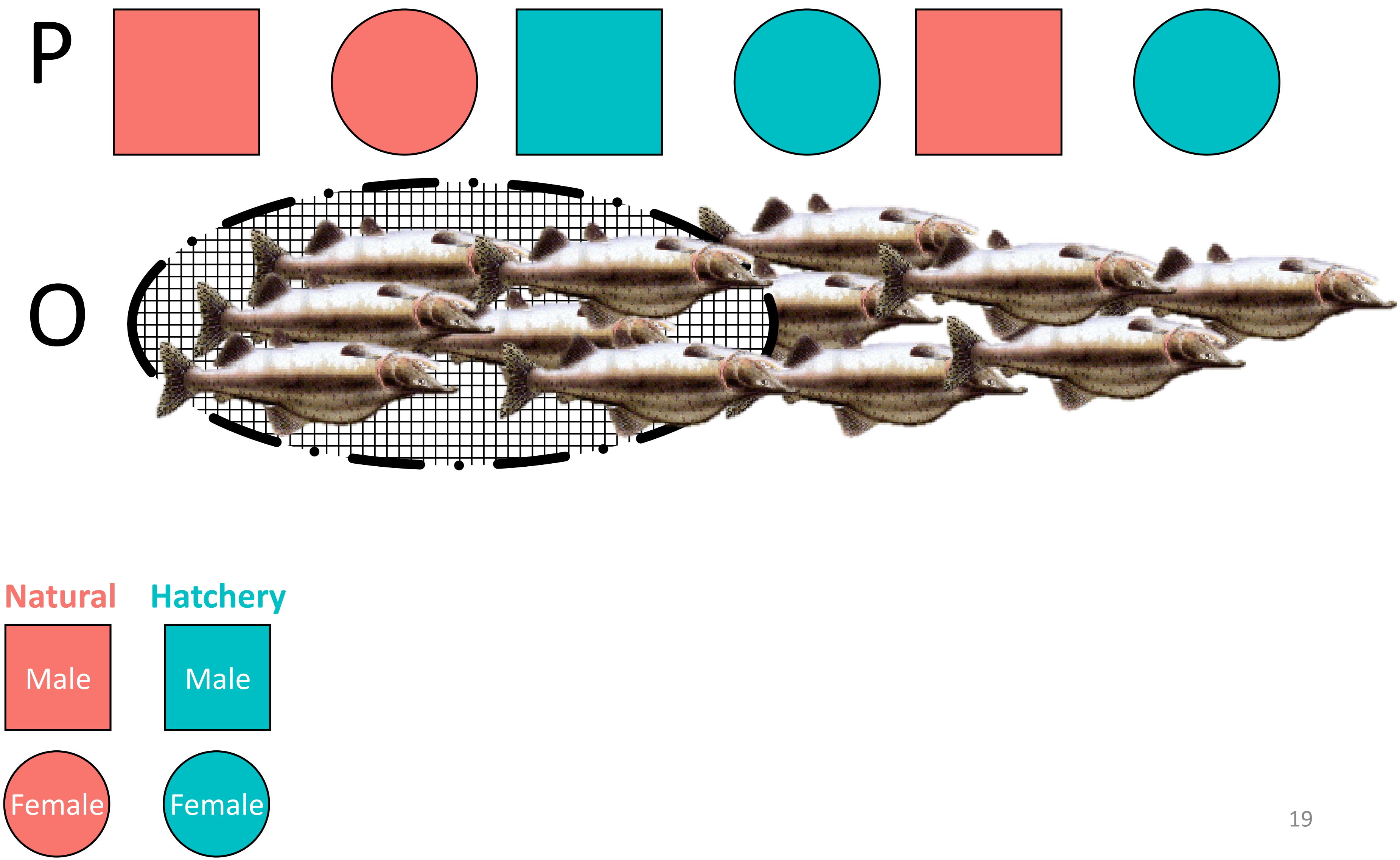
Female

Hatchery

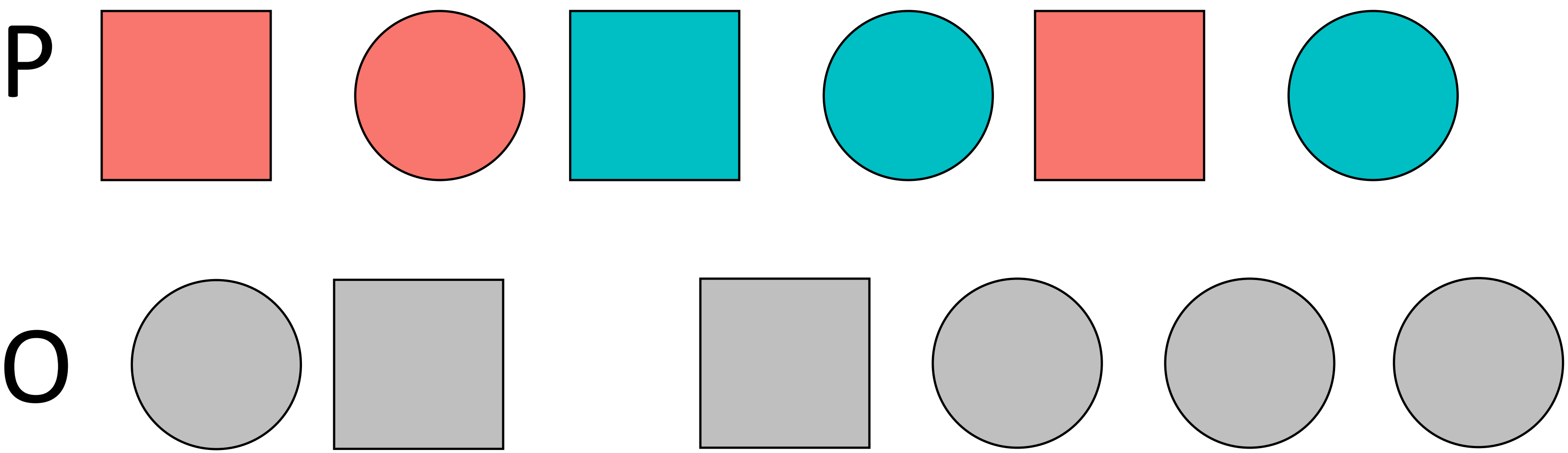
Male

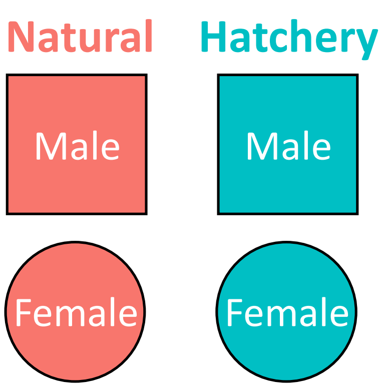
Female

Measuring Reproductive Success

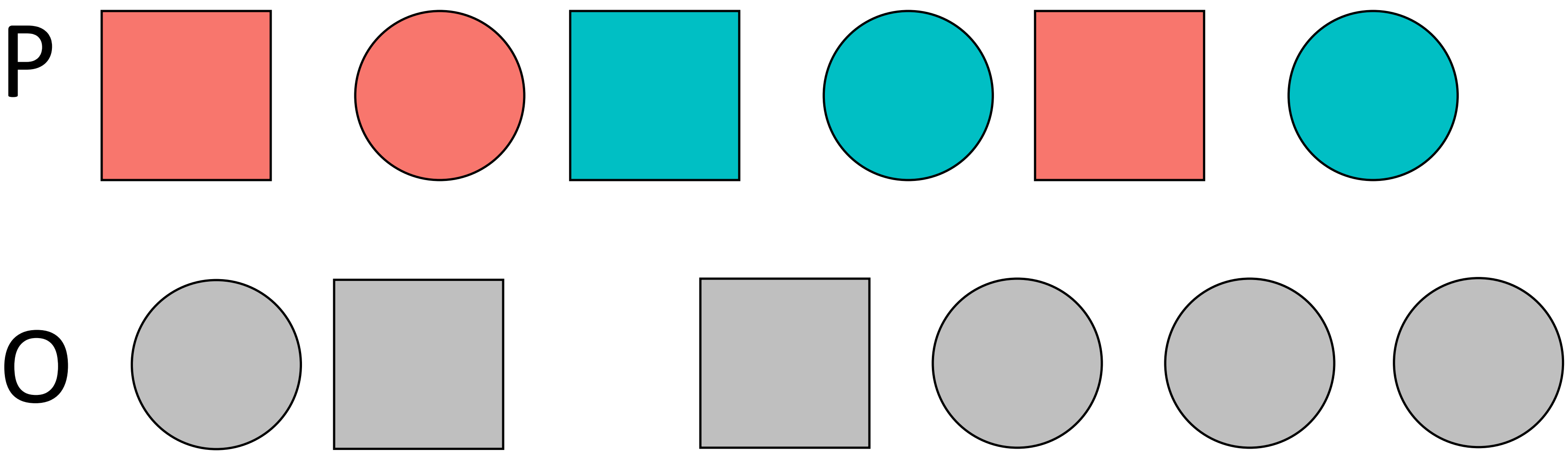


Measuring Reproductive Success



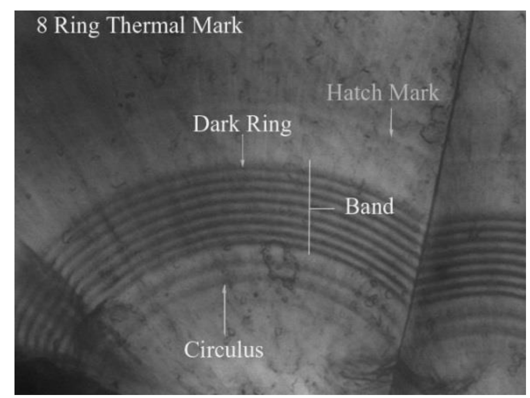


Measuring Reproductive Success



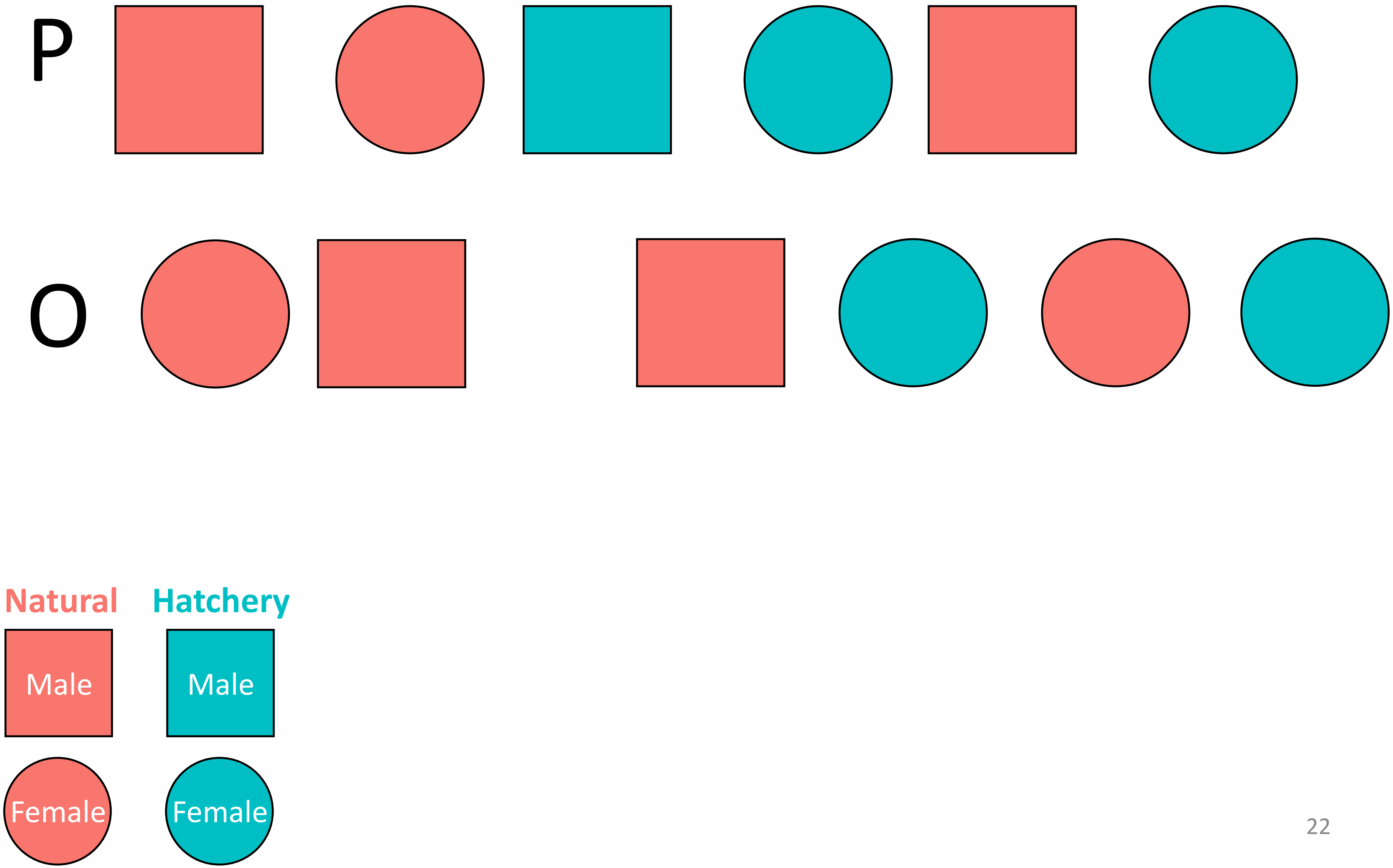
Natural
Male
Female

Hatchery
Male
Female

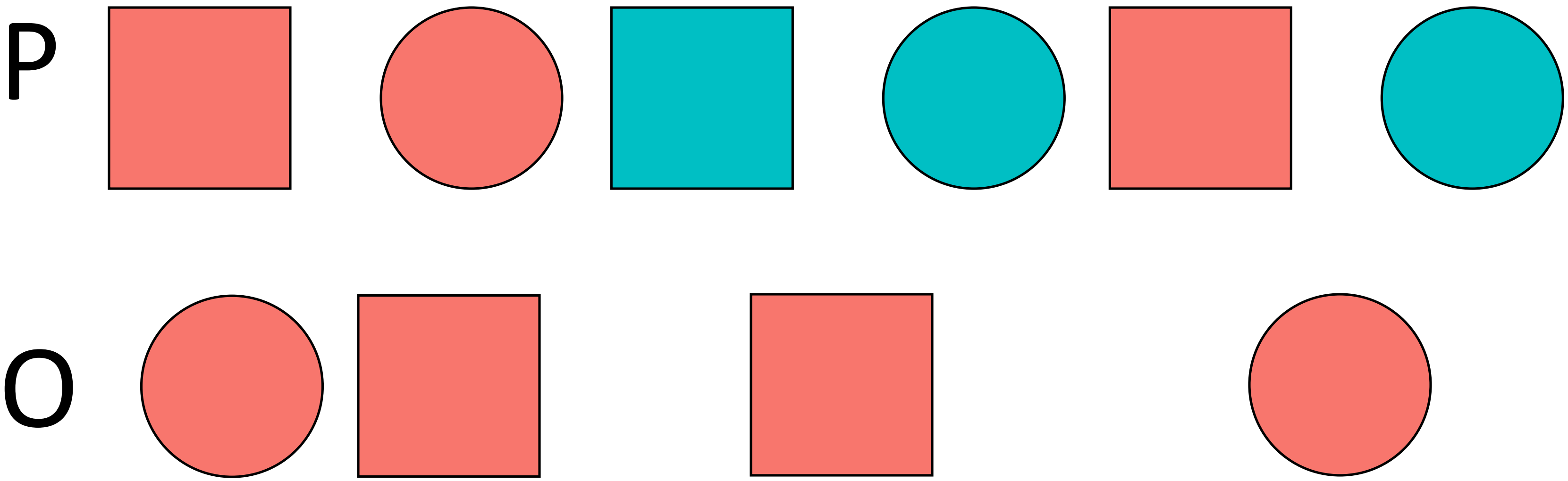


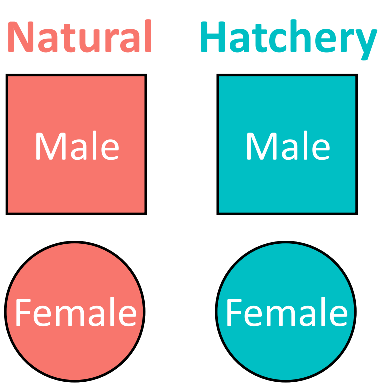
Hatchery-origin

Measuring Reproductive Success



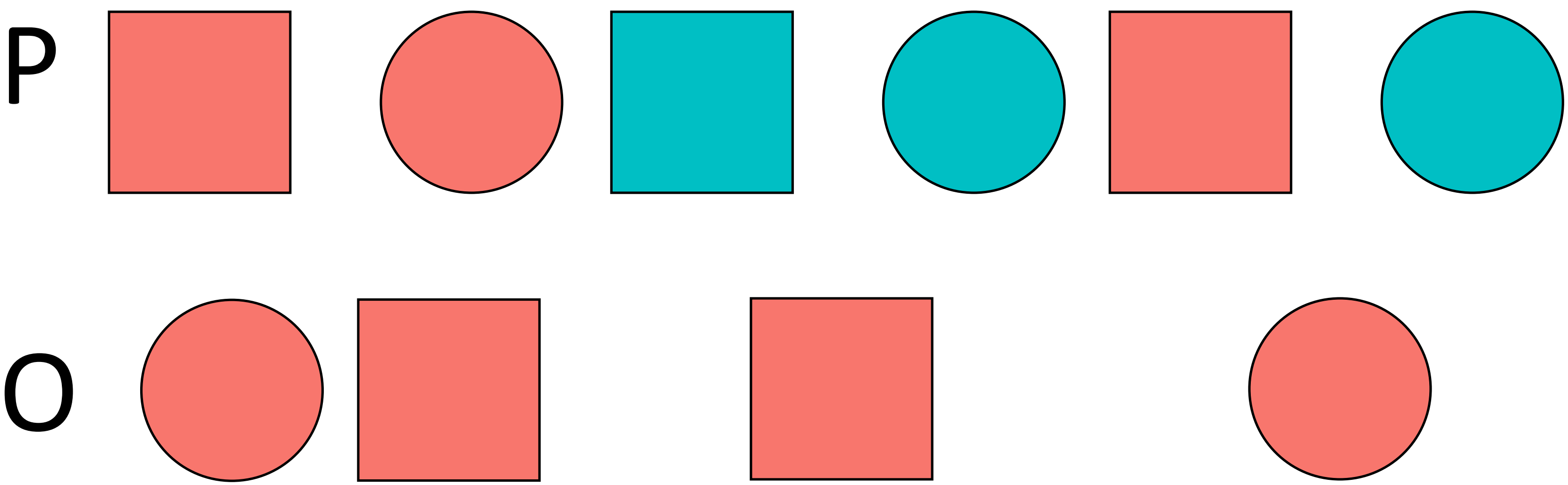
Measuring Reproductive Success

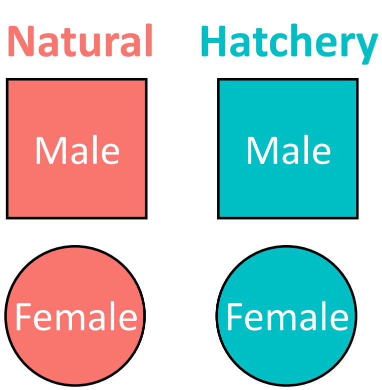




Hatchery-origin fish are not genotyped in the offspring generation because they have a known origin.

Measuring Reproductive Success





298 markers

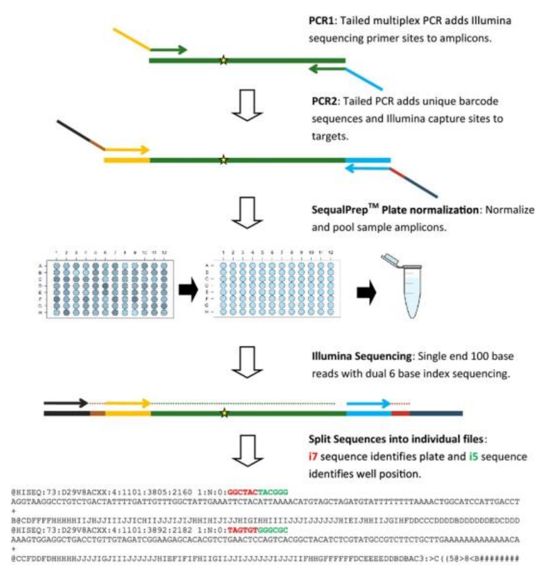
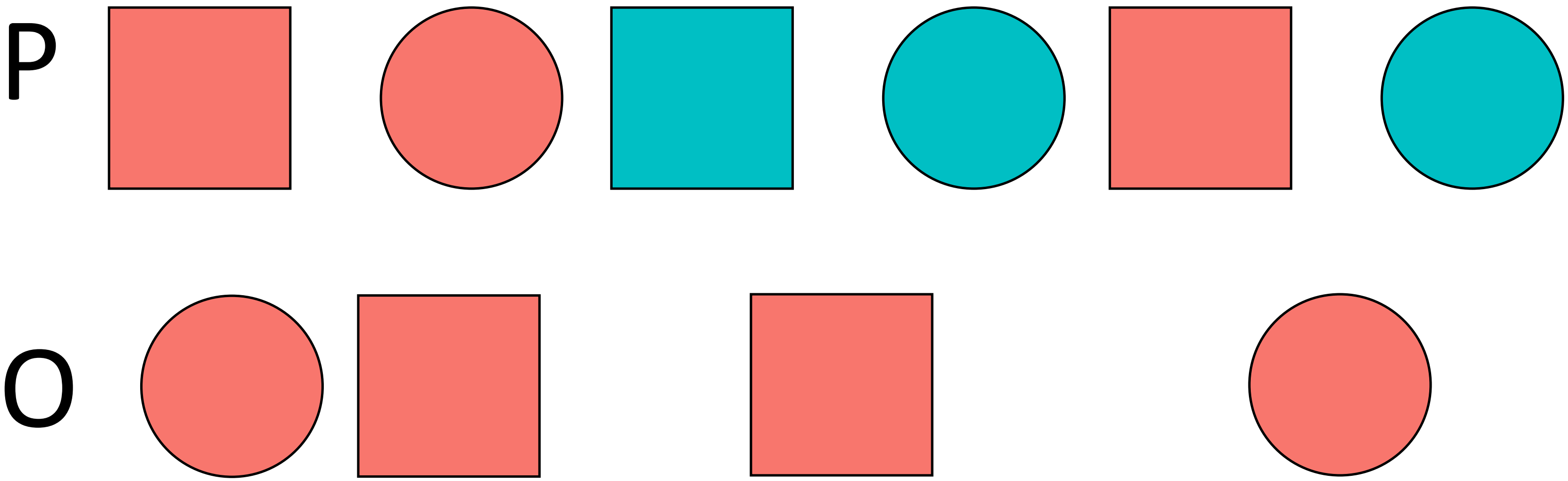


Figure 1 – Campbell et al. 2015

Measuring Reproductive Success



Natural | **Hatchery**

Male | Male

Female | Female

298 markers

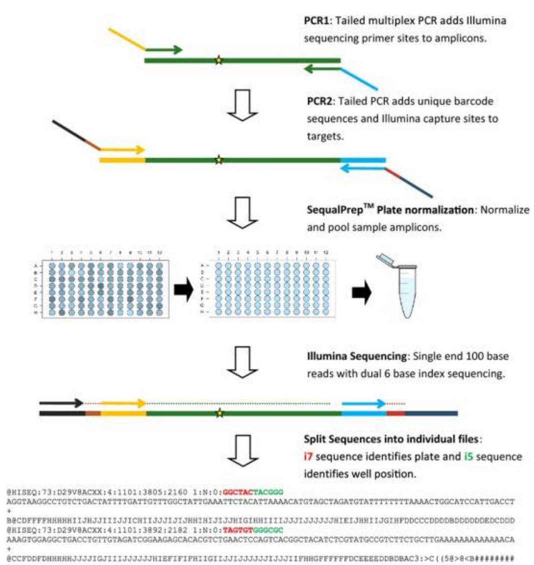


Figure 1 – Campbell et al. 2015

Riester et al. 2009

Genetic Parentage Analysis

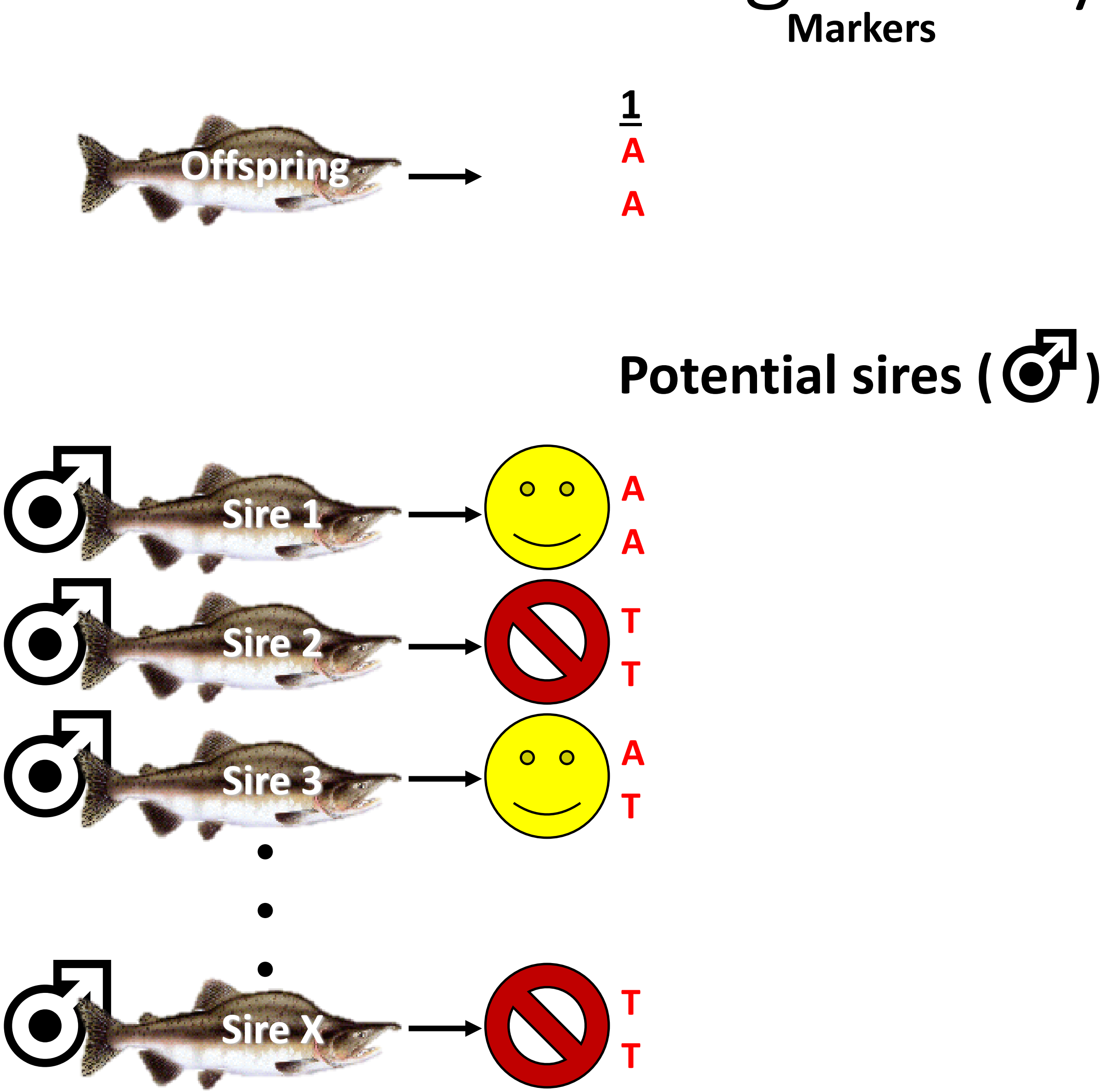
CTATGTATTAAATGTTAATAATAATAACTAGCTAACC — ***T** allele*
CTATGTAATAAATGTTAATAATAATAACTAGCTAACC — ***A** allele*

CTATGTAATAAATGTTAATAATAATAACTAGCTAACC — ***A** allele*
CTATGTAATAAATGTTAATAATAATAACTAGCTAACC — ***A** allele*

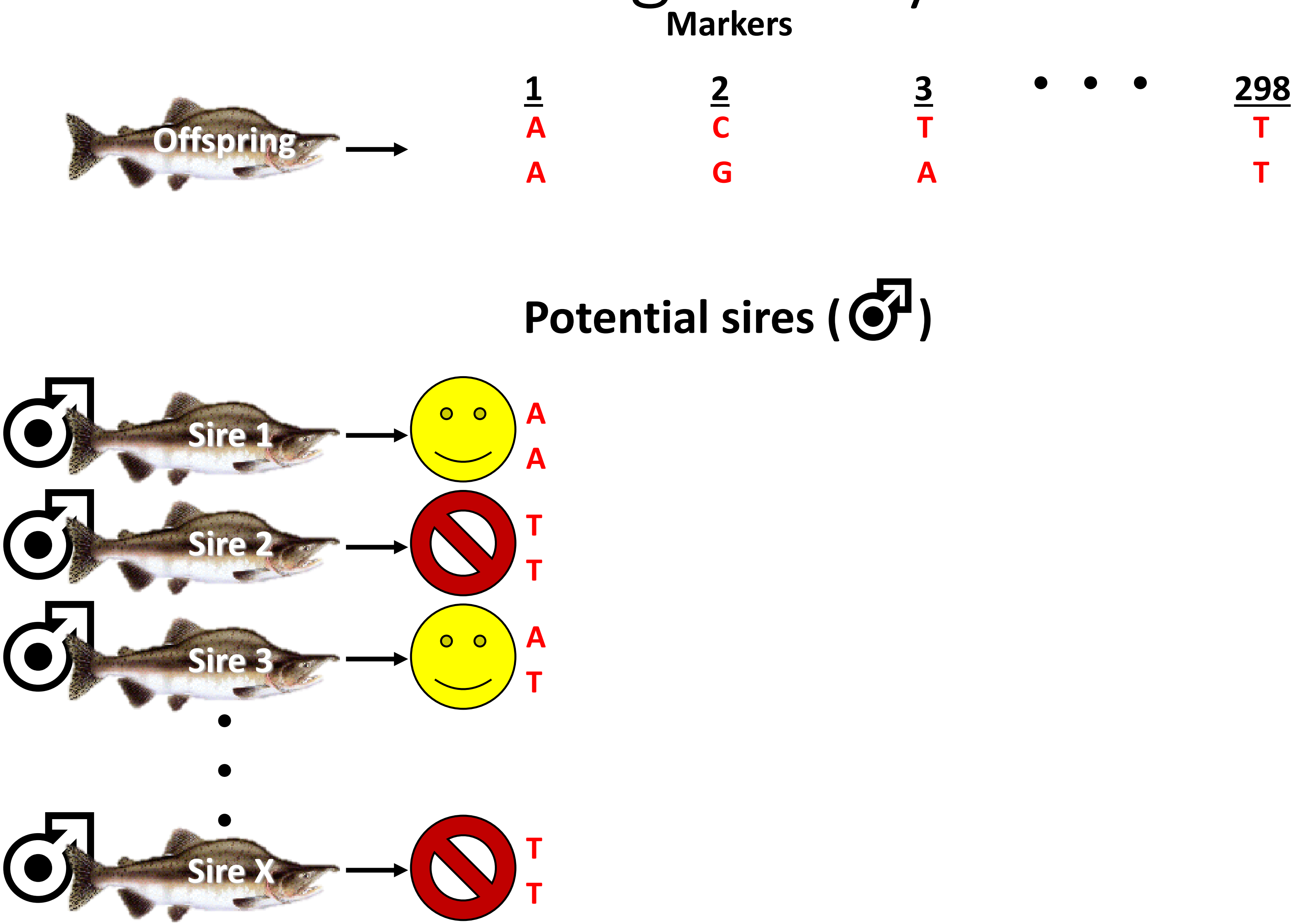
CTATGTAATAAATGTTAATAATAATAACTAGCTAACC — ***A** allele*
CTATGTATTAAATGTTAATAATAATAACTAGCTAACC — ***T** allele*

CTATGTATTAAATGTTAATAATAATAACTAGCTAACC — ***T** allele*
CTATGTATTAAATGTTAATAATAATAACTAGCTAACC — ***T** allele*

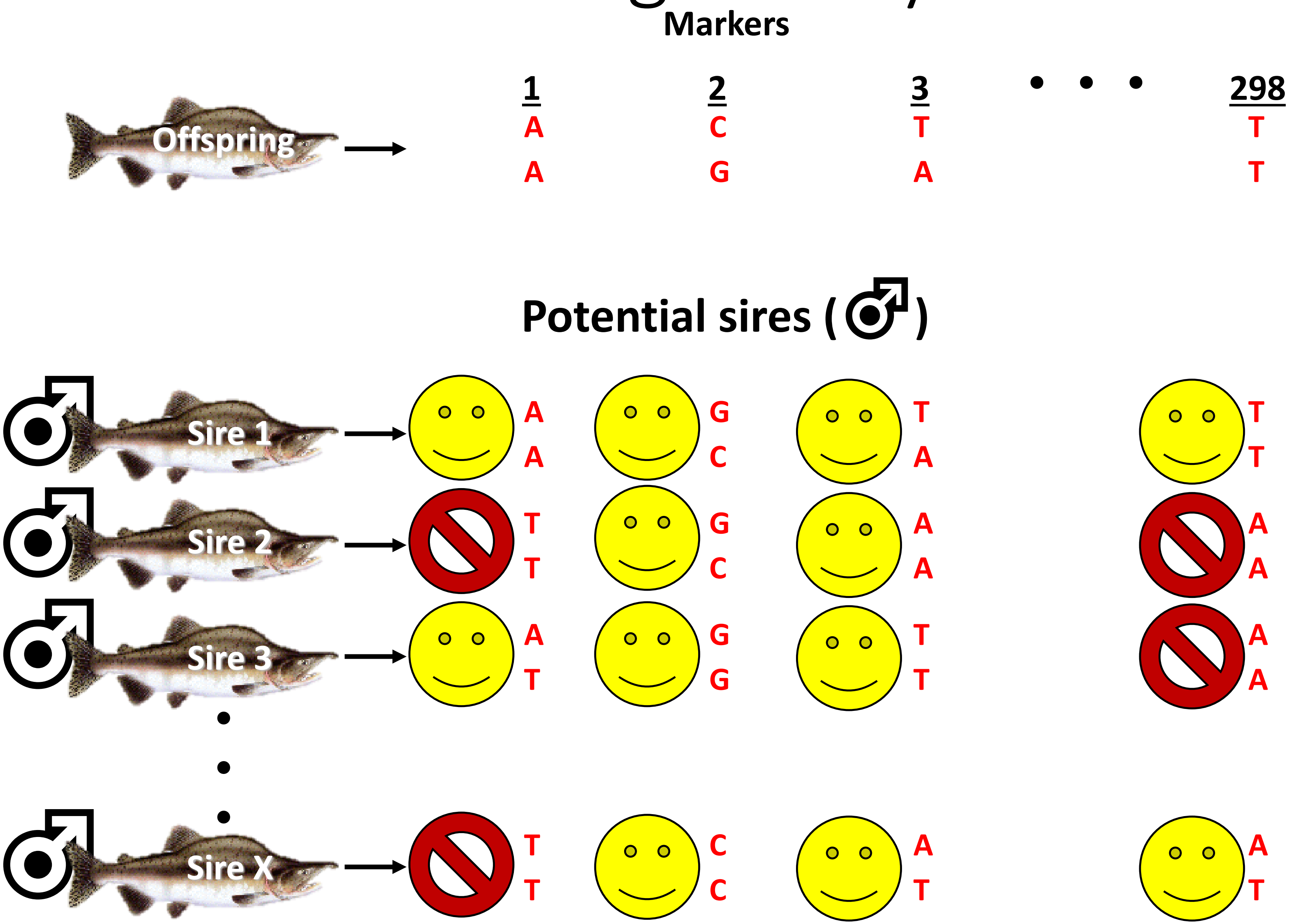
Genetic Parentage Analysis



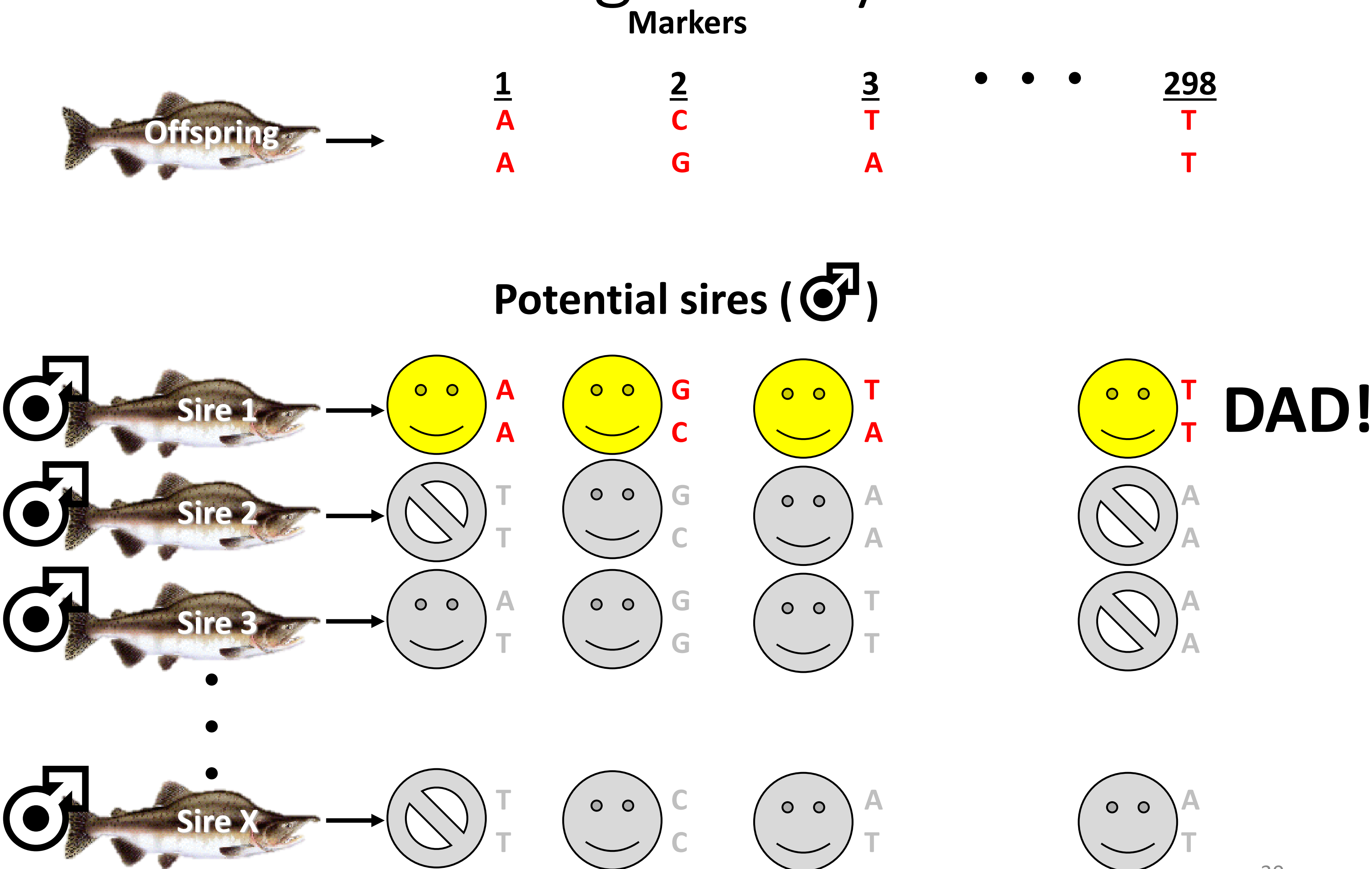
Genetic Parentage Analysis



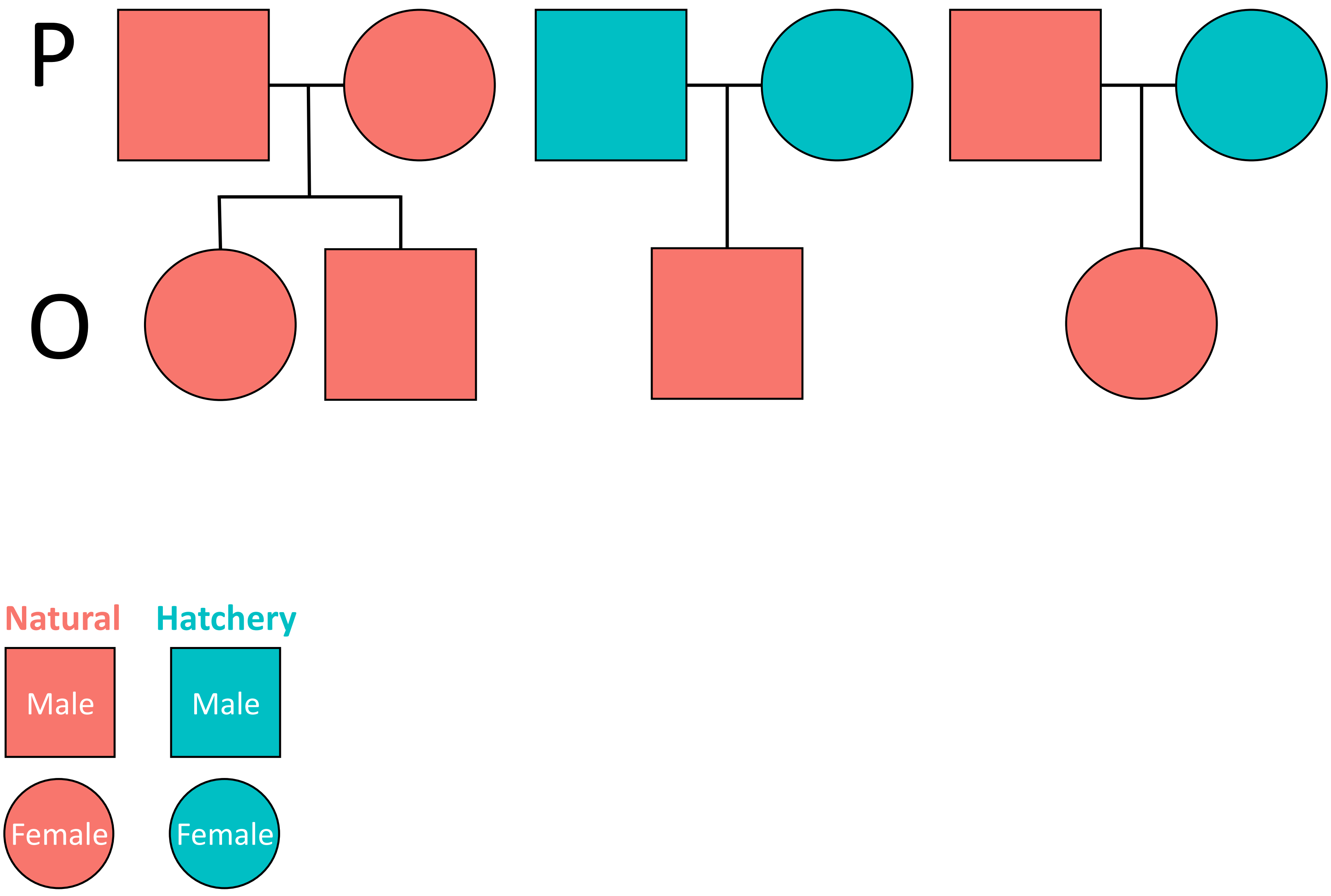
Genetic Parentage Analysis



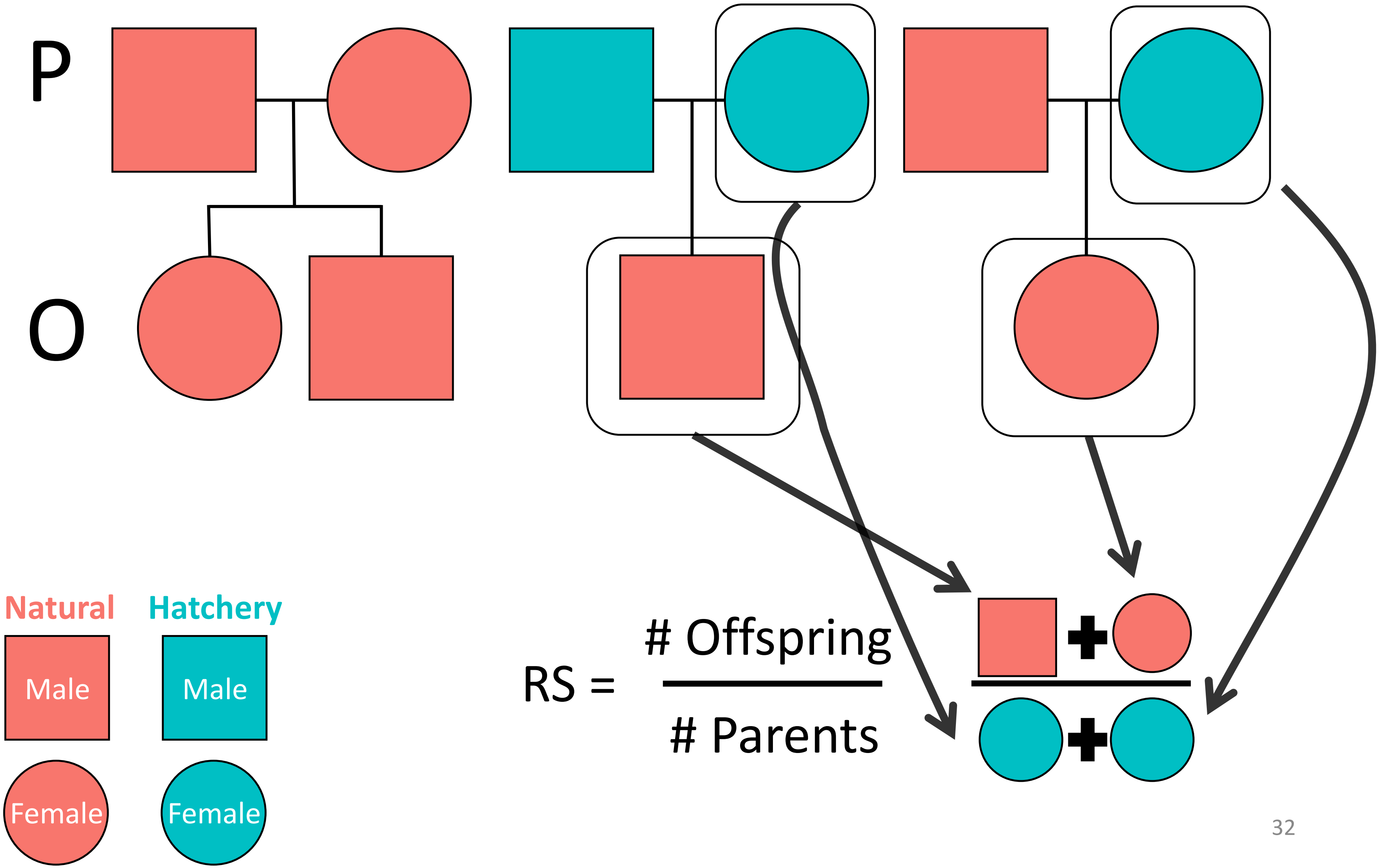
Genetic Parentage Analysis



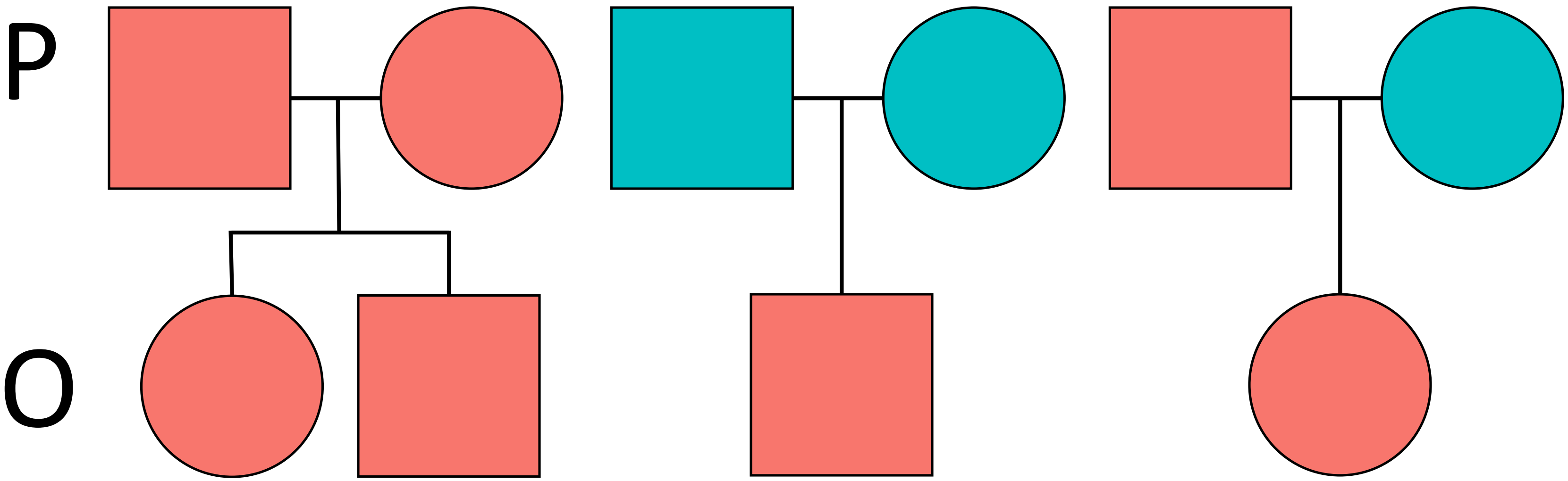
Measuring Reproductive Success



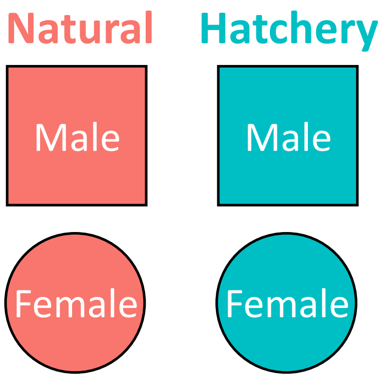
Measuring Reproductive Success



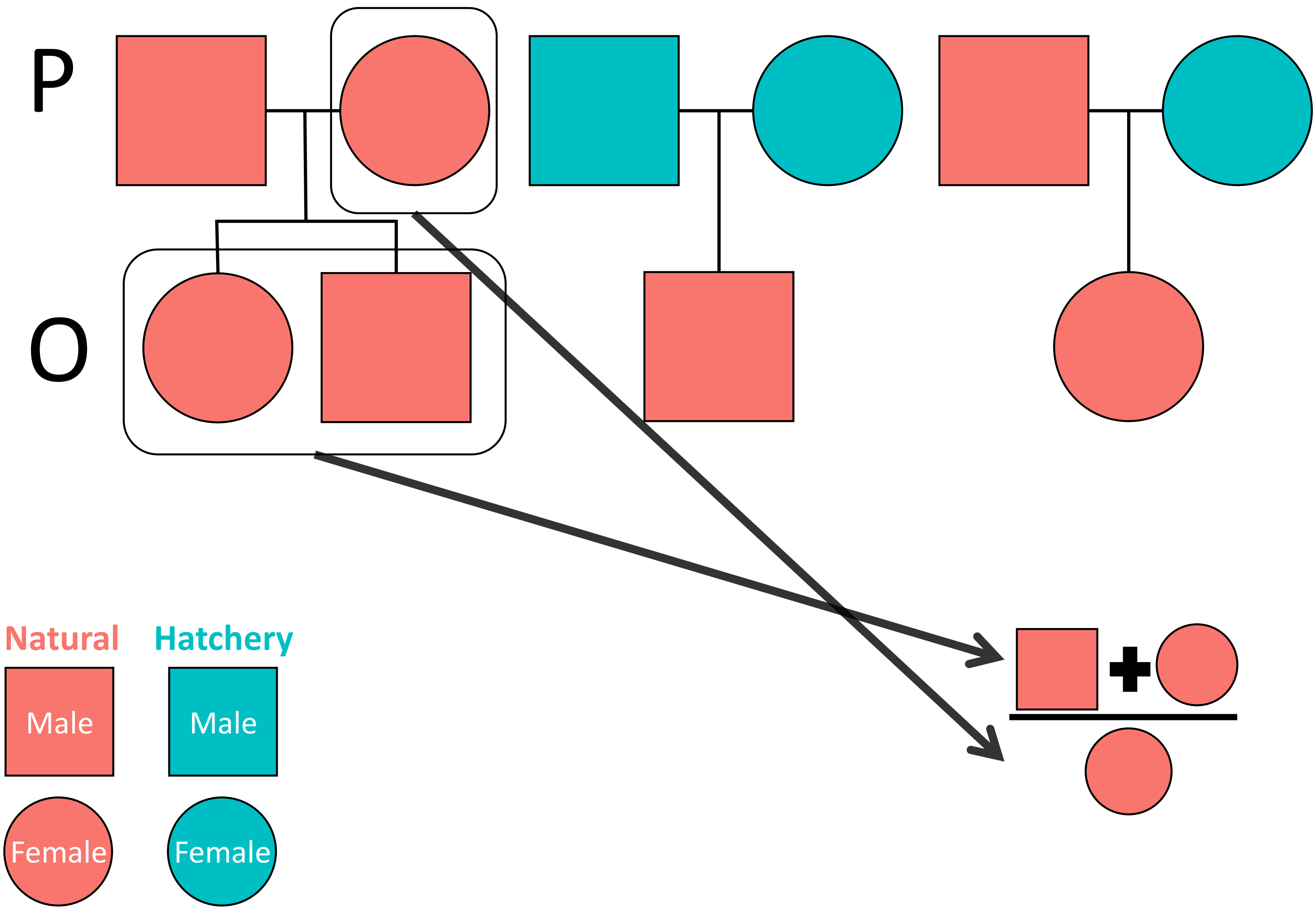
Measuring Reproductive Success



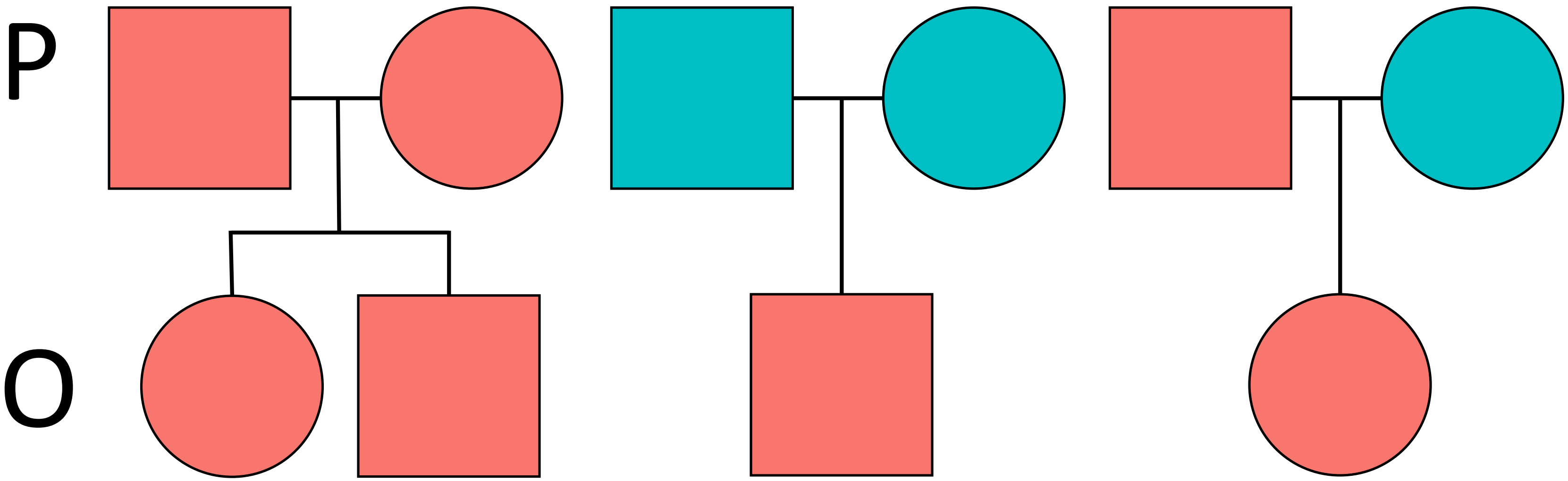
$$RS_{H\ Female} = 1$$



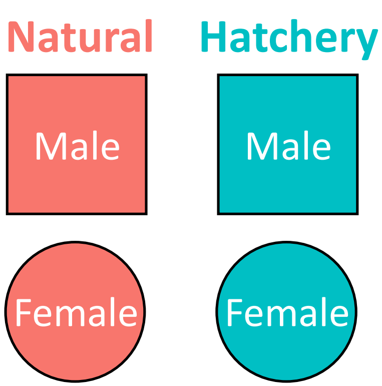
Measuring Reproductive Success



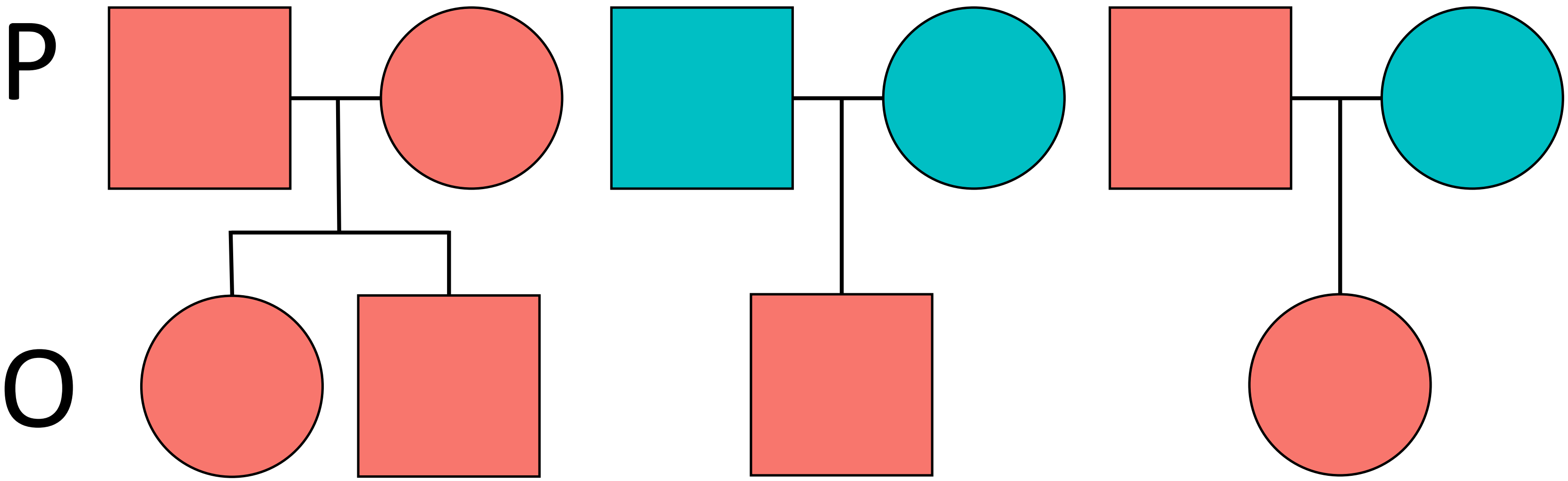
Measuring Reproductive Success



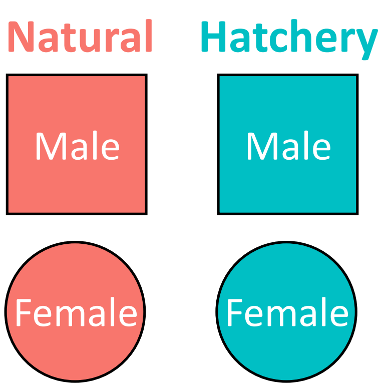
$RS_{N\ \text{Female}} = 2$ $RS_{H\ \text{Female}} = 1$



Measuring Reproductive Success



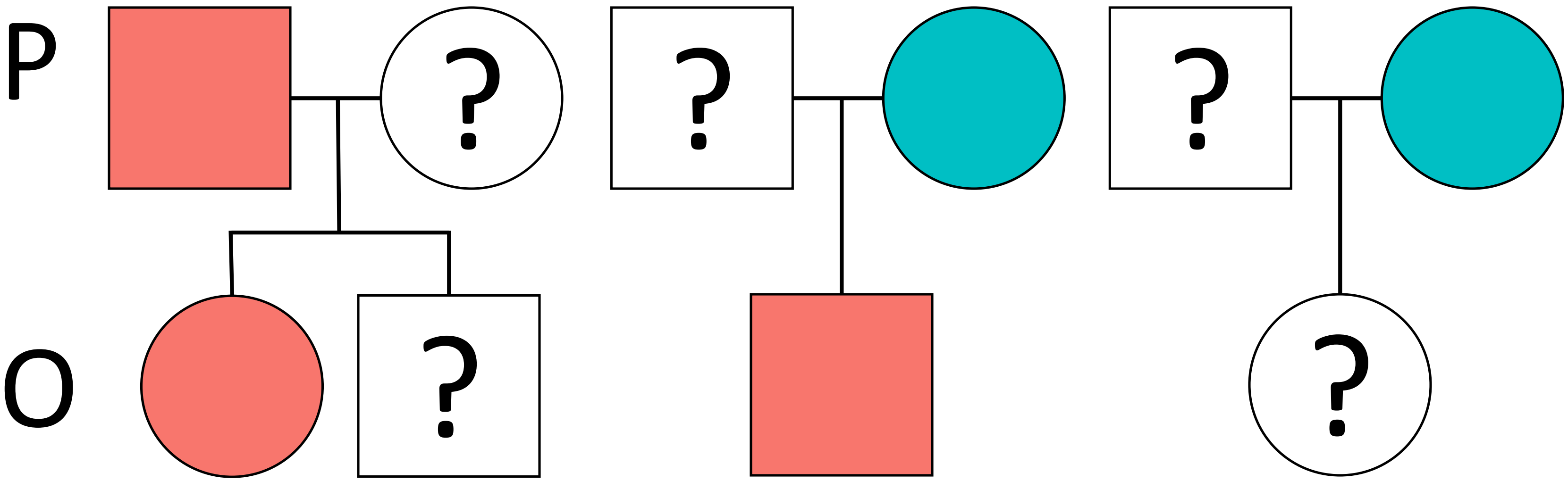
$RS_{N\ Female} = 2$ $RS_{H\ Female} = 1$

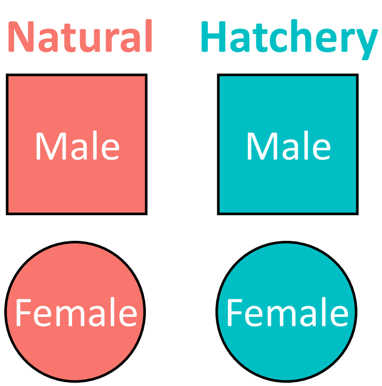


Relative Reproductive Success (RRS)

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

Measuring Reproductive Success





Relative Reproductive Success (RRS)

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

Average Reproductive Success

Stockdale 2014/2016

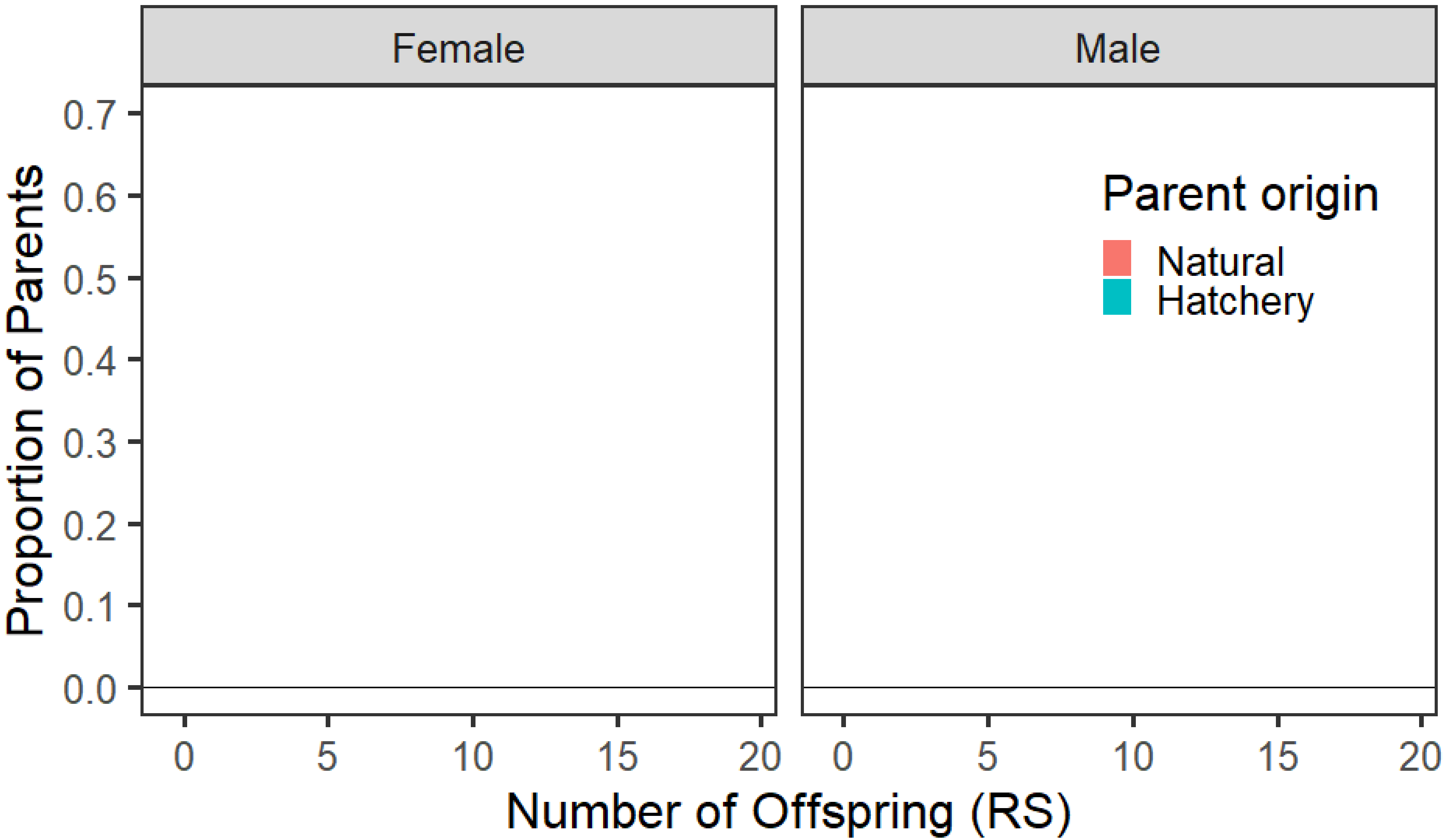
Female	2014 Parents	2016 Offspring	Average RS
Hatchery	**230**	**196**	**0.85**
Natural	**221**	**448**	**2.03**

RRS = 0.42

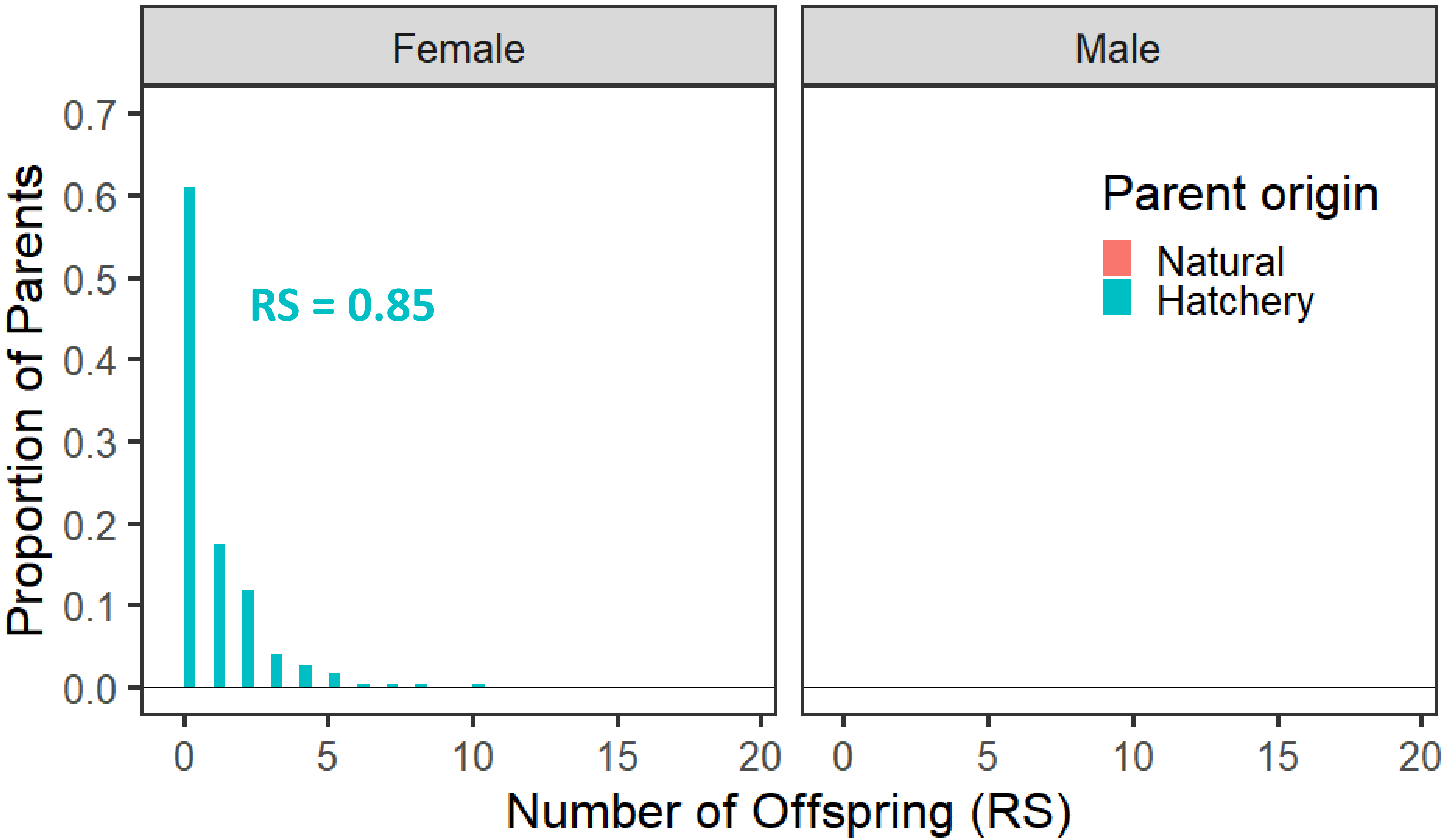
Male	2014 Parents	2016 Offspring	Average RS
Hatchery	**206**	**177**	**0.86**
Natural	**137**	**417**	**3.04**

RRS = 0.28

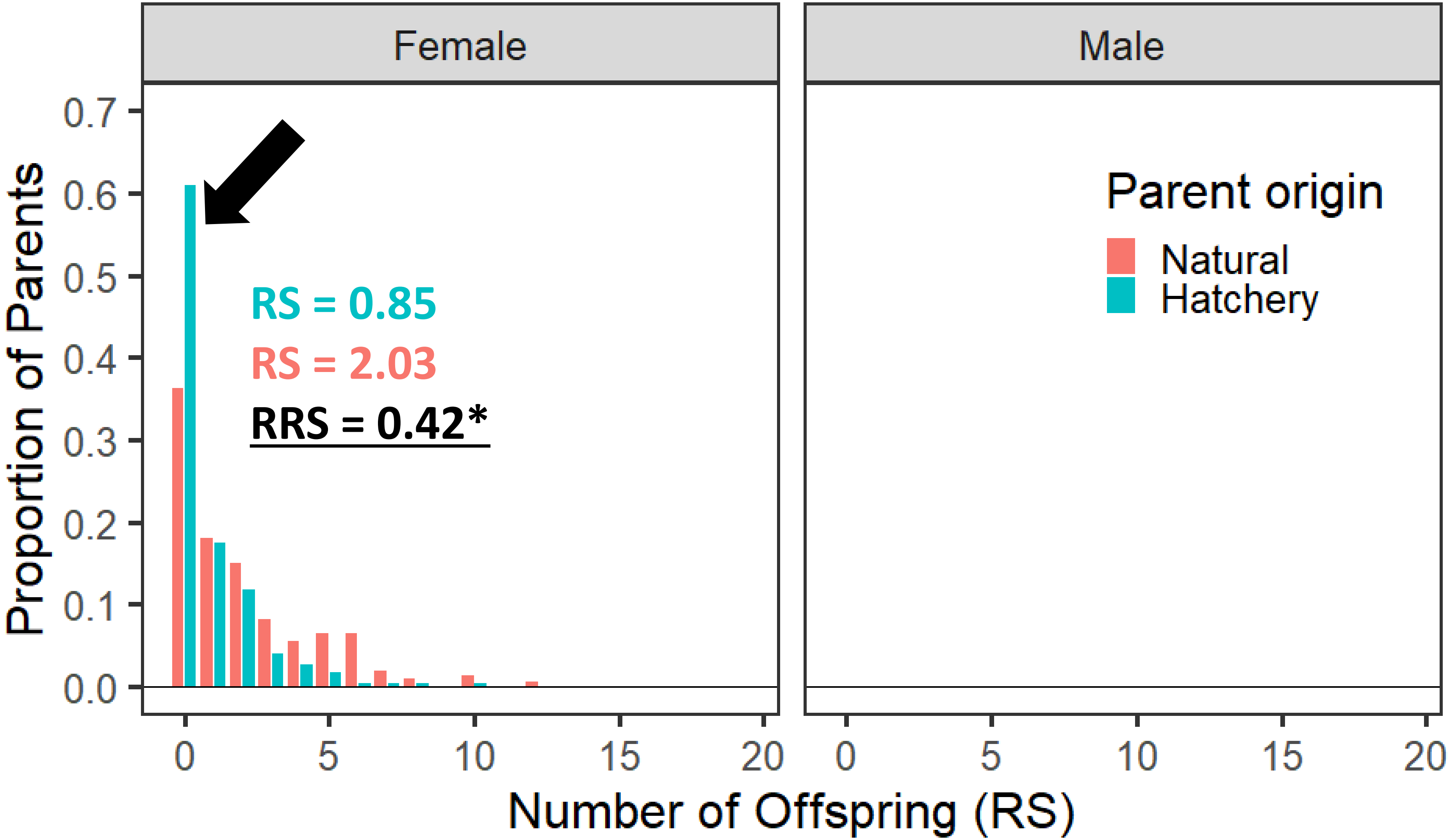
RS Distribution: Stockdale 2014/2016



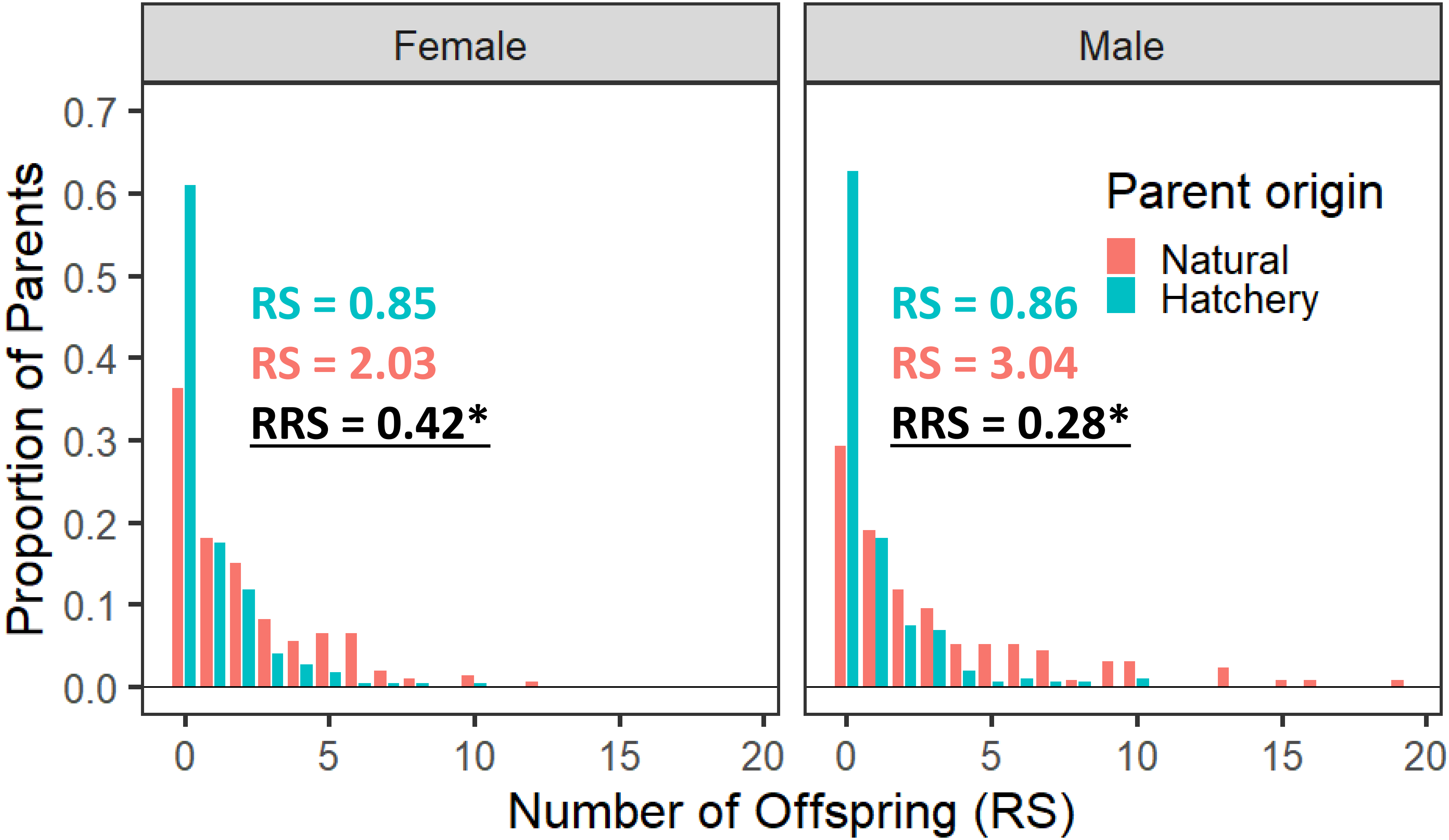
RS Distribution: Stockdale 2014/2016



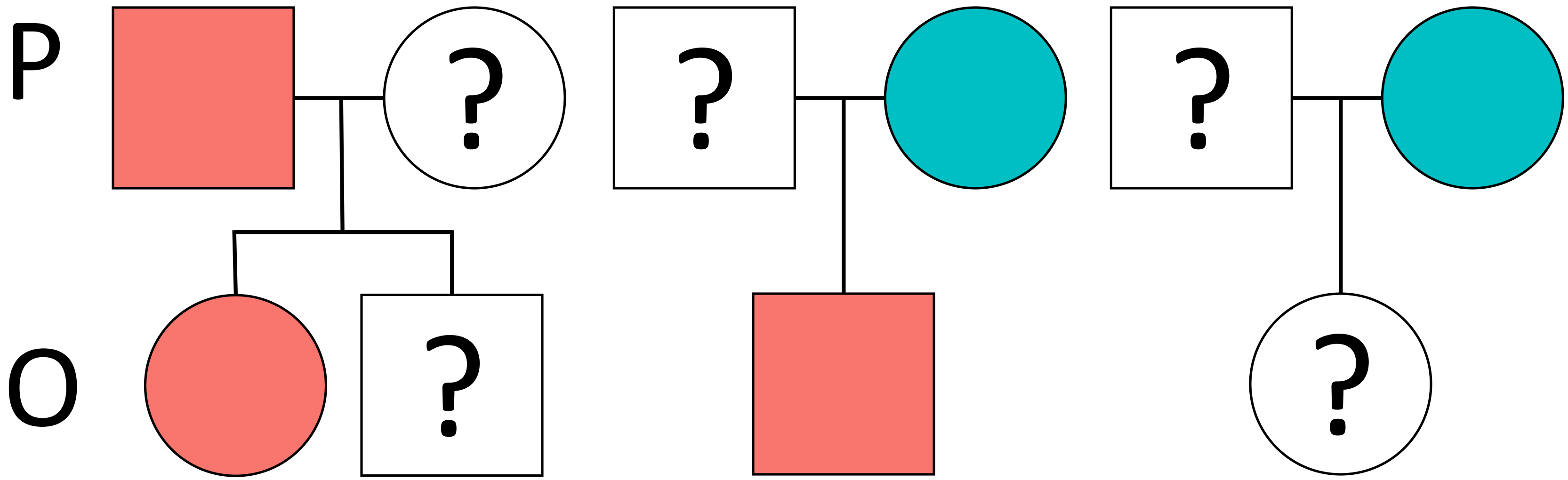
RS Distribution: Stockdale 2014/2016

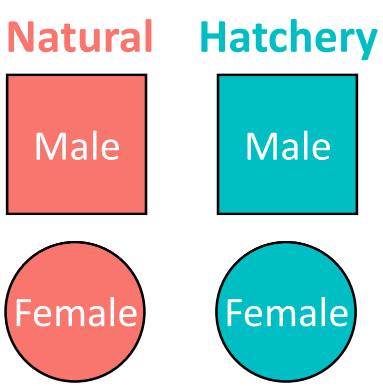


RS Distribution: Stockdale 2014/2016

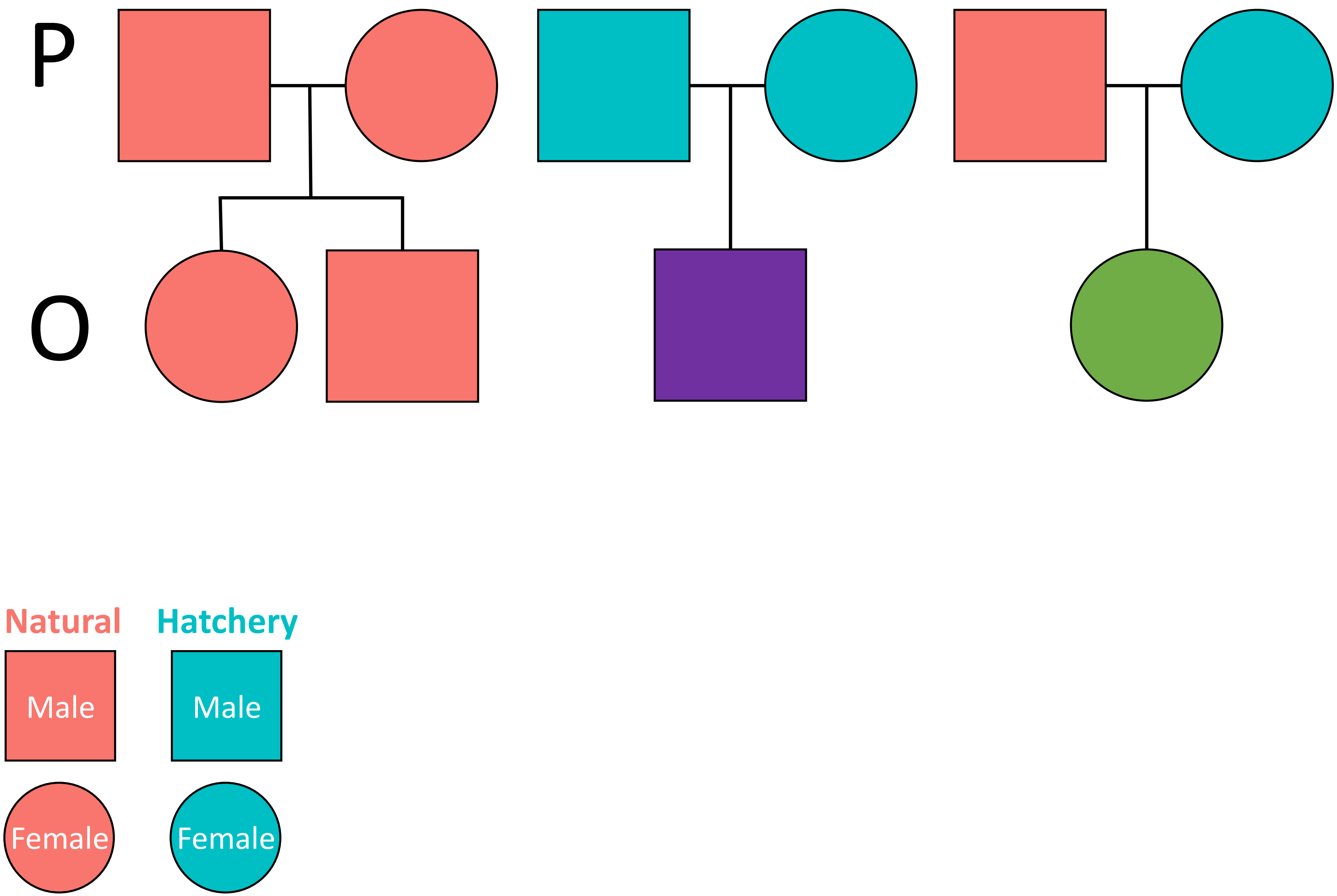


Parent-Offspring Duos

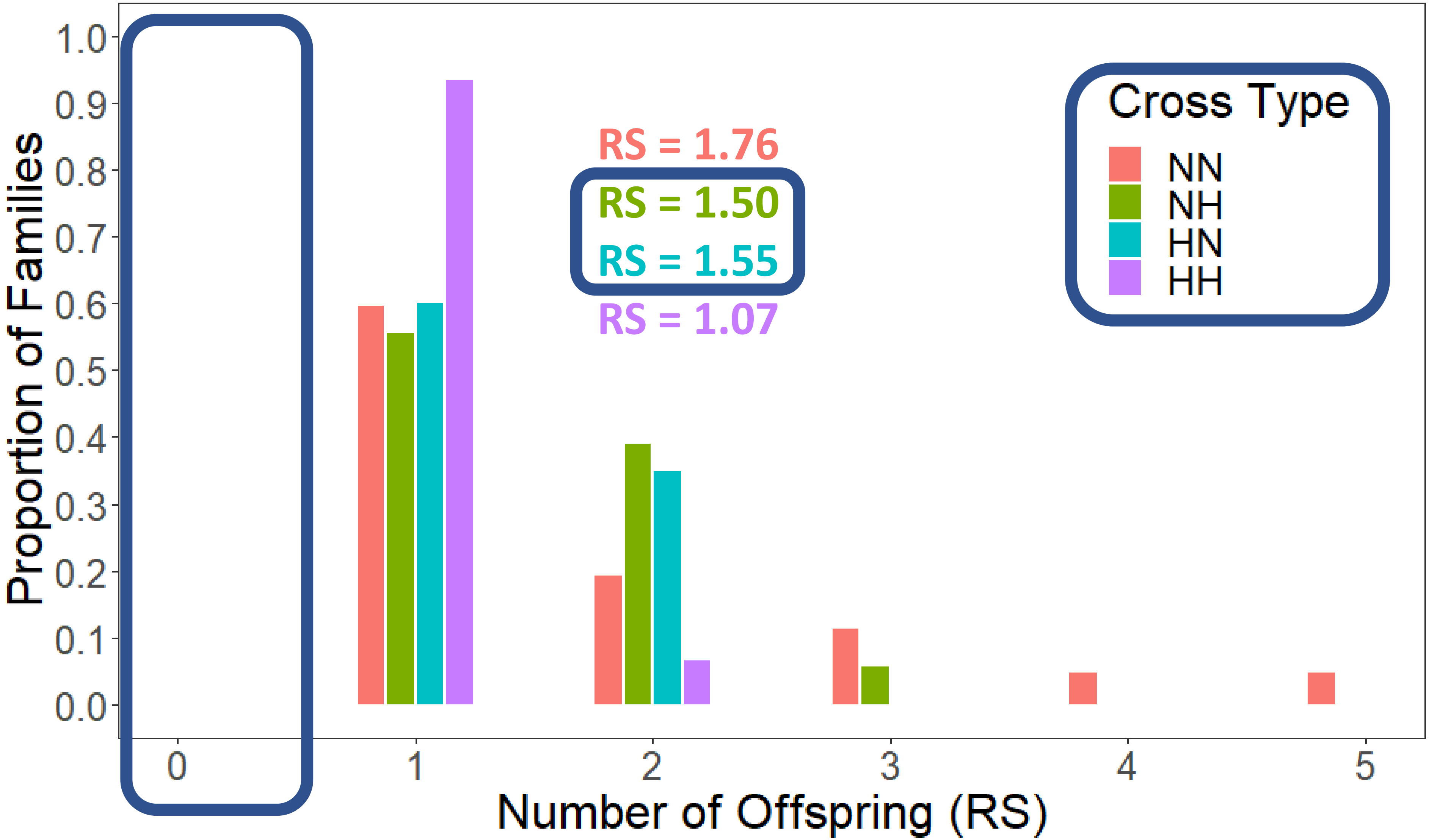




Parent-Pair-Offspring Trios



RS Distribution: Stockdale 2014/2016

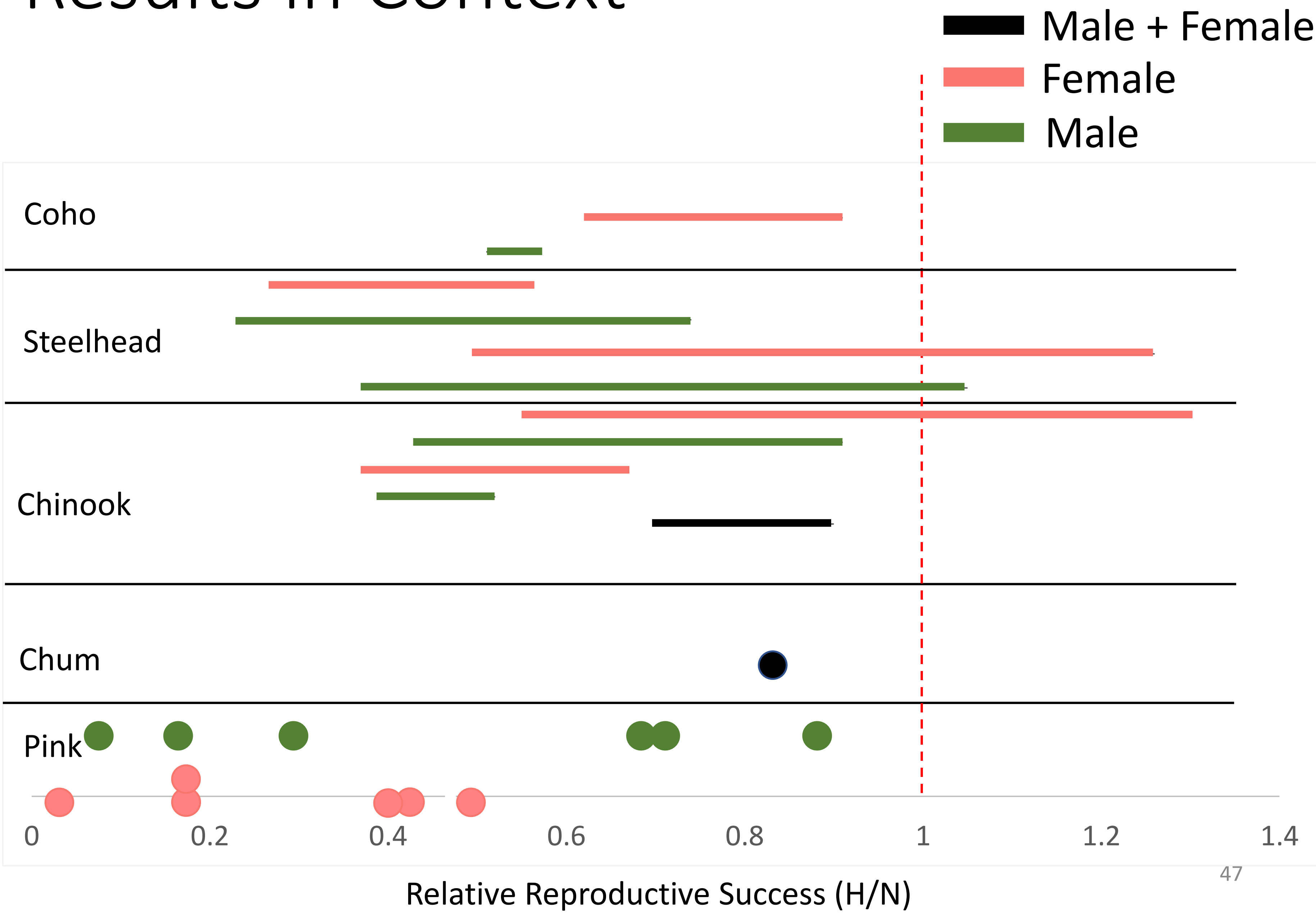


Summary of RRS to Date

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)
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)

Results in Context



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

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%)

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
- 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 (grand-offspring and beyond)?

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

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 (2013-2016)
- Saltonstall-Kennedy (NA16NMF4270251)
  - Funding for Stockdale analyses (2014/2016)
- Prince William Sound Science Center
  - Field collection
- ADF&G Cordova Otolith Lab
- University of Washington - Seeb Lab
- ADF&G Gene Conservation Laboratory


Questions?
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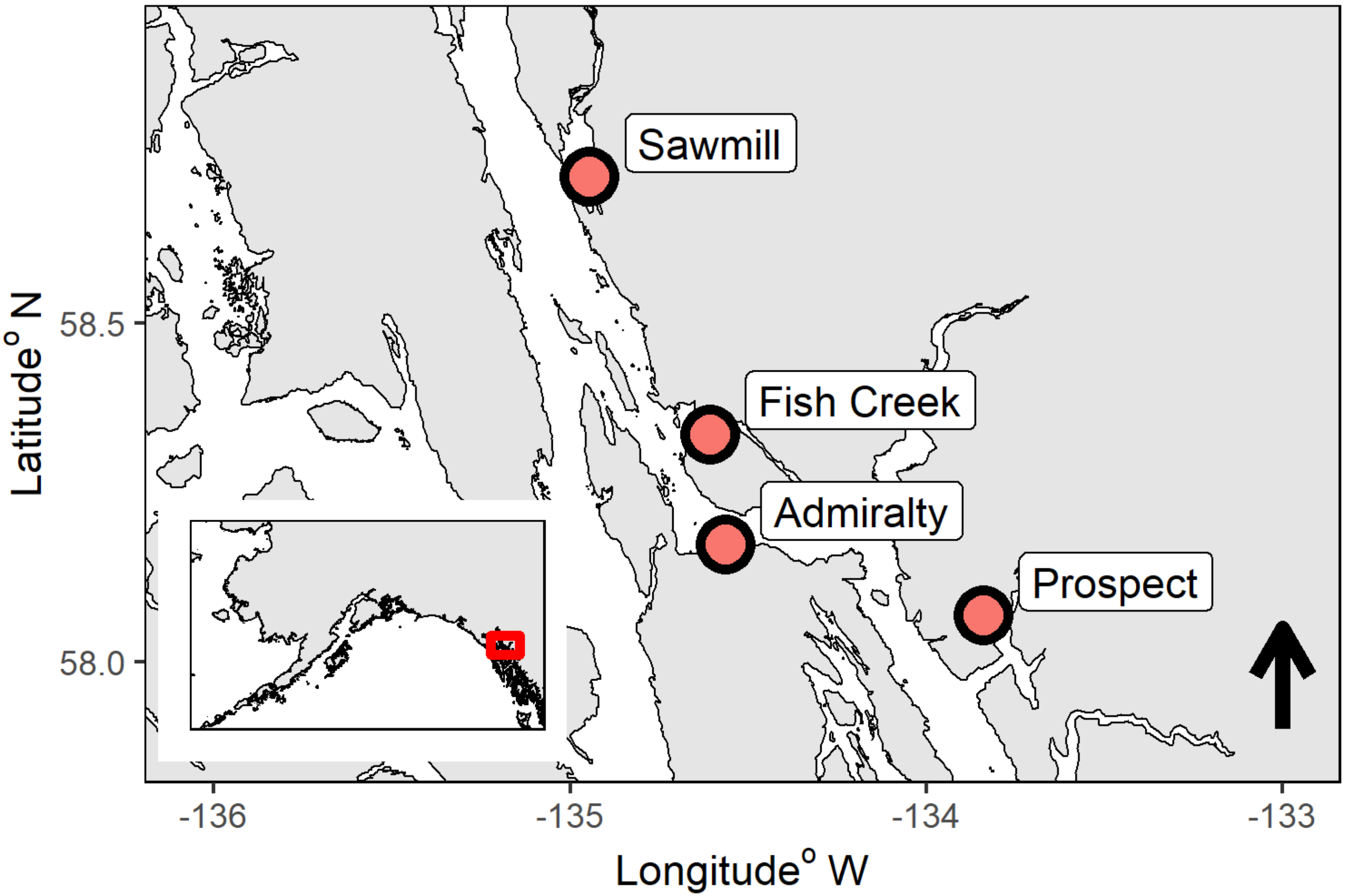
AHRP Fitness Study: SEAK Chum Salmon

Map of SEAK Chum fitness streams



Study plan

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
						Sampling year					
Chum (BY 1)	F_0	F_1		F_1	F_1	F_1/F_2	F_1/F_2	F_2	F_2	F_2	
Chum (BY 2)		F_0	F_1		F_1	F_1/F_2	F_1/F_2	F_2	F_2	F_2	F_2

P – parents

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Chum (BY1)	P				O	O					
Chum (BY2)		P			O	O	O				

G – grand-offspri

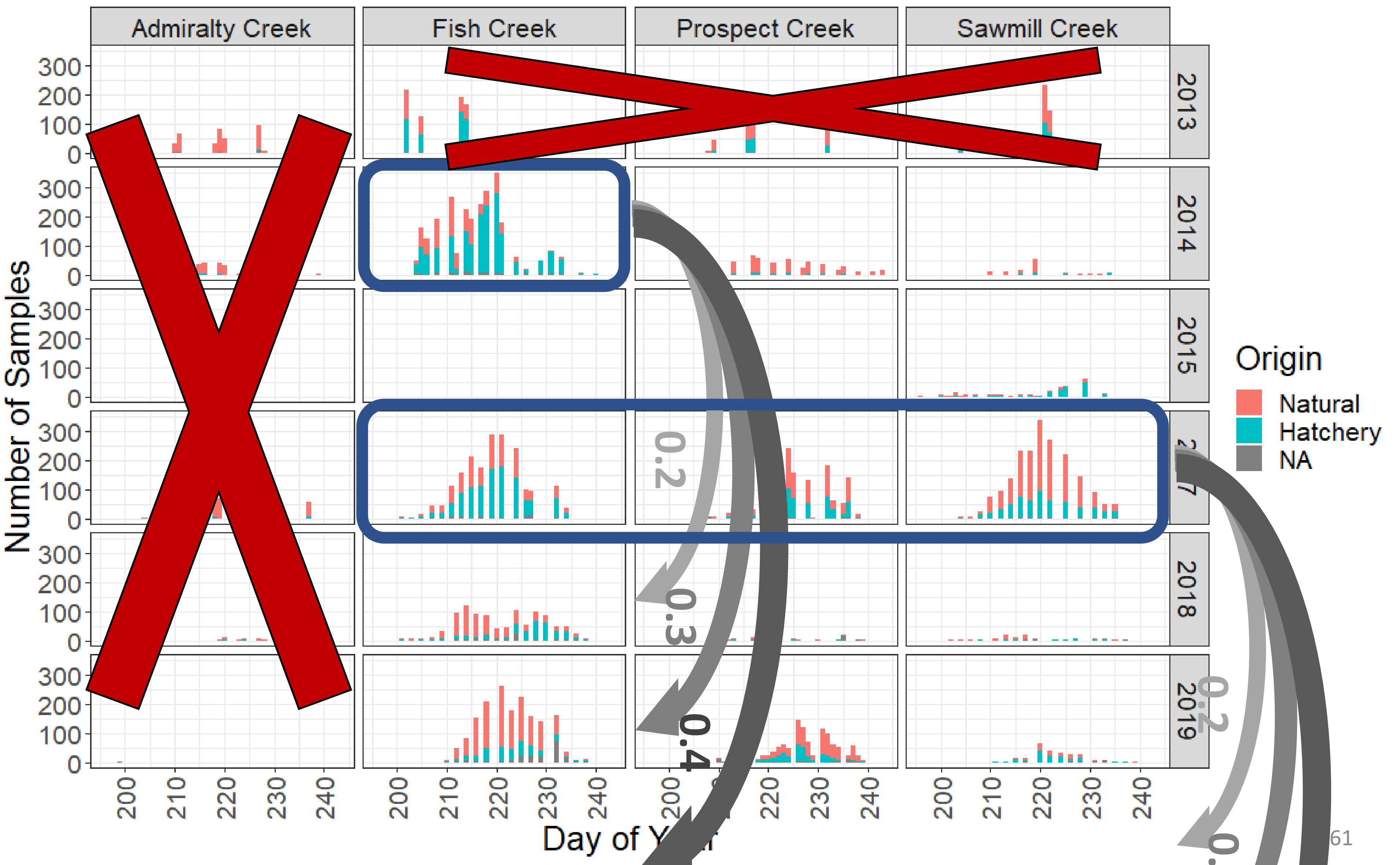
Adult

Adult + Alevin

Statistical power of study plan

- Need minimum ~100 parents of each sex/origin
- Ideally a high proportion of parents
  - Hogan Bay 2013/2015
    - Low sampling rate = few parent-offspring assignments
- Sample high proportion of offspring
  - Consistent proportion for all return years
  - Differences in age at return?

Samples by origin, stream, and year



Acknowledgements

- Alaska Hatchery Research Program
  - State of Alaska
  - Seafood industry
  - Private non-profit hatcheries
- Sitka Sound Science Center
  - Field collection
- ADF&G Mark, Tag and Age Lab
- ADF&G Gene Conservation Laboratory


Questions?