Examining power of parentage analysis for the Alaska Hatchery Research Program (AHRP)

Kyle Shedd, Tyler Dann, Jim Jasper

Chris Habicht, & Bill Templin

Alaska Department of Fish & Game, Gene Conservation Lab

2014 AHRP Annual Meeting
Anchorage, Alaska

Why do power analysis?

- How big of an effect can we detect with current field sampling methods?
- Will that achieve program objectives?
  - RFP states $RRS_{H/N} = 0.5$
  - Does this study need to detect smaller effects?
- How much would we need to sample to detect smaller effects?
- How would we do that?

See AHRP Technical Document 4 & 5

Outline

- Background of AHRP
- Parentage and RRS
- Proposed study design
- Simulations
- Power analysis
- Christie et al. 2014 review

AHRP Research Questions

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?

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What is the relative reproductive success (RRS) of hatchery-origin and natural-origin fish?

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

Previous research

Previous research

Steelhead

433

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

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

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

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

VÉRONIQUE THÉRIAULT,* GREGORY R. MOYER,*[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

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

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

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

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

biology letters
Conservation biology
Biol. Lett. (2009) 5, 621–624
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Published online 10 June 2009

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

Hitoshi Araki*,†, Becky Cooper and Michael S. Blouin

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

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

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

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

PNAS

Genetic adaptation to captivity can occur in a single generation

Mark R. Christie[a,1], Melanie L. Marine[a], Rod A. French[b], and Michael S. Blouin[a]
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Edited by Fred W. Allendorf, University of Montana, Missoula, MT, and accepted by the Editorial Board November 11, 2011 (received for review July 14, 2011)

Captive breeding programs are widely used for the conservation and restoration of threatened and endangered species. Nevertheless, captive-born individuals frequently have reduced fitness when

have a high standing mutational load or spend many generations in captivity (9). Unintentional domestication selection, on the other hand, can rapidly reduce fitness in the wild, especially if

Previous research

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Chinook

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[Article]

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

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1840

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

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

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Evolutionary Applications

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ORIGINAL ARTICLE

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

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

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

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

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

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Abstract

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

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

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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

Previous research

Steelhead | Chinook | Coho | Chum

- Also lots of Atlantic salmon
- No pinks, few chum
- Different hatchery culture
- Smaller releases
- None in Alaska
- Sample ↑ prop. adults/offspring

Outline

- Background of AHRP
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How to measure RS?

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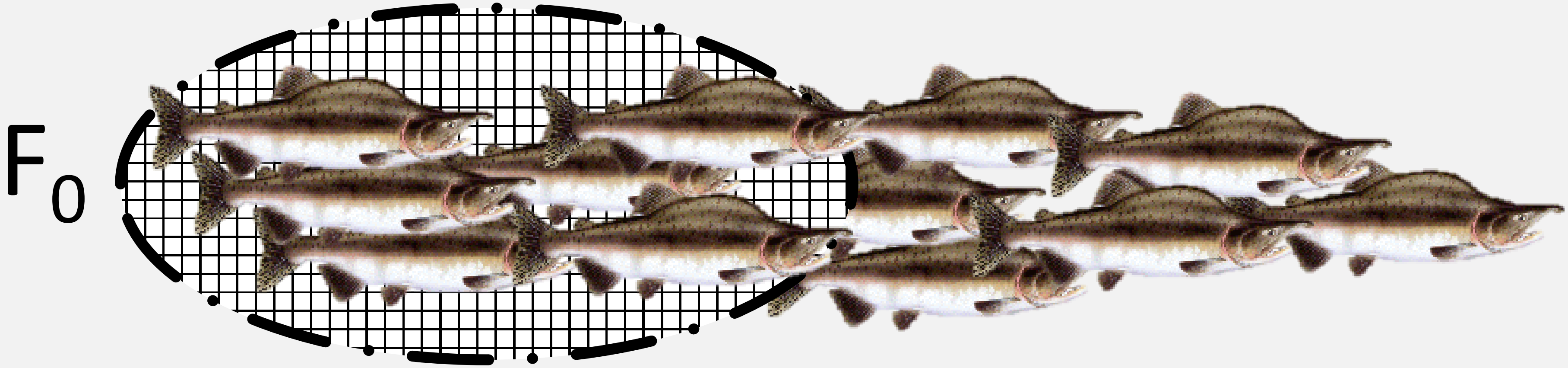

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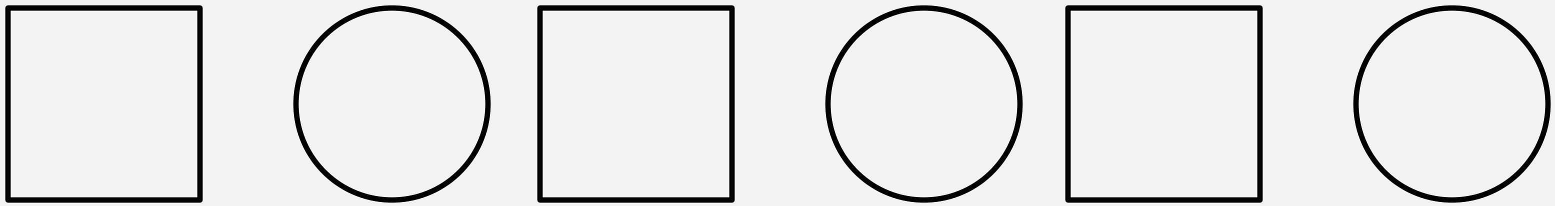

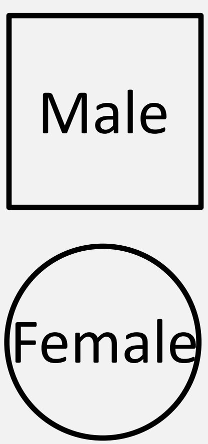

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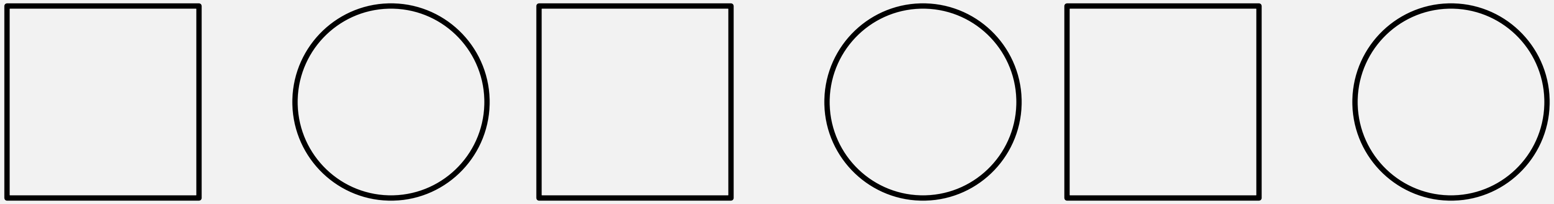

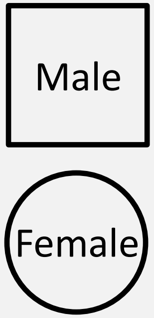

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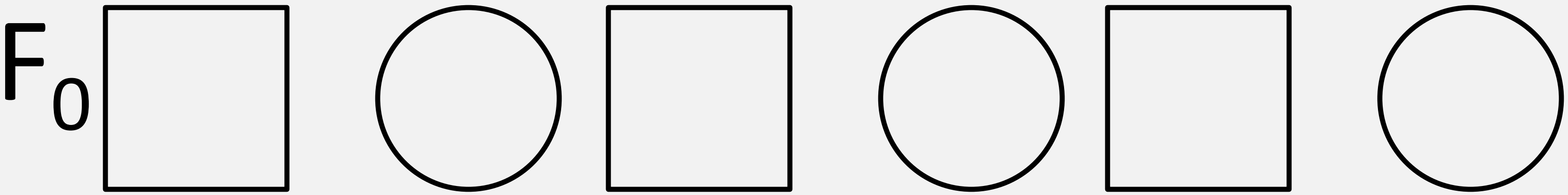

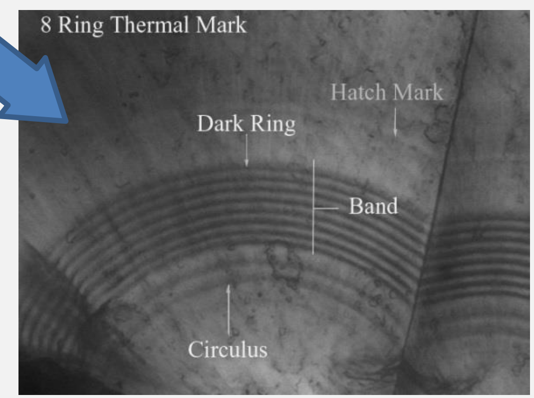

Hatchery-origin

Male

Female

How to measure RS?

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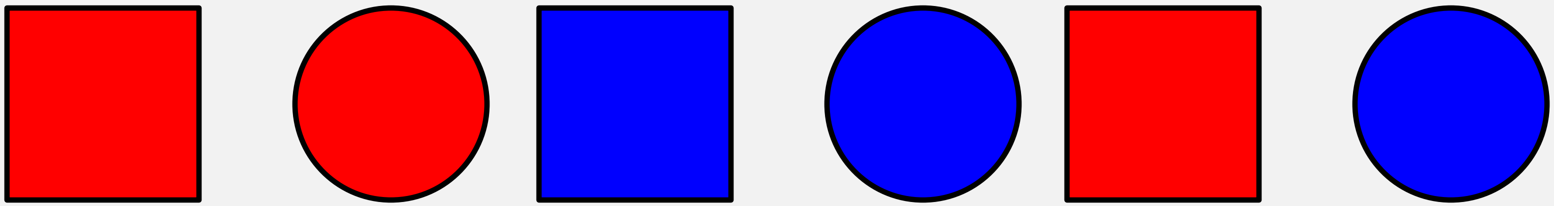

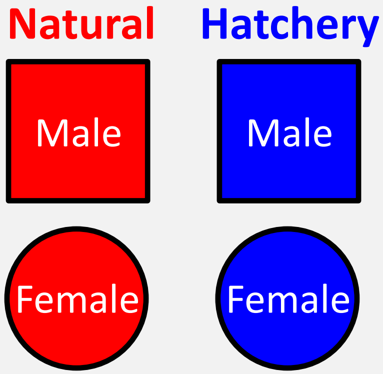

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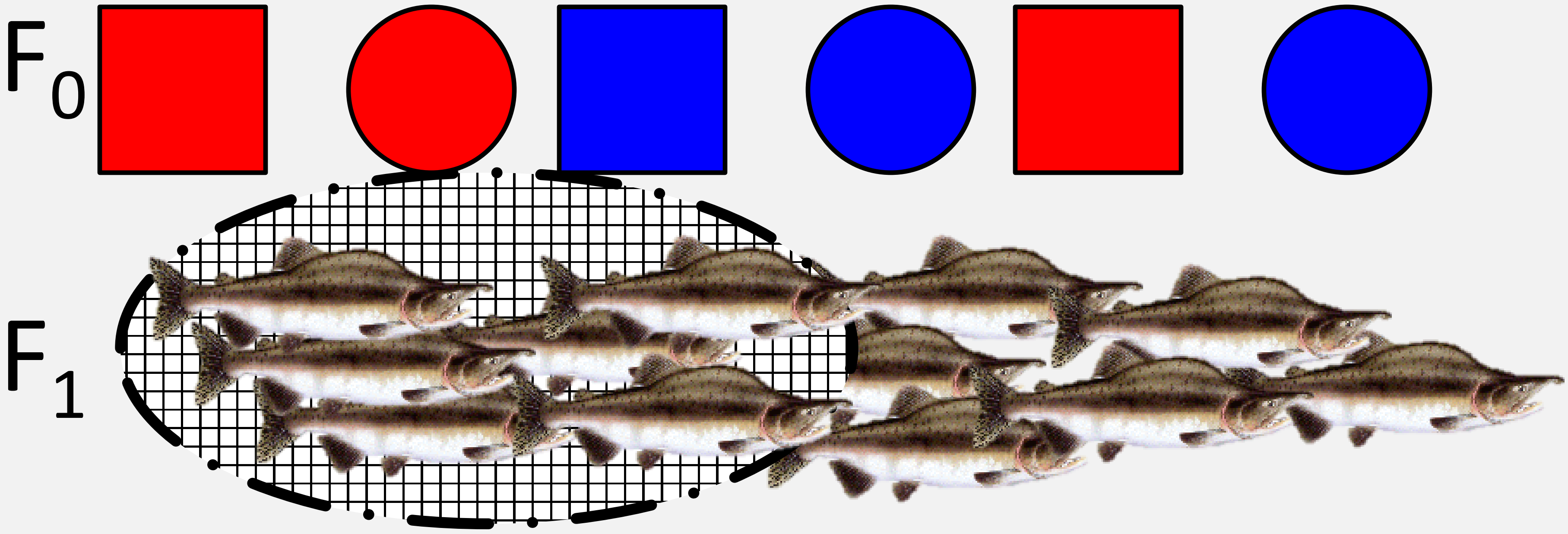

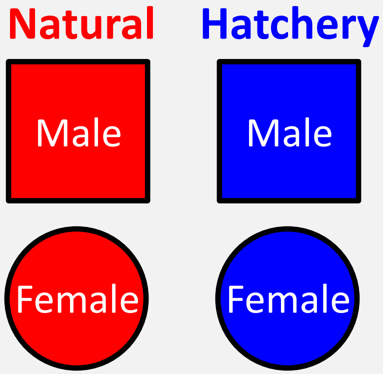

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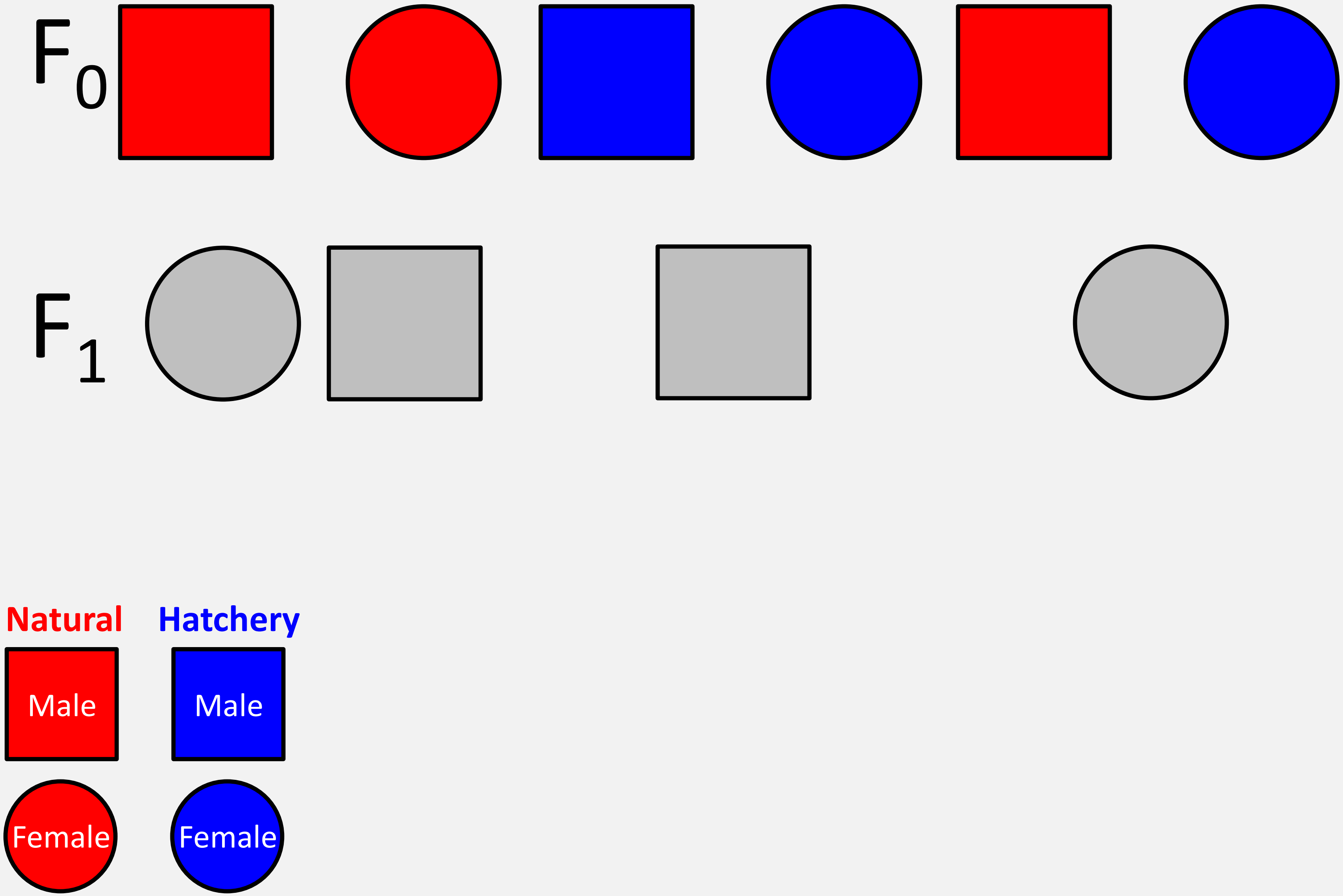

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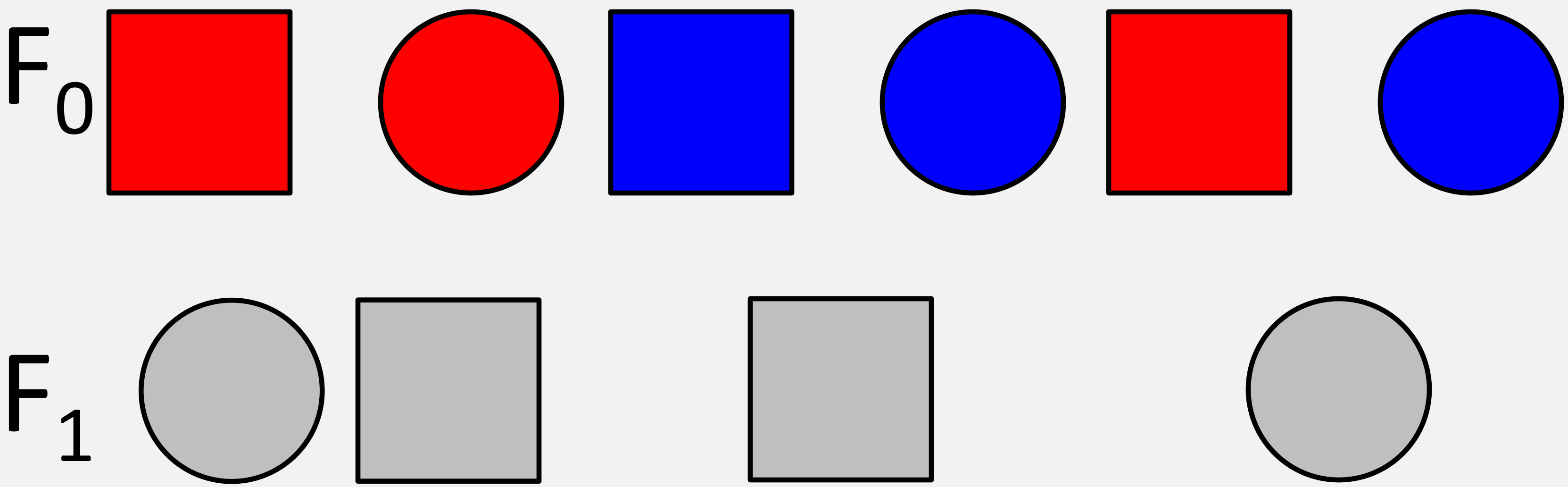
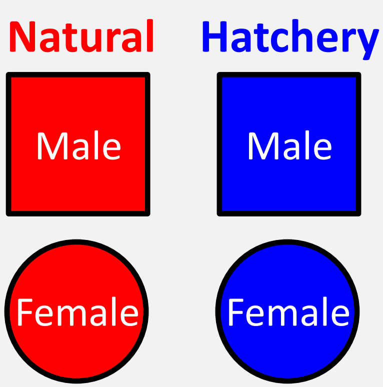
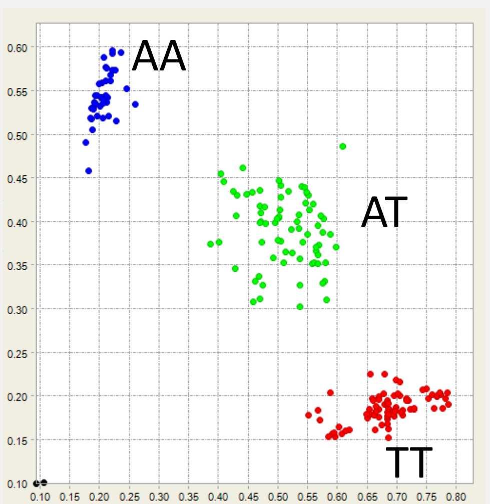




96
SNPs



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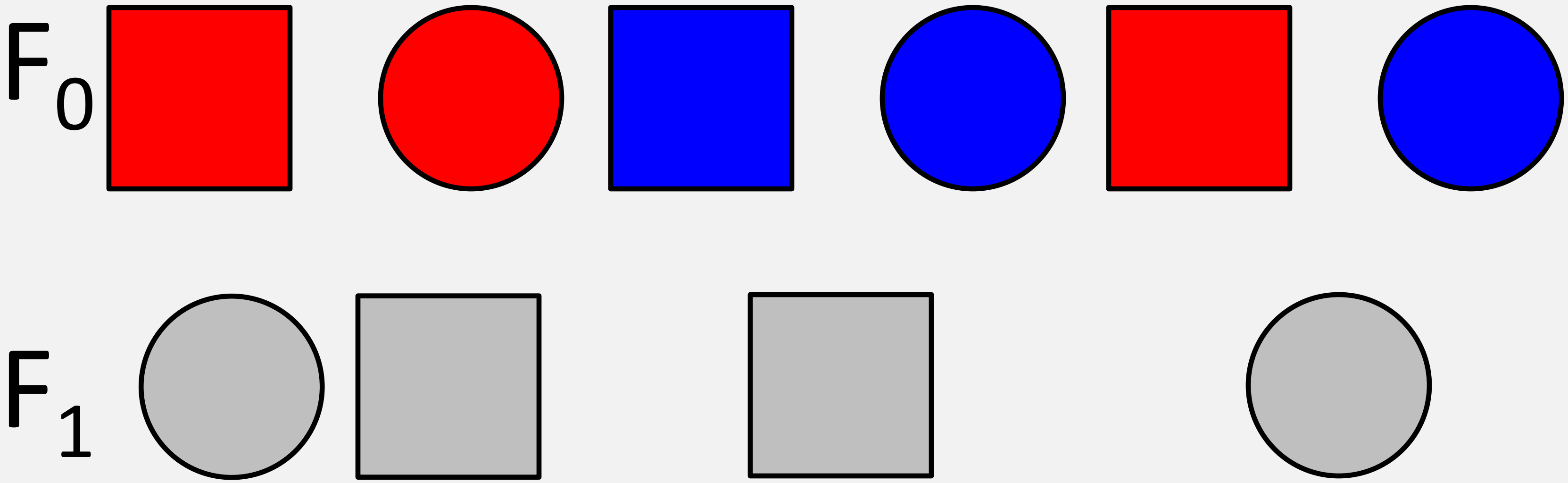

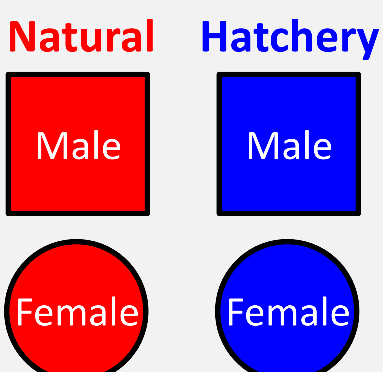

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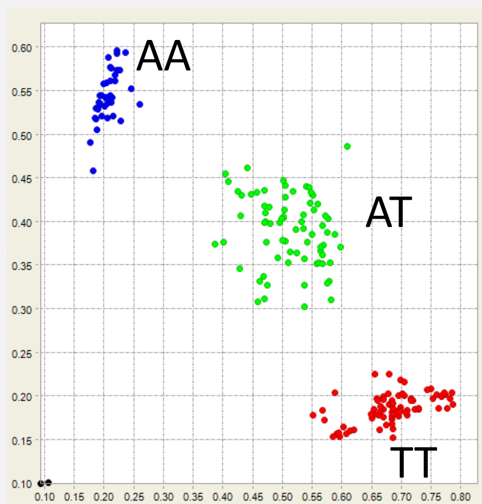

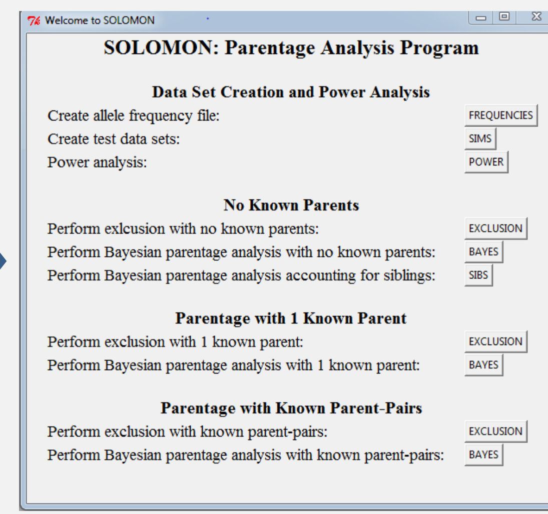

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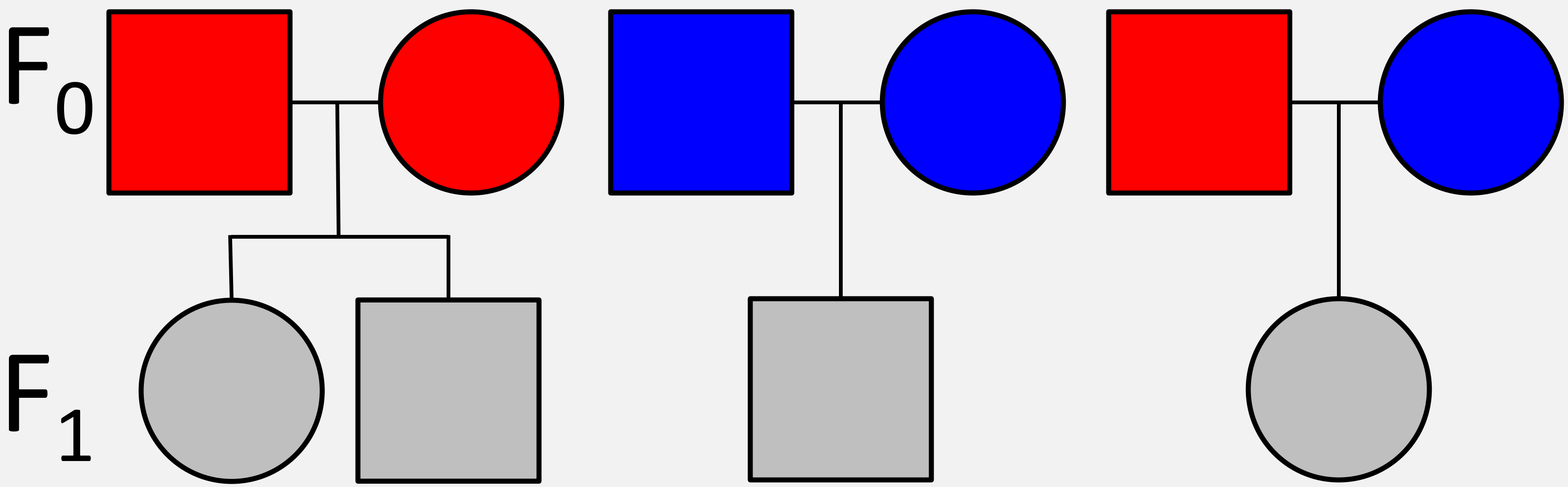

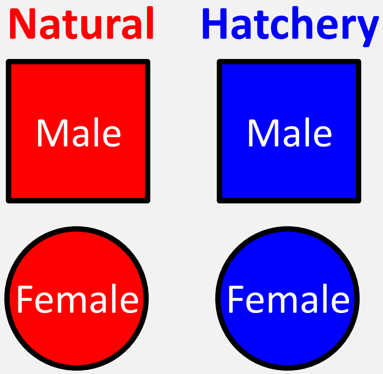

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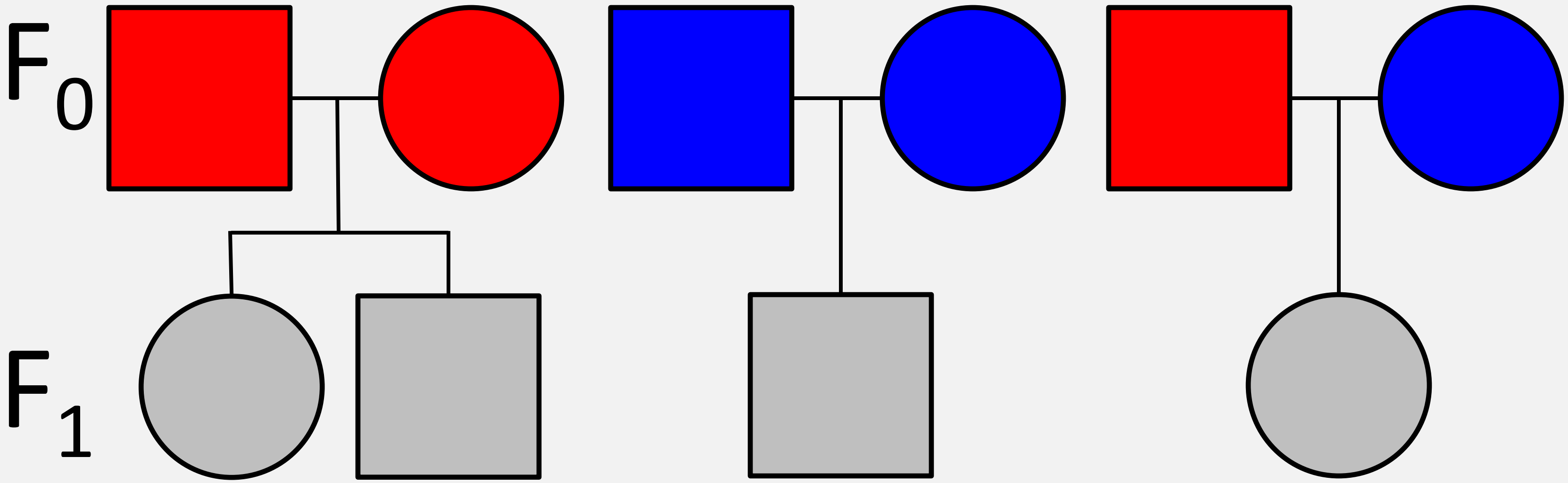
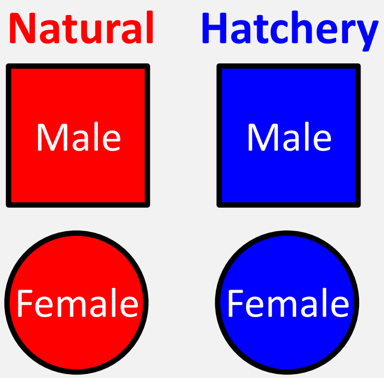
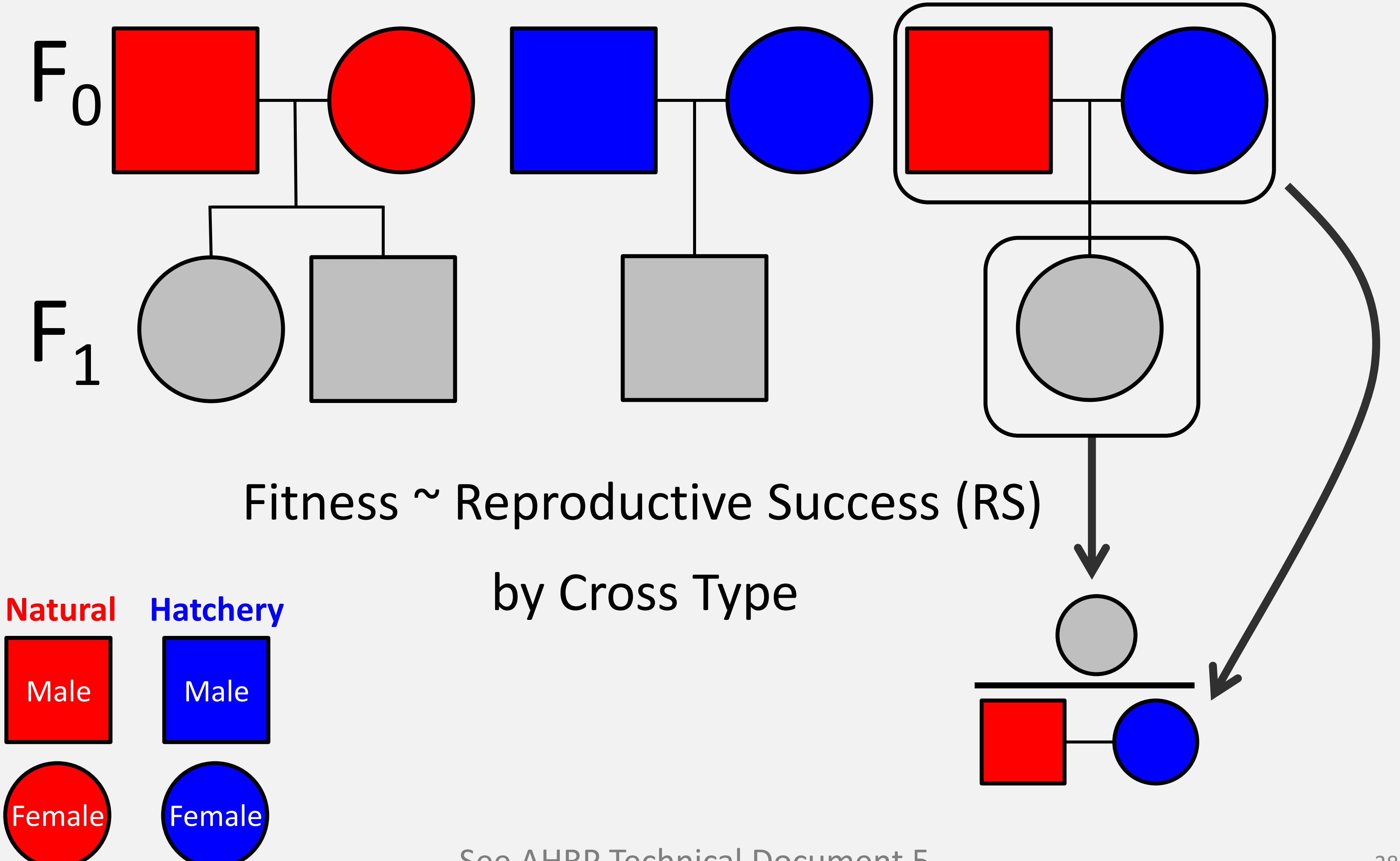


Fitness ~ Reproductive Success (RS)



How to measure RS?

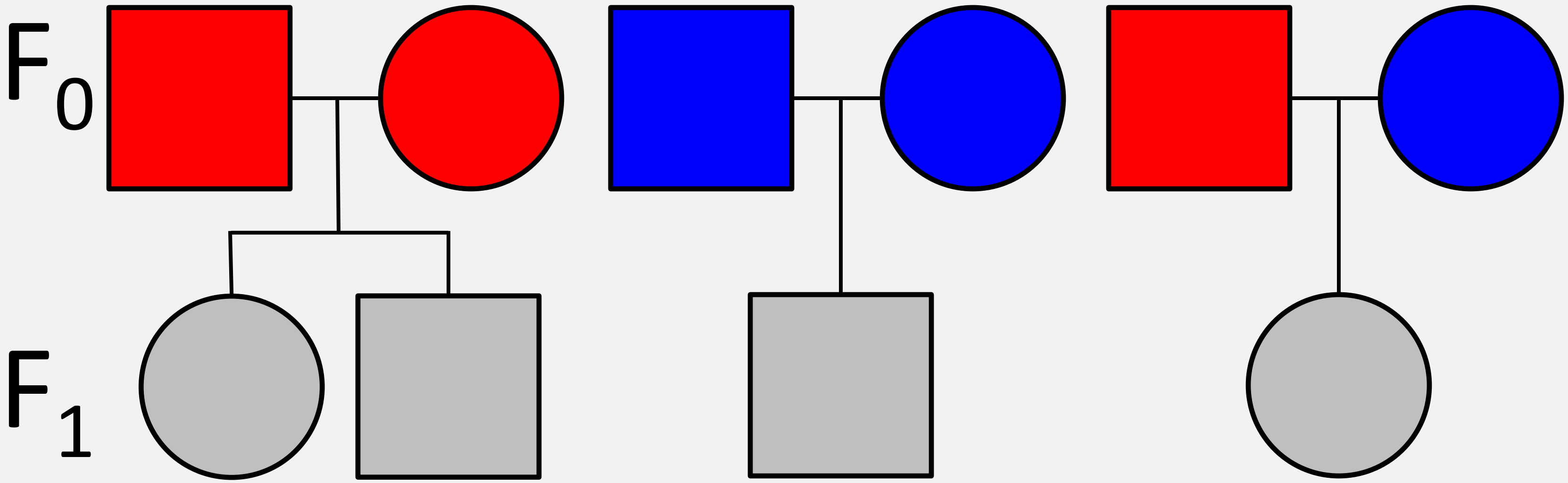


Fitness ~ Reproductive Success (RS)

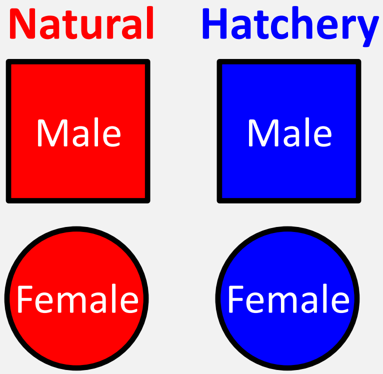
by Cross Type

See AHRP Technical Document 5

How to measure RS?

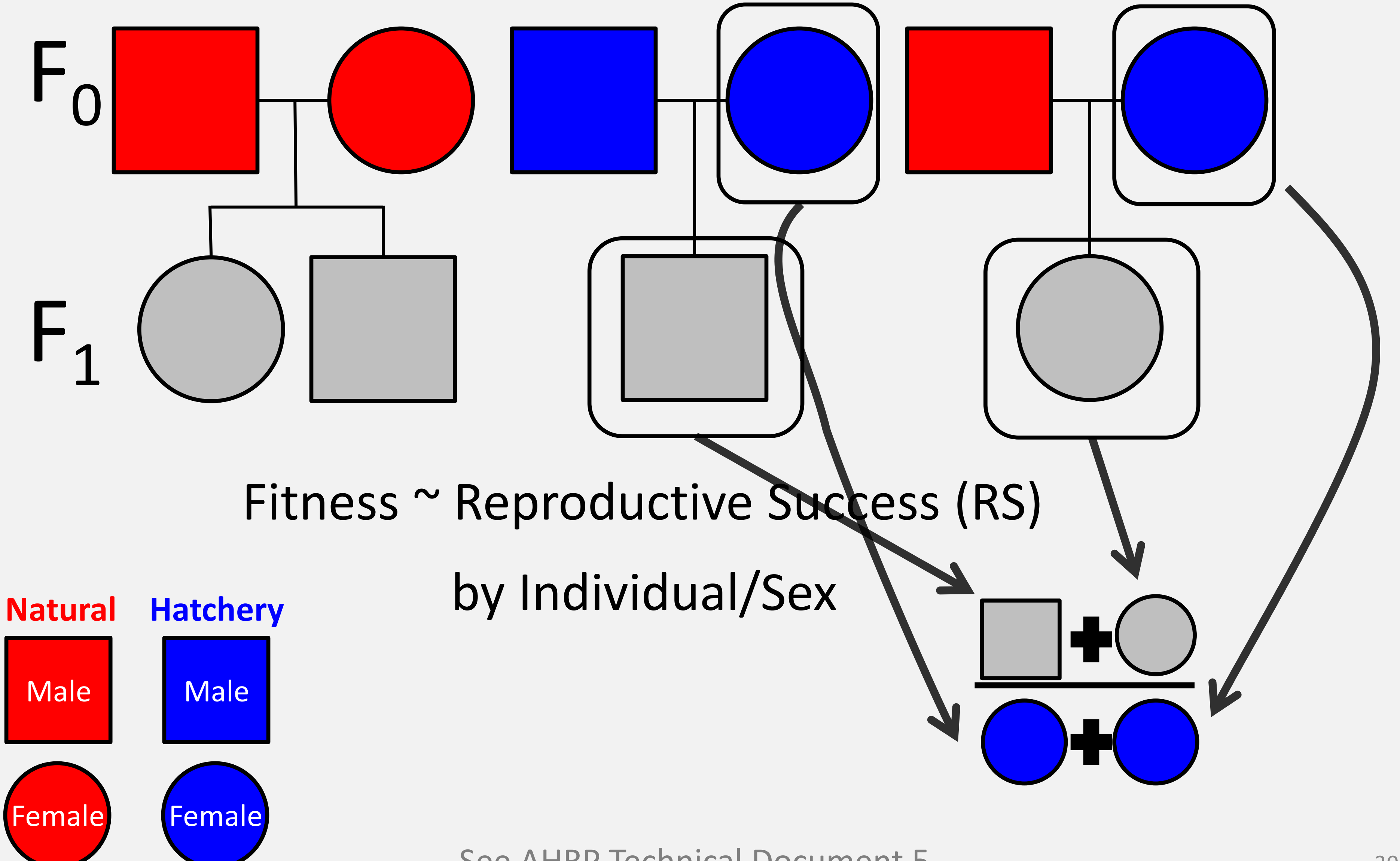


$RS_{N/N} = 2$ $RS_{H/H} = 1$ $RS_{H/N} = 1$



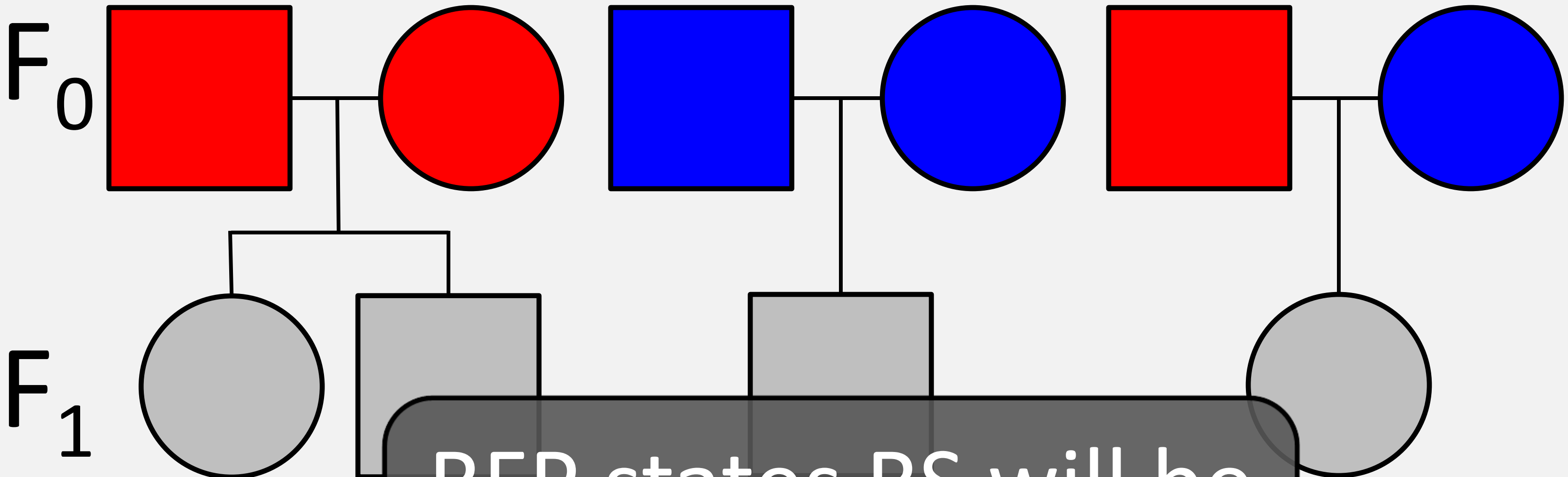
See AHRP Technical Document 5

How to measure RS?



See AHRP Technical Document 5

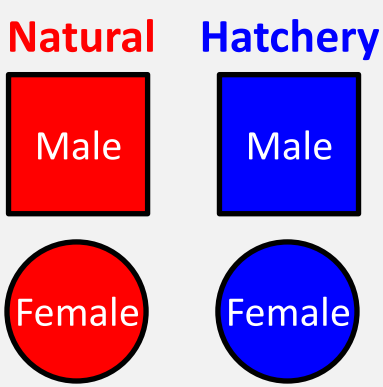
How to measure RS?



RFP states RS will be determined by sex

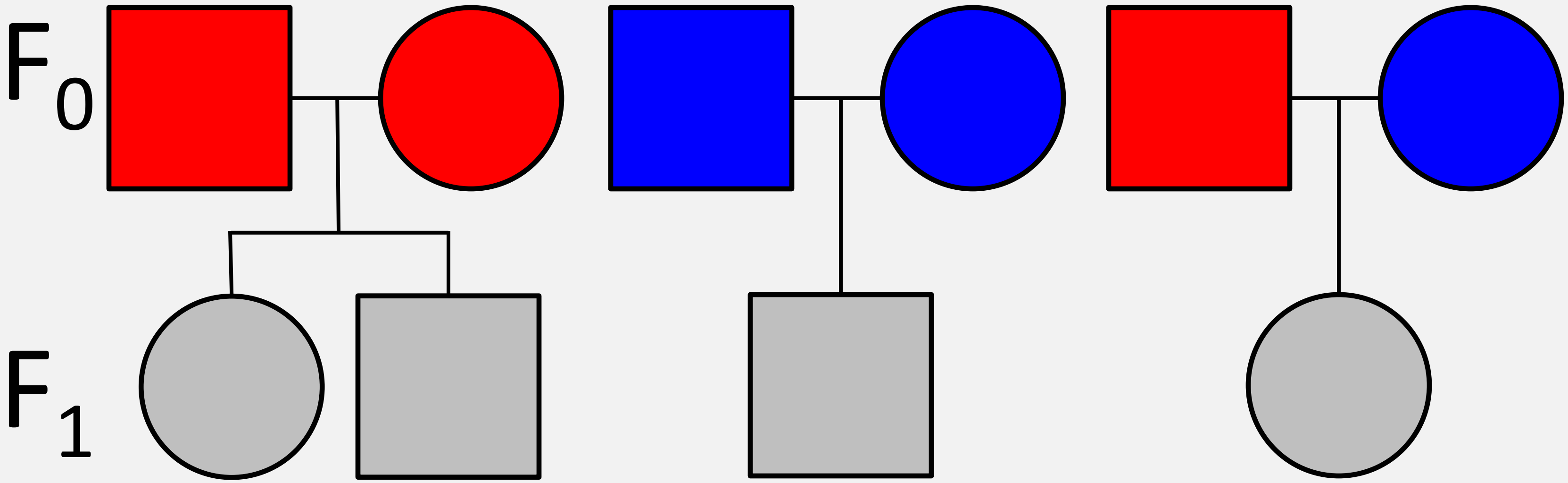
$RS_{N\ Female} = 2$ $RS_{H\ Female} = 1$

$RS_{N\ Male} = 1.5$ $RS_{H\ Male} = 1$

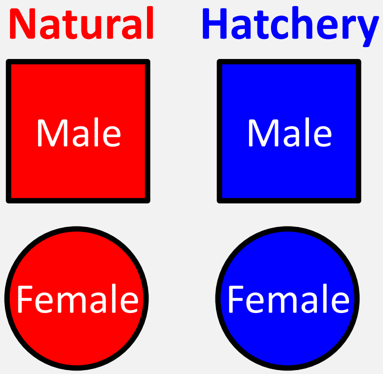


See AHRP Technical Document 5

How to measure RS?



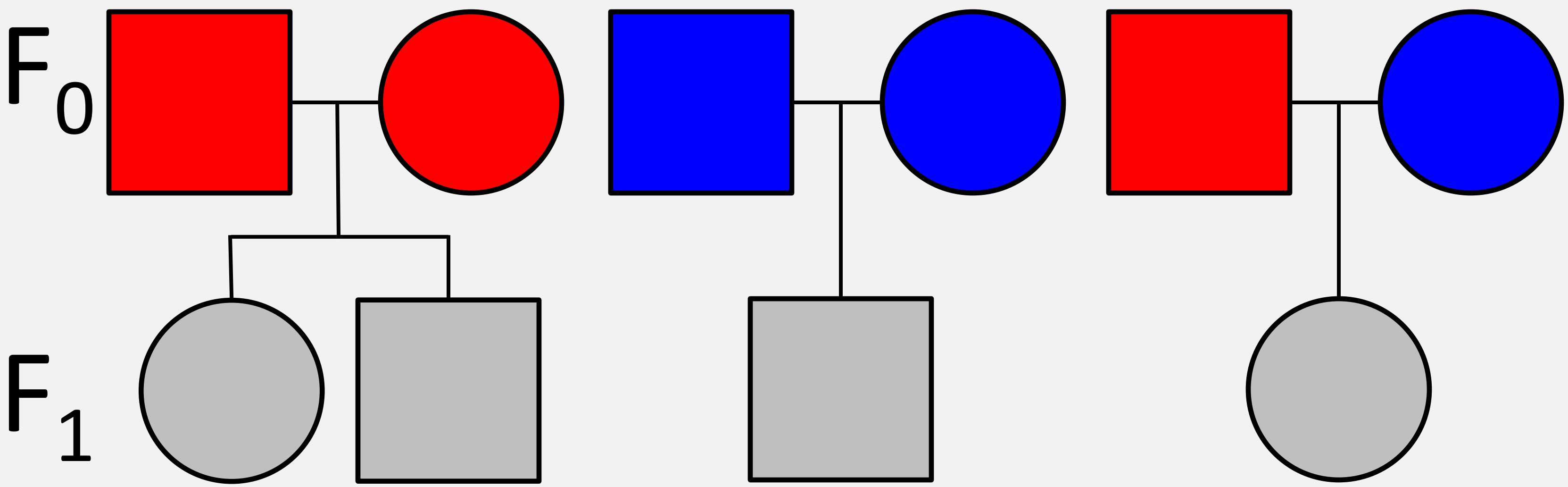
Fitness ~ Reproductive Success (RS)



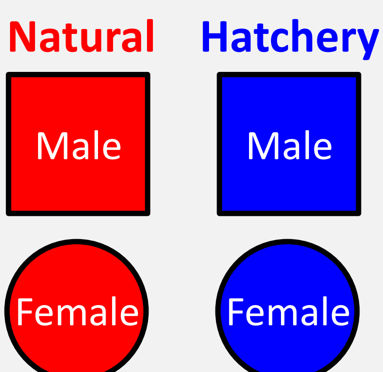
Relative Reproductive Success (RRS)

See AHRP Technical Document 5

How to measure RS?



Fitness ~ Reproductive Success (RS)



Relative Reproductive Success (RRS)

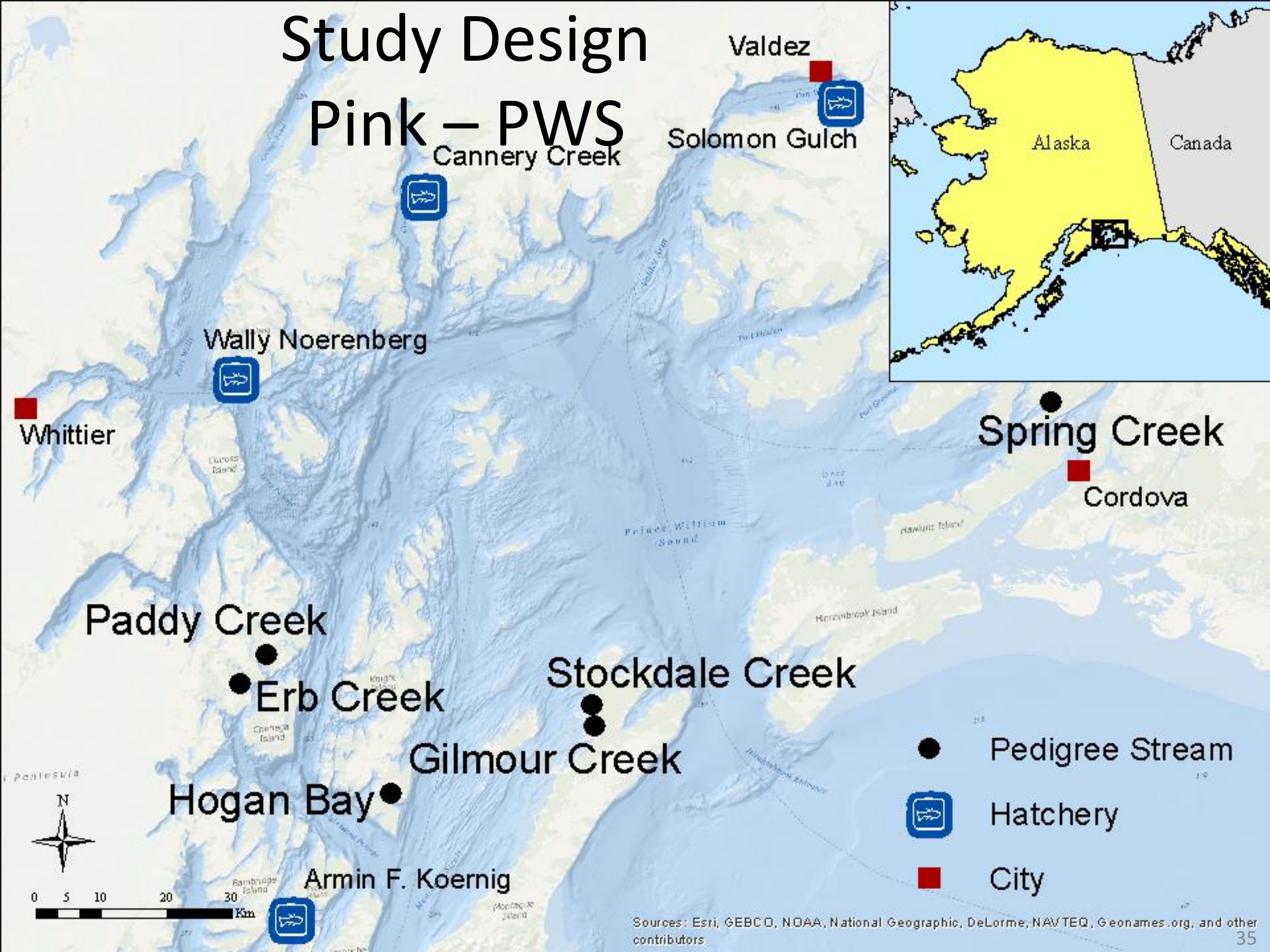
$$\mathbf{RRS} = \frac{\widehat{RS}_{Hatchery}}{\widehat{RS}_{Natural}}$$

See AHRP Technical Document 5

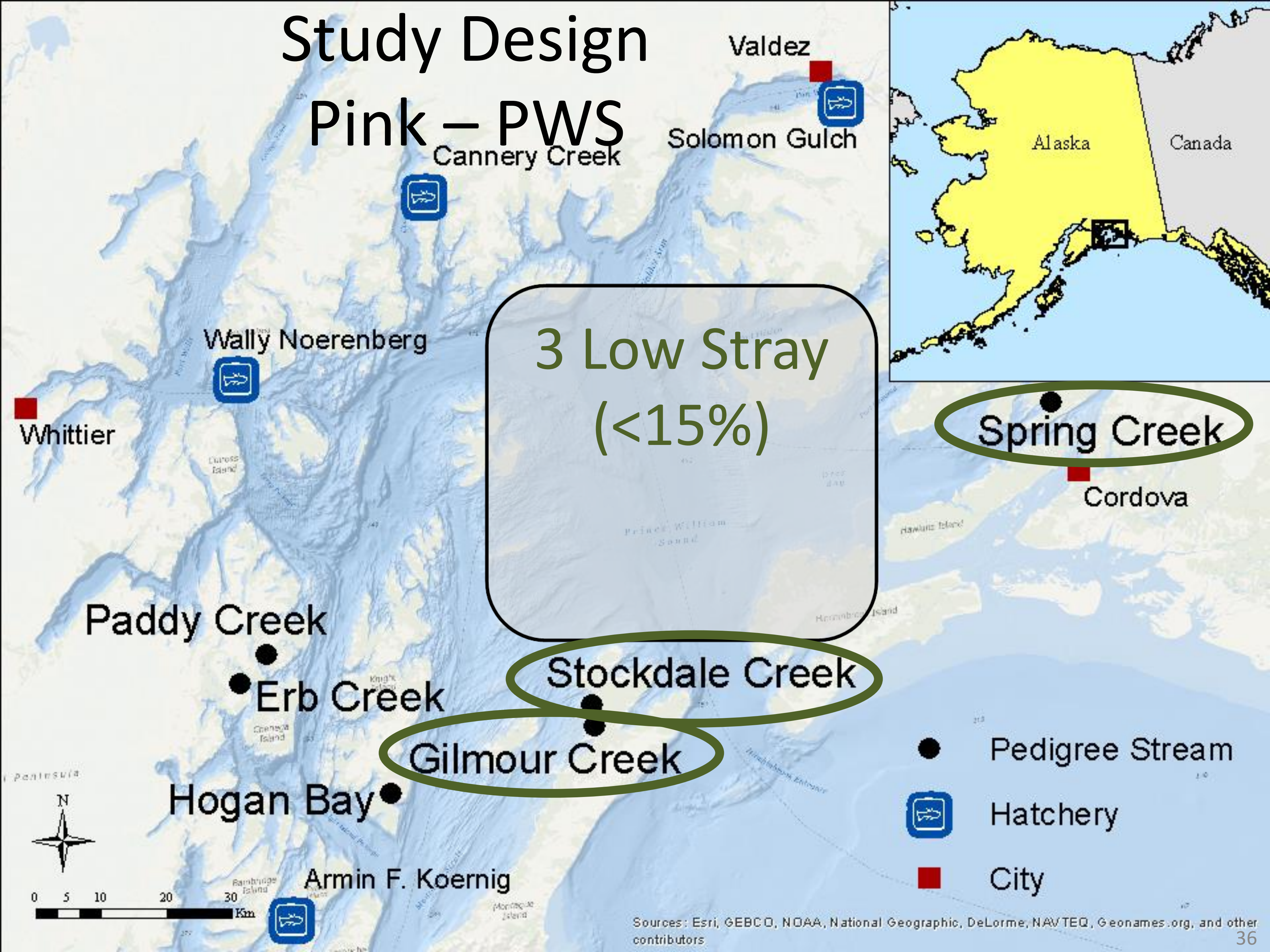
Outline

- Background of AHRP
- Parentage and RRS
- Proposed study design
- Simulations
- Power analysis
- Christie et al. 2014 review

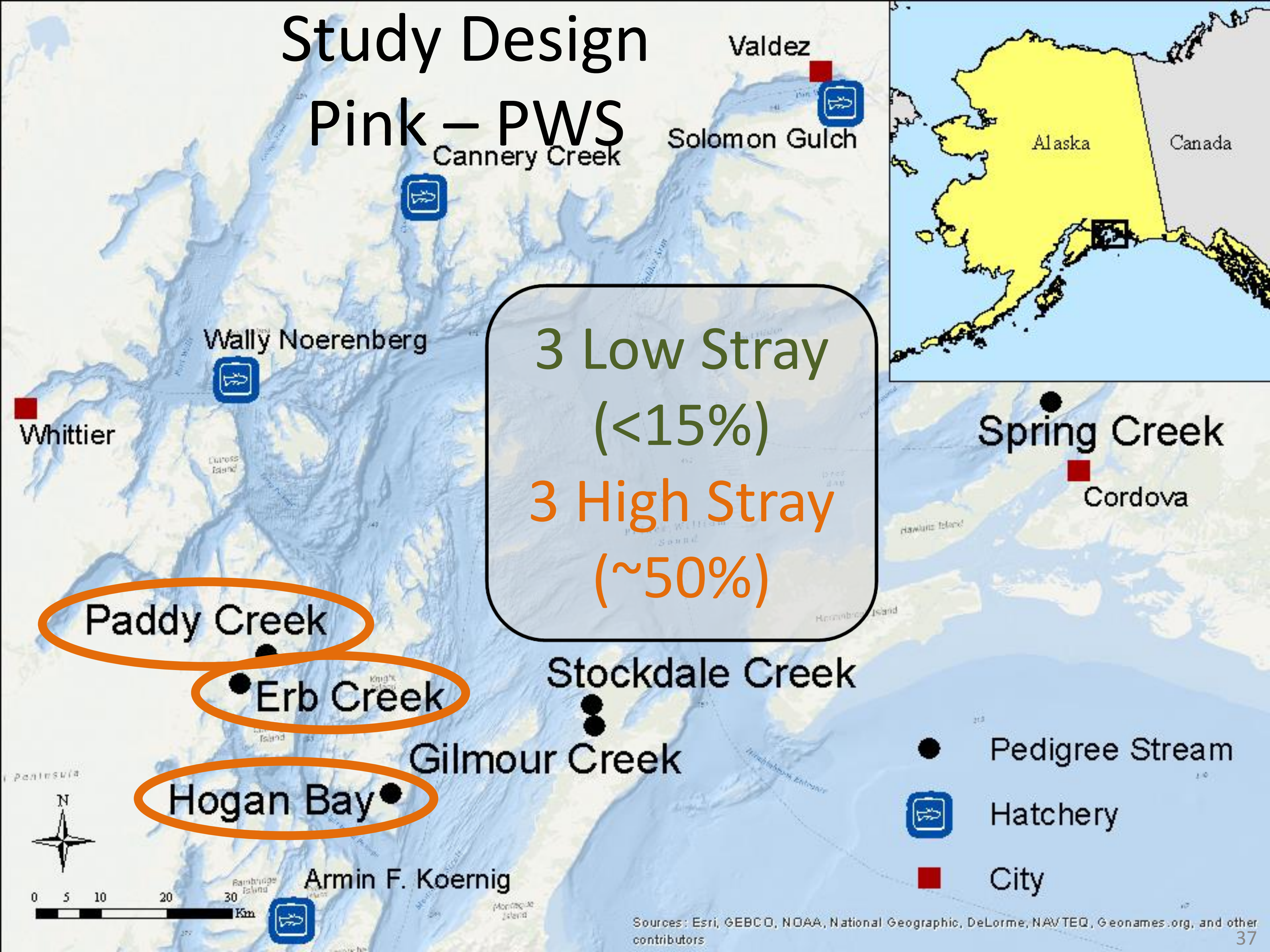
Study Design
Pink – PWS



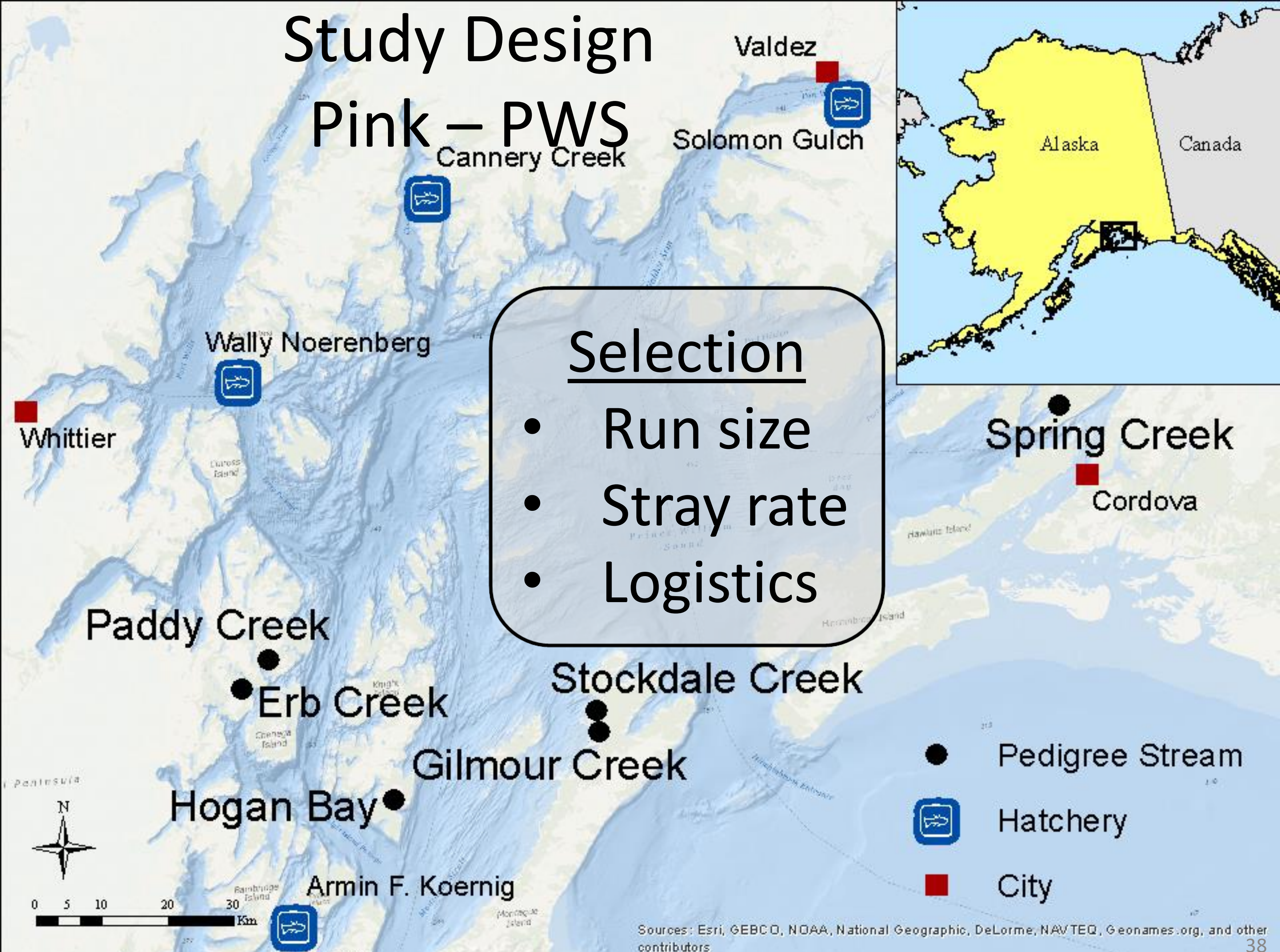
Study Design
Pink – PWS



Study Design
Pink – PWS



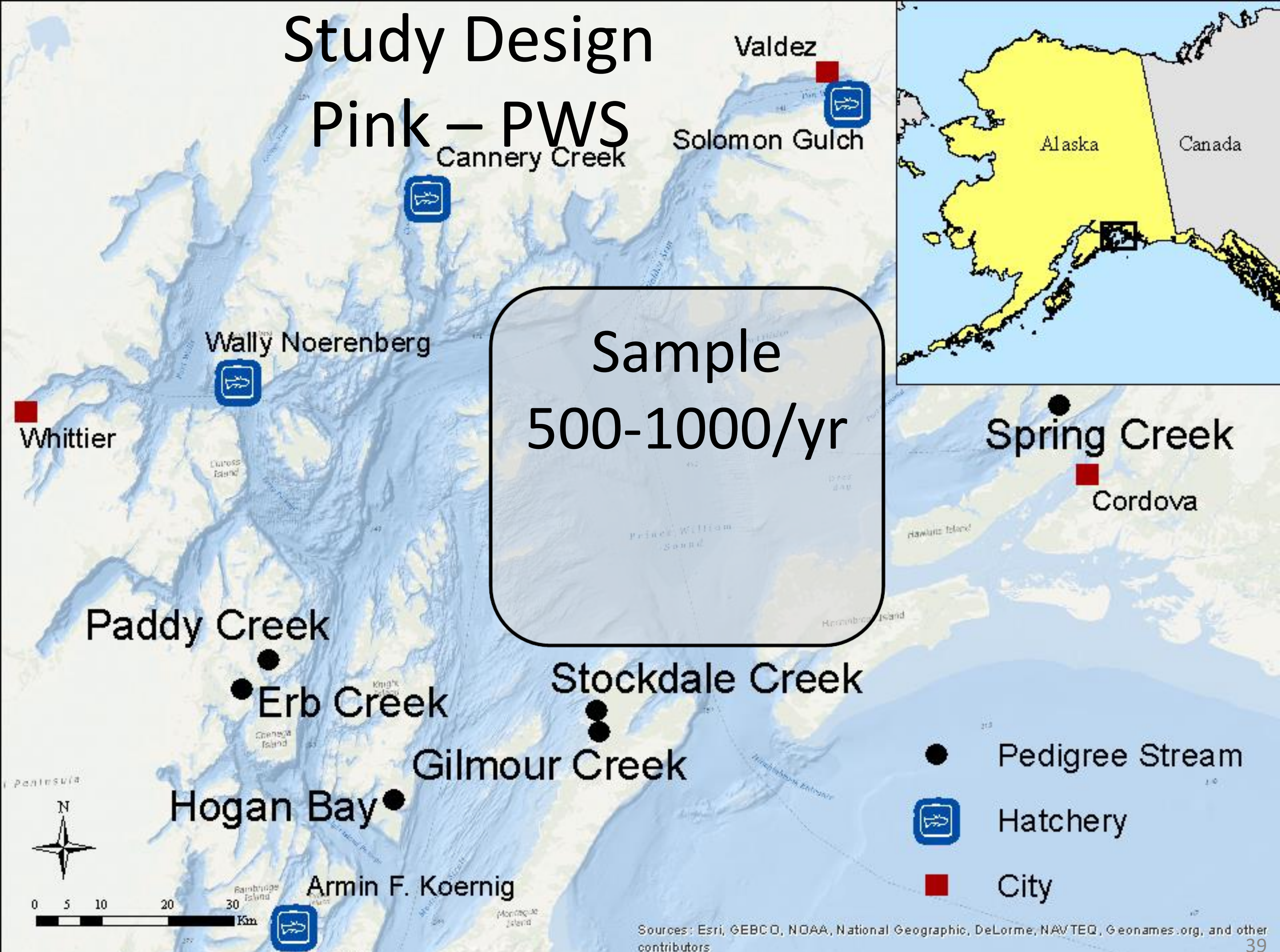
Study Design
Pink – PWS



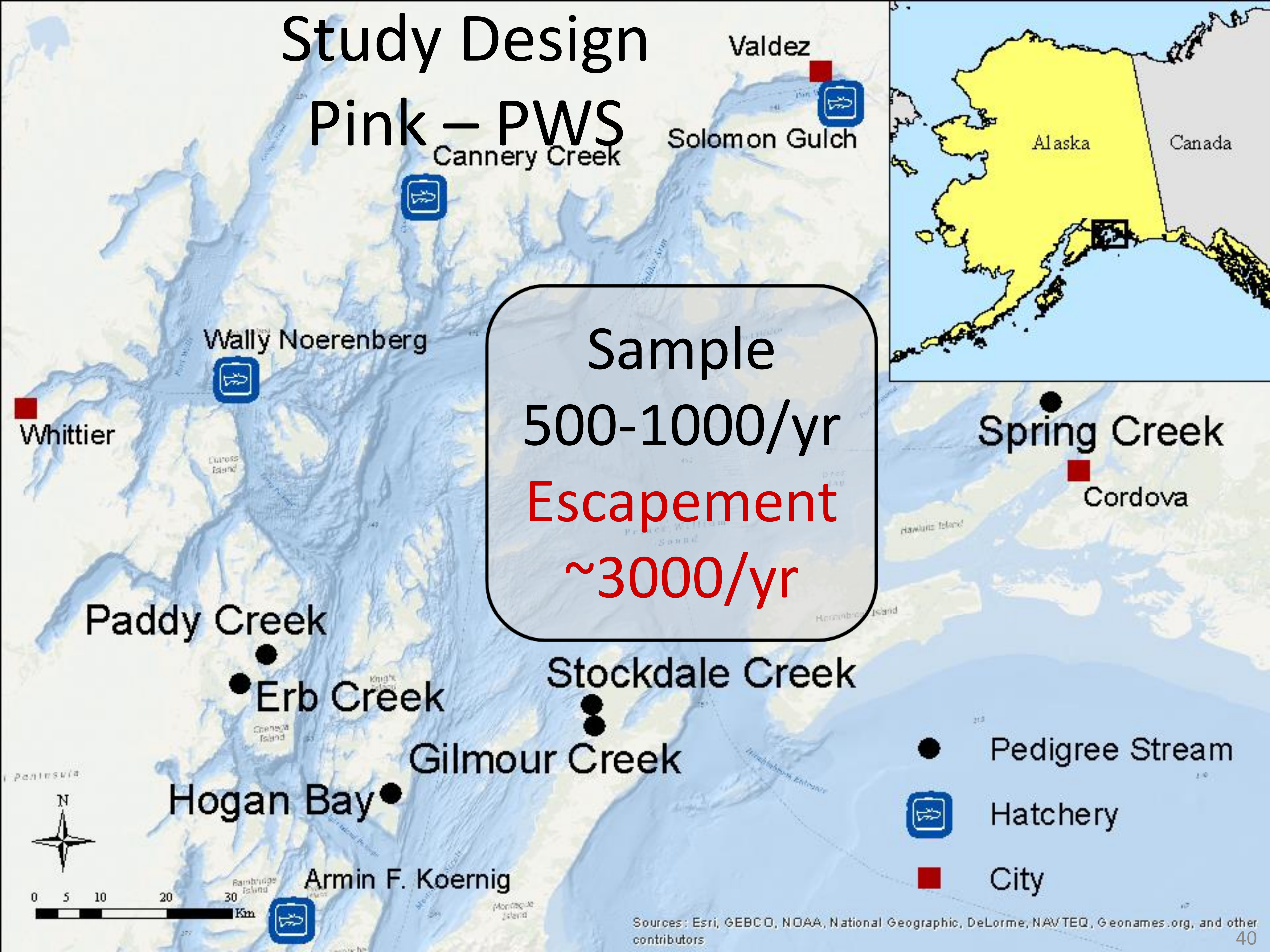
Selection

- Run size
- Stray rate
- Logistics

Study Design
Pink – PWS

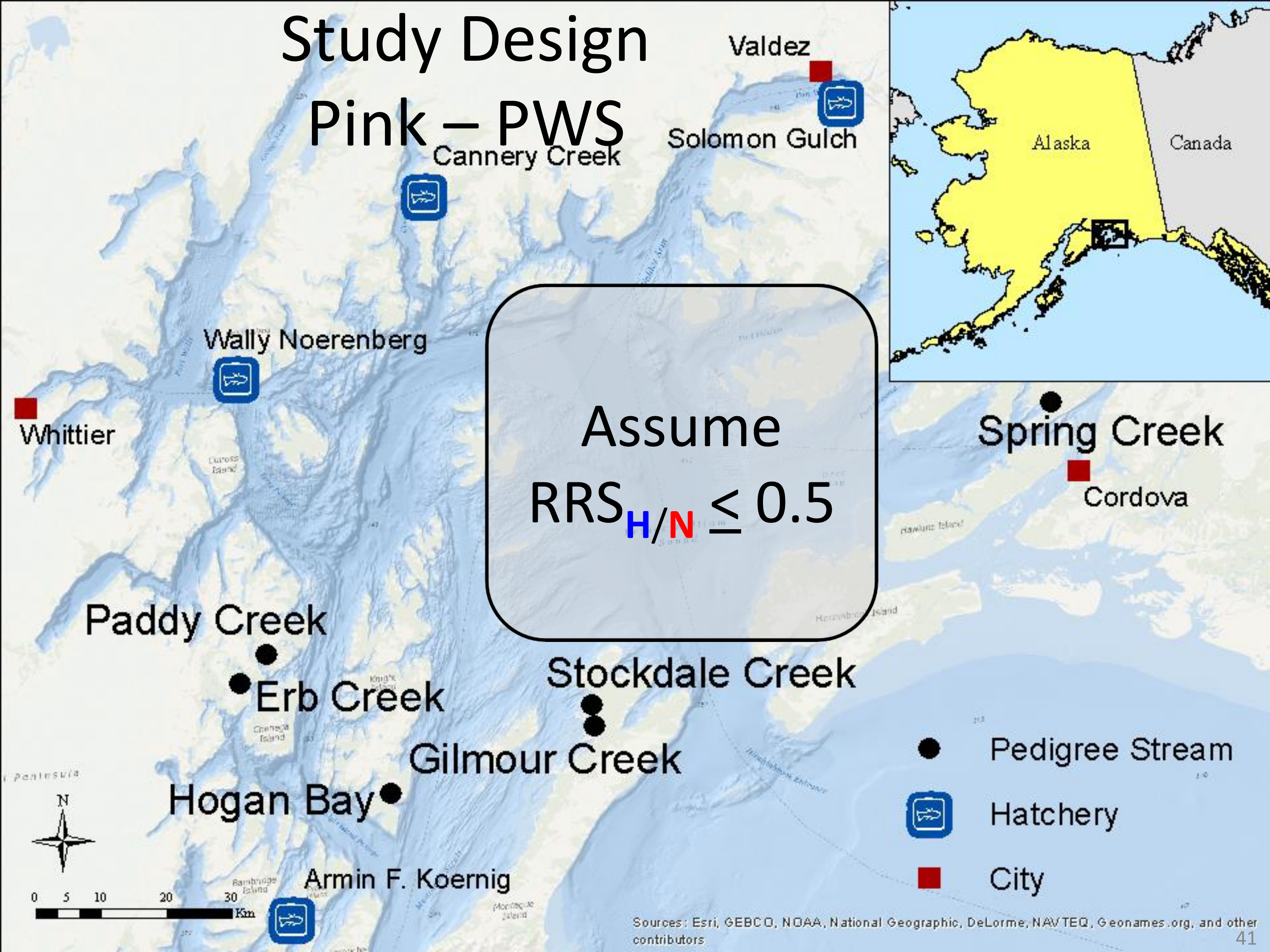


Study Design
Pink – PWS



Sample
500-1000/yr
Escapement
~3000/yr

Study Design
Pink – PWS

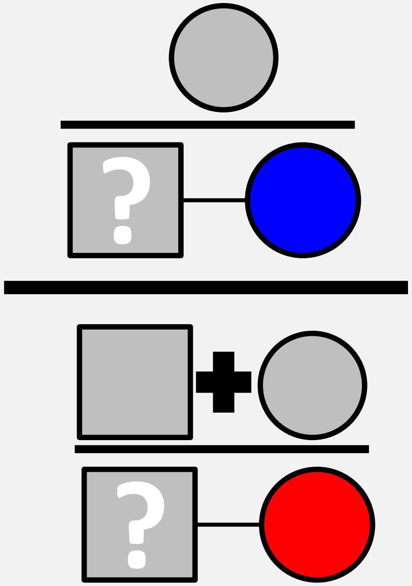


Assume

$RRS_{H/N} \leq 0.5$

RFP Guidelines

- Sampling
  - High stray
    - 500 adults / 3000 escapement = 1/6
  - Low stray
    - 1000 adults / 3000 escapement = 1/3
- RRS measured by sex



Considerations

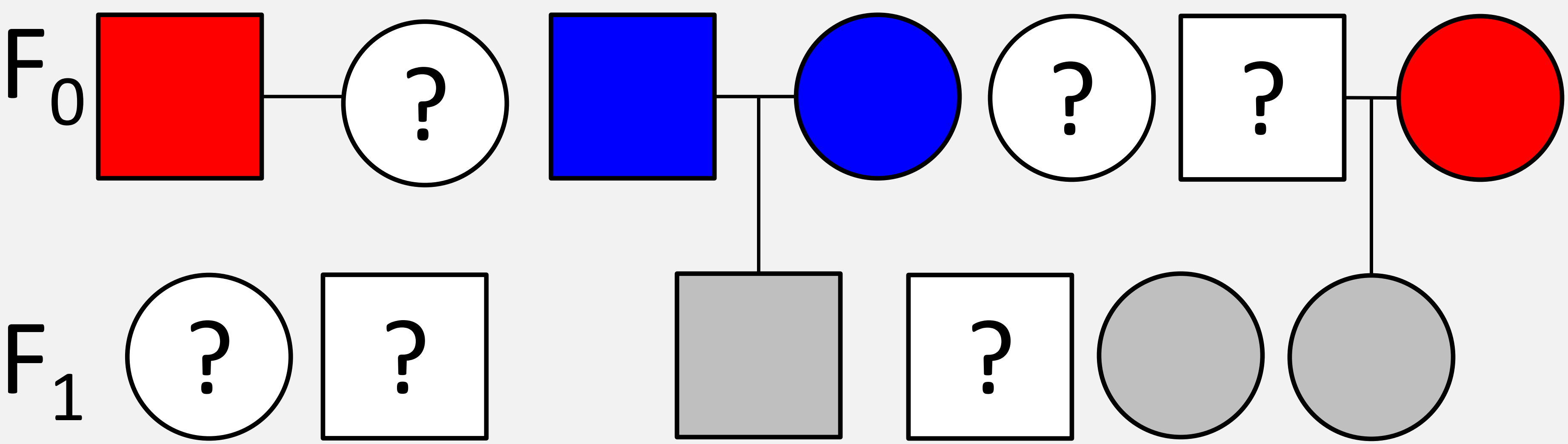
Missing F_0 parents + Missing F_1 offspring = ?

-Araki and Blouin 2005

Considerations

Missing F_0 parents + Missing F_1 offspring = ?

-Araki and Blouin 2005

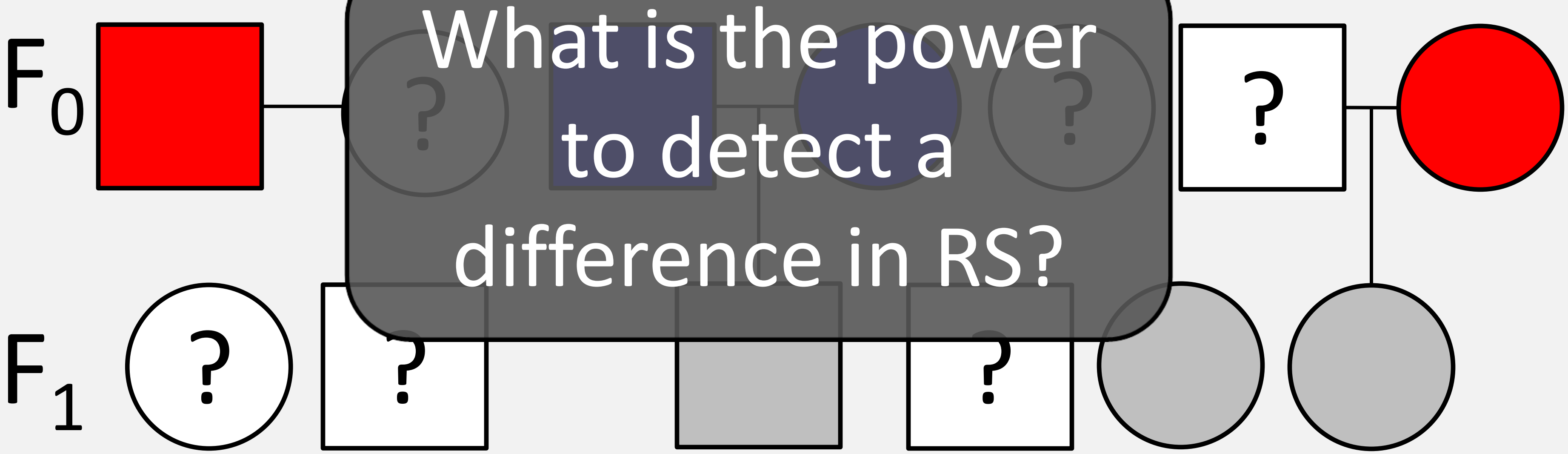


See AHRP Technical Document 4 & 5

Considerations

Missing F_0 parents + Missing F_1 offspring = ?

-Araki and Blouin 2005



What is the power to detect a difference in RS?

See AHRP Technical Document 4 & 5

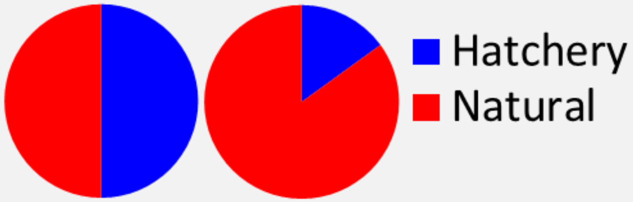
BREAK: Questions so far?

Outline

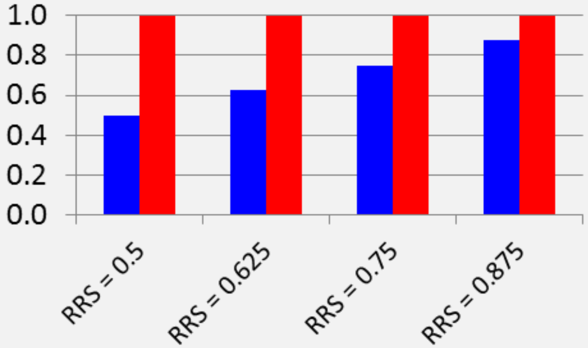
- Background of AHRP
- Parentage and RRS
- Proposed study design
- Simulations
- Power analysis
- Christie et al. 2014 review

Simulation design

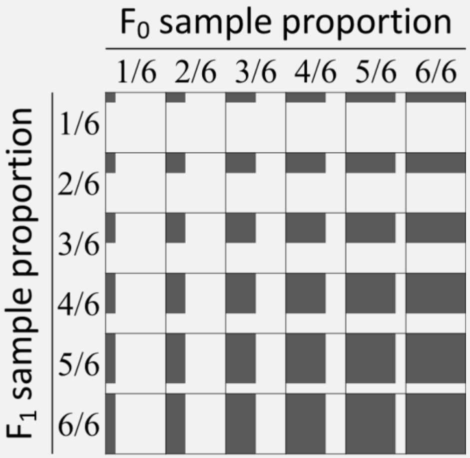
- Stray rate
  - ❖% hatchery-origin in stream
    - ➢high (50%), low (15%)



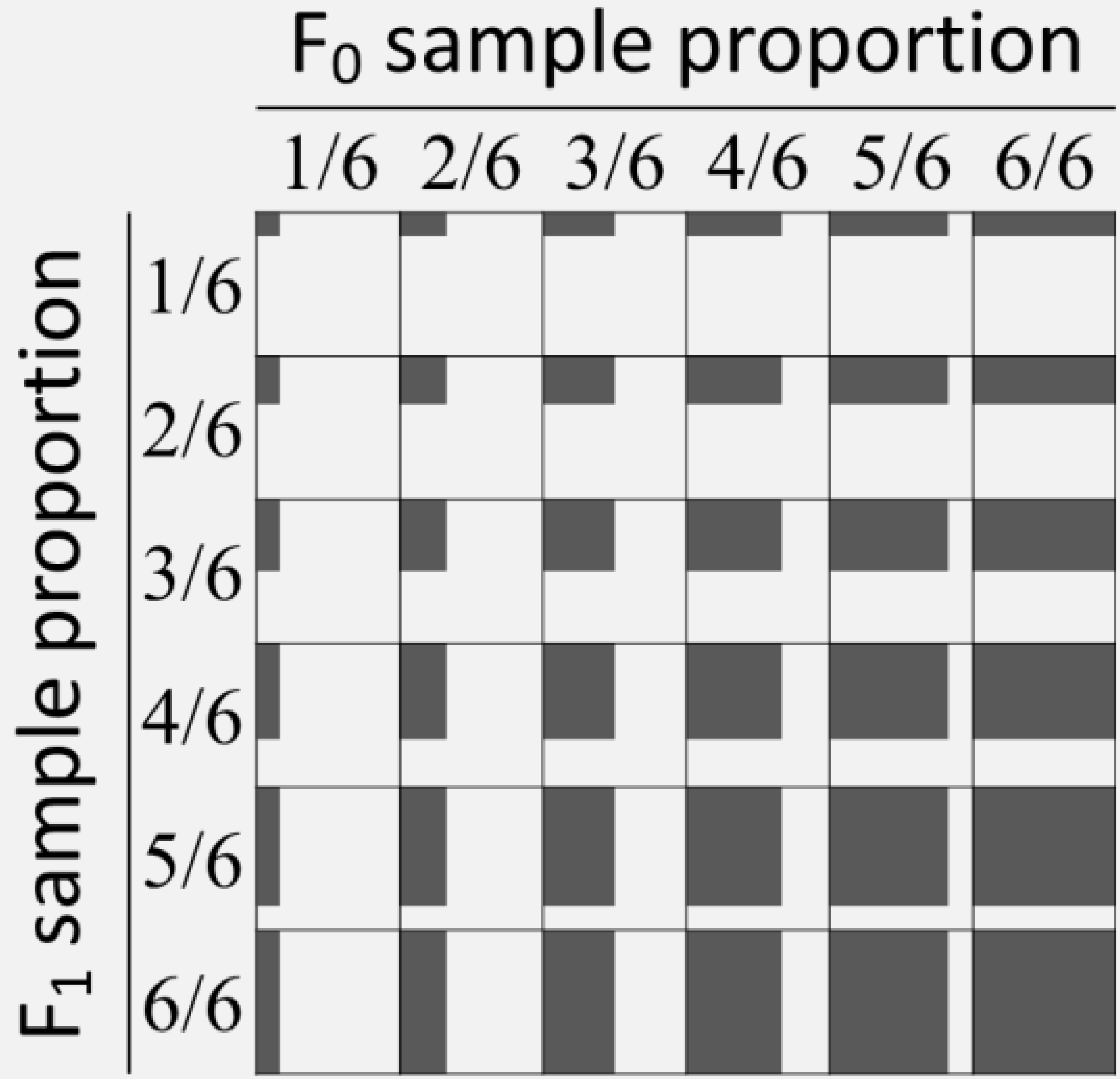
- Effect size
  - ❖RRS_{H/H to N/N}
    - ➢0.5 to 0.875



- Proportion of population sampled
  - ❖Adults <u>and</u> offspring
    - ➢1/6 to 1



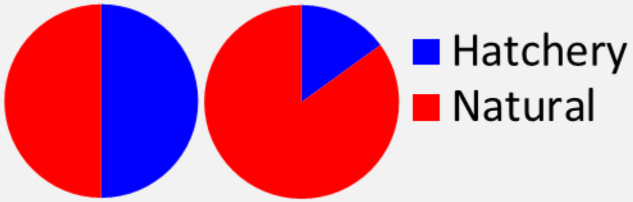
See AHRP Technical Document 5



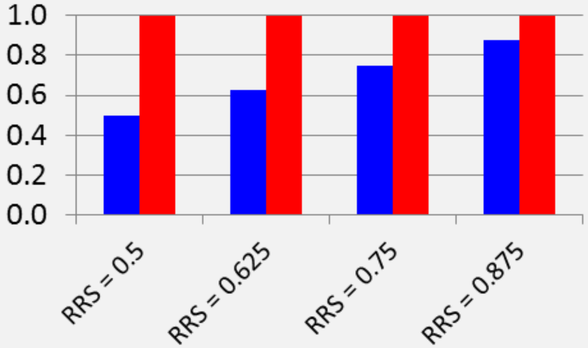
See AHRP Technical Document 5

Simulation design

- Stray rate
  - ❖% hatchery-origin in stream
    - ➢high (50%), low (15%)



- Effect size
  - ❖$RRS_{H/H \text{ to } N/N}$
    - ➢0.5 to 0.875



- Proportion of population sampled
  - ❖Adults <u>and</u> offspring
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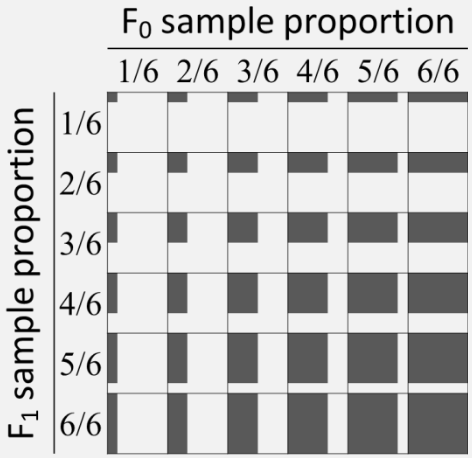


288 simulated data sets for parentage

See AHRP Technical Document 5

Hatchery

Natural

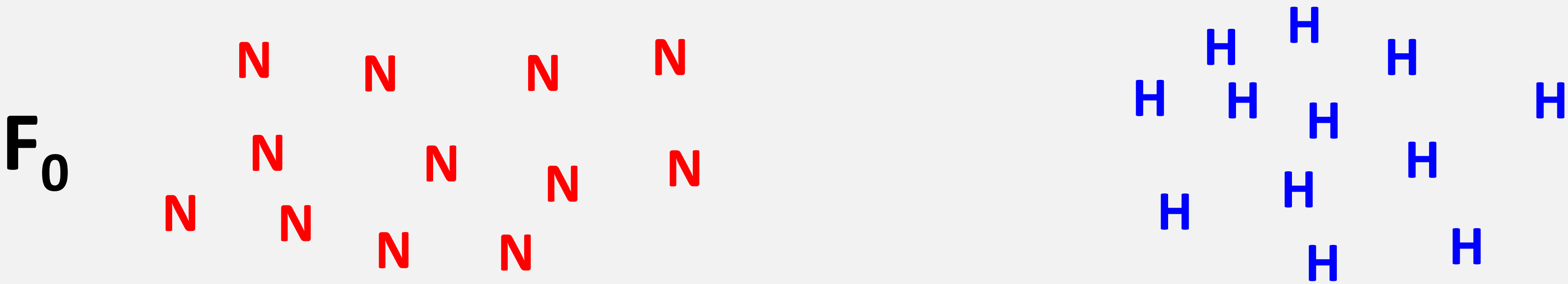
Simulation design

See AHRP Technical Document 5

Simulation design

Hatchery

Natural



See AHRP Technical Document 5

Simulation design

Hatchery

Natural

F_0

N N N N N N N N N N N N N

H H H H H H H H H H H H H

Mating

NxN NxN NxN NxH NxH NxH HxN HxN HxN HxH HxH HxH

See AHRP Technical Document 5

Simulation design

Hatchery

Natural

F_0

N N N N N N N N N N N N N

H H H H H H H H H H H H H

Mating

NxN NxN NxN NxH NxH HxN HxN HxN NxH HxH HxH HxH

$\# F_1$

2 3 1 0 1 4 3 2 2 4 0 2

See AHRP Technical Document 5

Simulation design

Hatchery

Natural

F_0

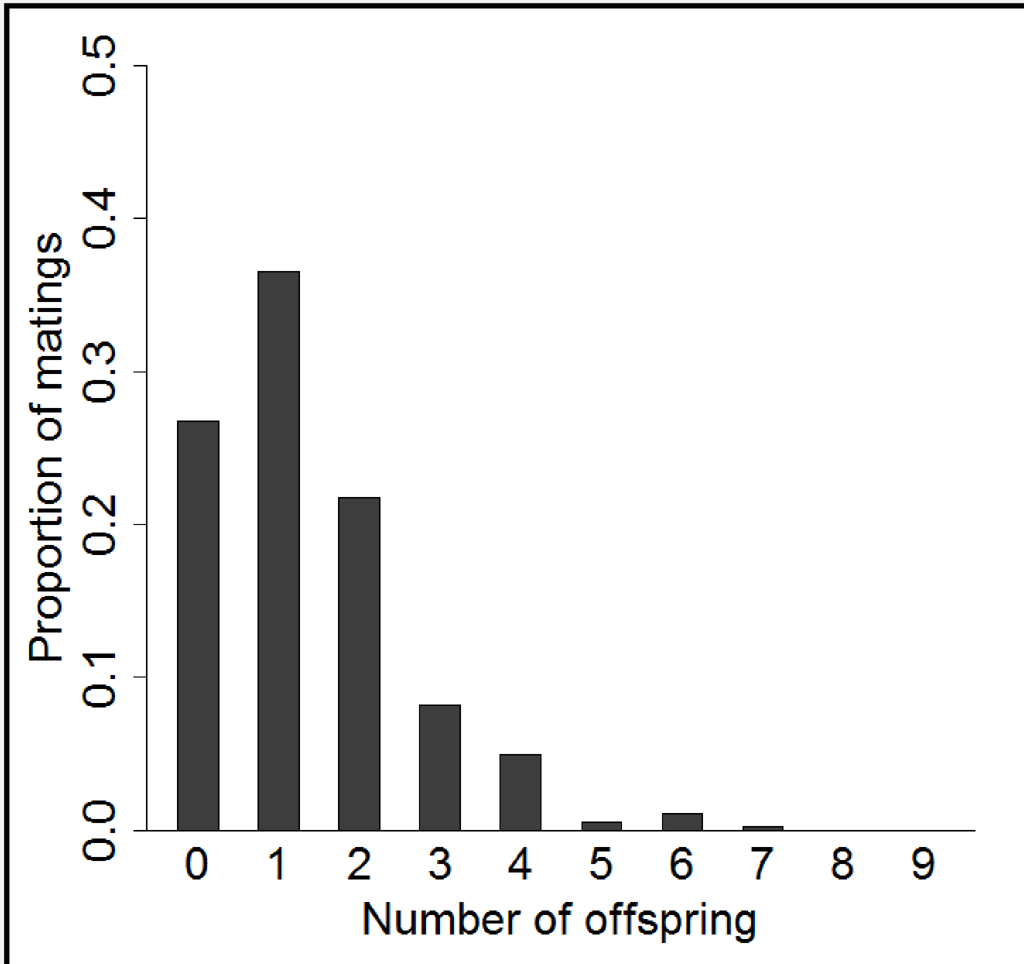
N N N N

H H H H H H H H H

Mating

NxN NxN

HxH HxH HxH



F_1

2 1 0 2 4 0

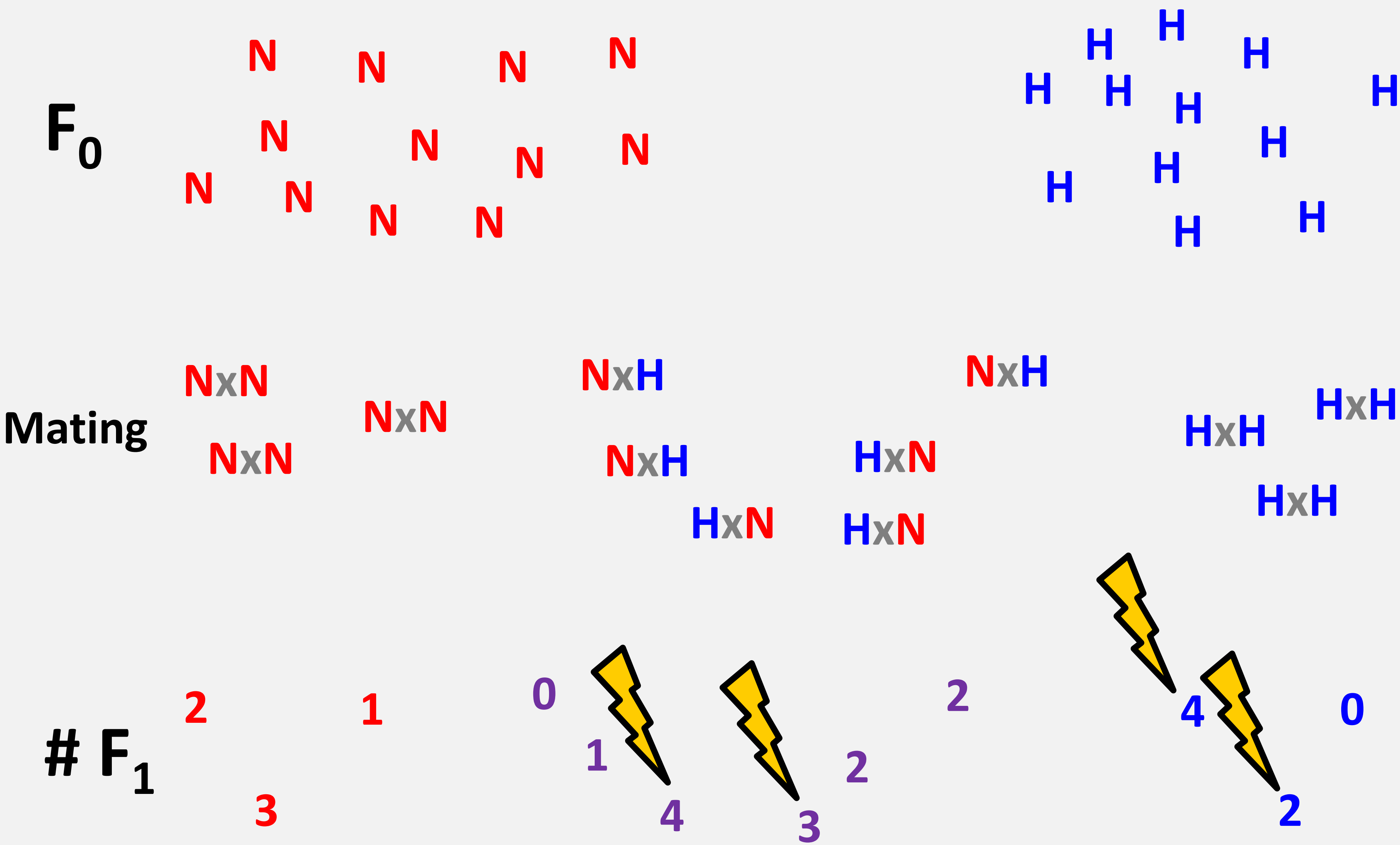
3 1 4 3 2 2

See AHRP Technical Document 5

Hatchery

Natural

Simulation design



Simulation design

Hatchery

Natural

F_0

N N N N N N N N N N N N N

H H H H H H H H H H H H H

Mating

NxN NxN NxN NxH NxH HxN HxN HxN NxH HxH HxH HxH

F_1

2 3 1 0 1 2 2 2 2 2 1 0

See AHRP Technical Document 5

Simulation design

Hatchery

Natural

F_0

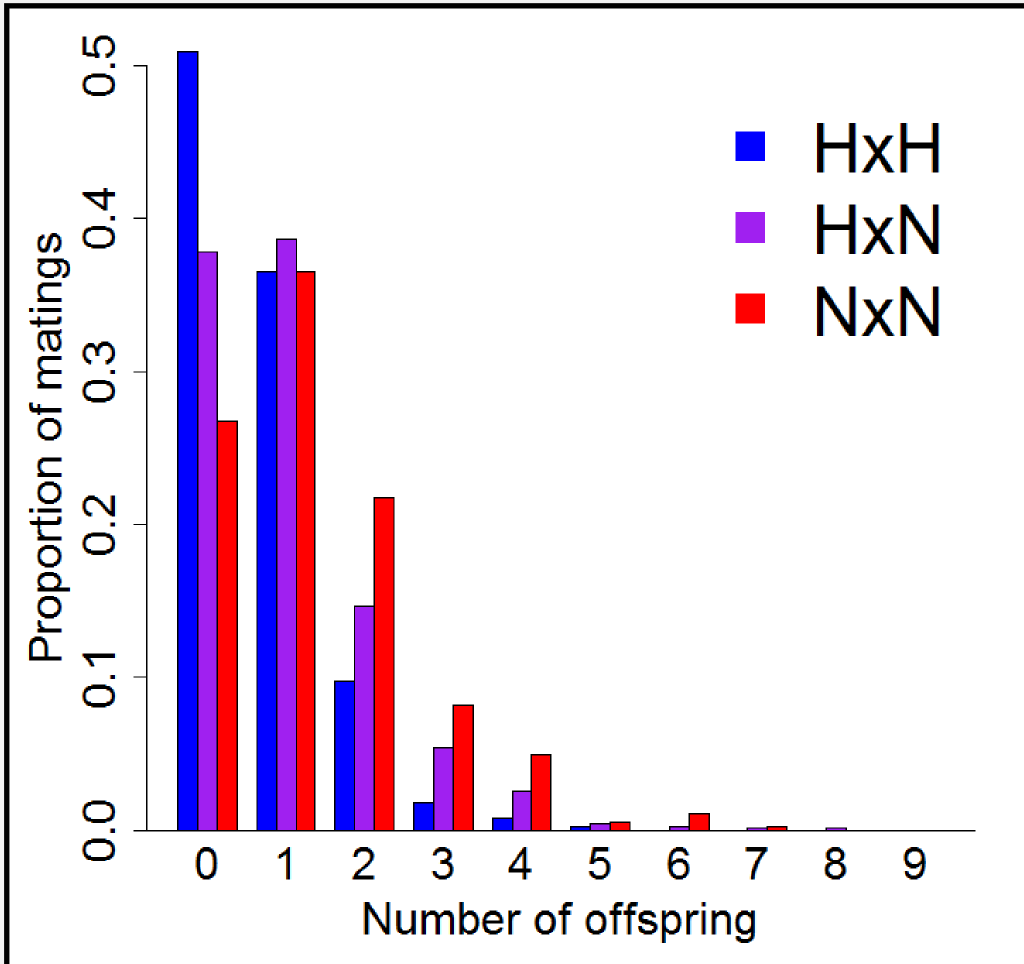
N N N N

H H H H H H H H H

Mating

NxN NxN

HxH HxH HxH



\# F_1

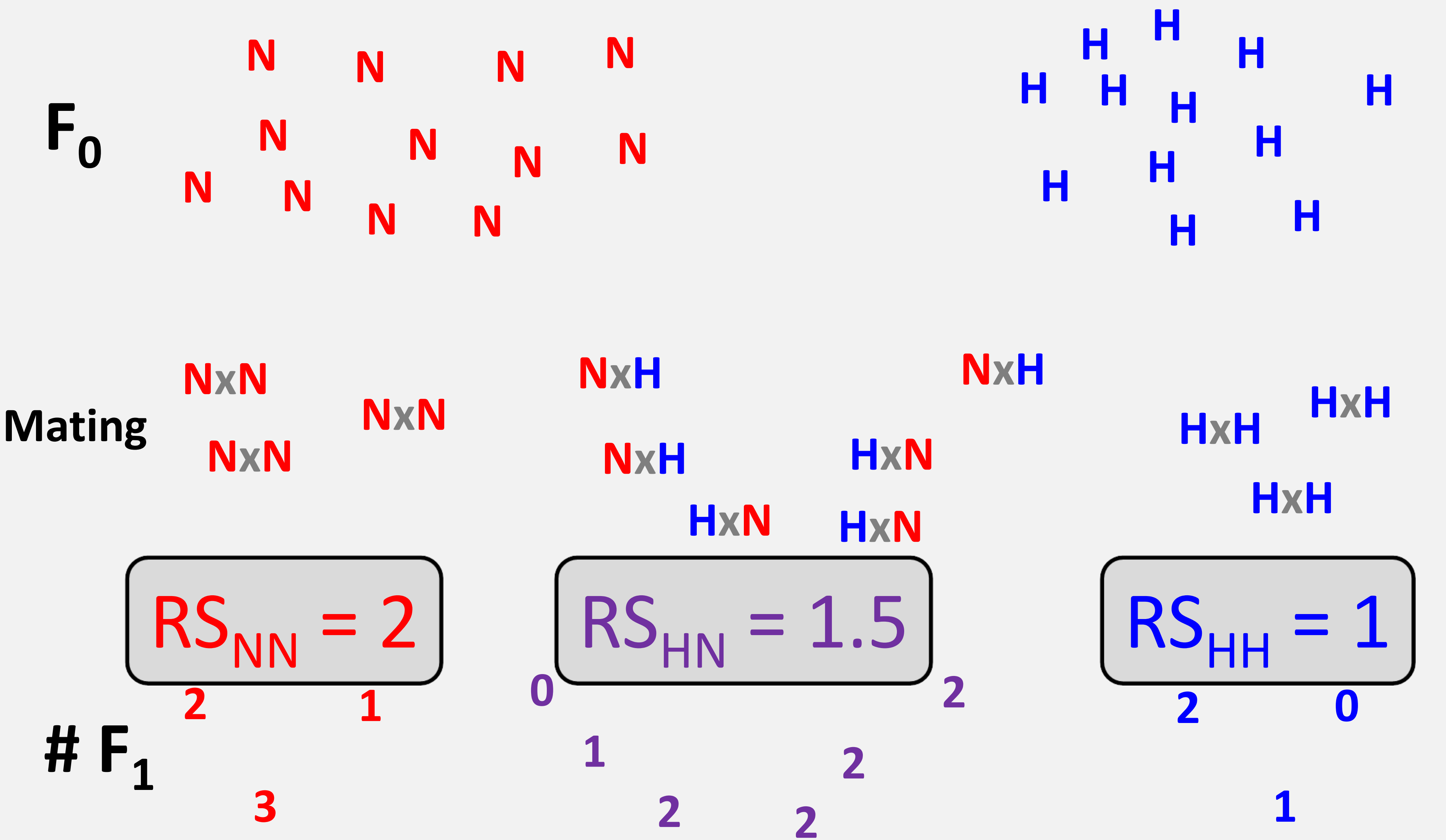
2 3 1 0 1 2 2 2 2 2 0 1

See AHRP Technical Document 5

Simulation design

Hatchery

Natural



See AHRP Technical Document 5

Simulation design

Hatchery

Natural

F_0

N N N N
N N N N
N N N N

H H H H H H H H H H H H

Mating

NxN NxN NxN NxH NxH NxH HxN HxN HxN HxH HxH HxH

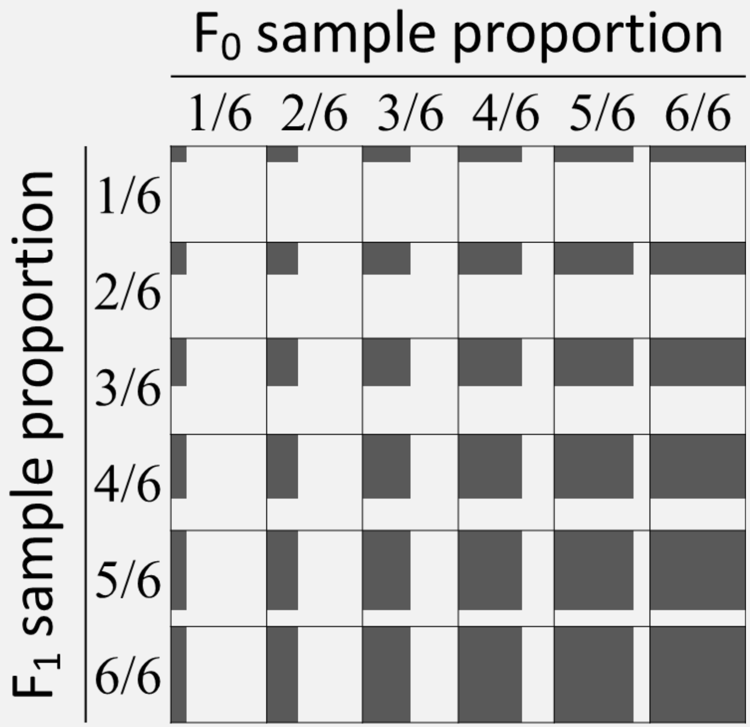
 # F_1

	NxN	HxN/NxH	HxH
RRS	1	0.75	0.5

See AHRP Technical Document 5

Simulation design

- Create F_1 genotypes
- Sample adults
  - 1/6, 2/6, 3/6, 4/6, 5/6, 6/6
- Sample offspring
  - 1/6, 2/6, 3/6, 4/6, 5/6, 6/6
- Incorporate random 0.5% genotype error rate



See AHRP Technical Document 3 & 5

Outline

- Background of AHRP
- Parentage and RRS
- Proposed study design
- Simulations
- Power analysis
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Relative reproductive success

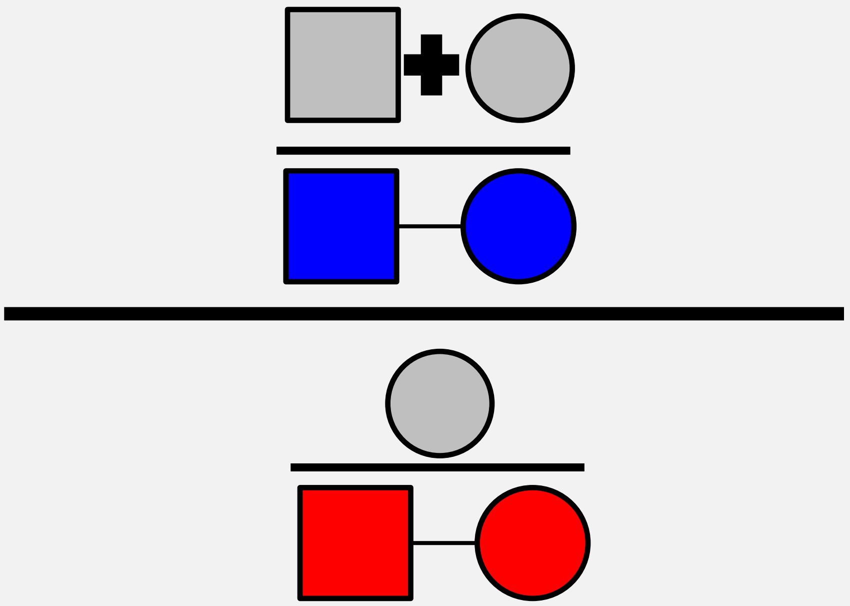
- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**

Fitness impact of hatchery strays on natural fitness

See AHRP Technical Document 5

Relative reproductive success

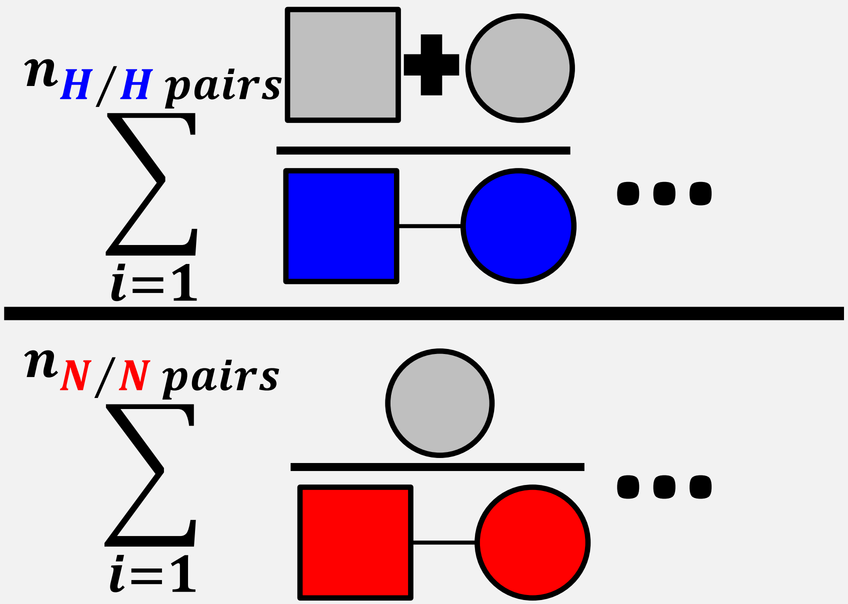
- Four comparisons
  - By cross type
    - **H/H** to **N/N** →
    - **H/N** to **N/N**



See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N** →
    - **H/N** to **N/N**



See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N** →
    - **H/N** to **N/N**

$$\frac{\sum_{i=1}^{n_{H/H\,pairs}} 2;3;1;2\ \ldots}{\sum_{i=1}^{n_{N/N\,pairs}} 1;2;1;1\ \ldots}$$

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N** →
    - **H/N** to **N/N**

$$\frac{\sum_{i=1}^{n_{H/H\ pairs}} n_{off_i}}{\sum_{i=1}^{n_{N/N\ pairs}} n_{off_i}}$$

See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N** →
    - **H/N** to **N/N**

$$\frac{\sum_{i=1}^{n_{H/H\ pairs}} n_{off_i} \Big/ n_{H/H\ pairs}}{\sum_{i=1}^{n_{N/N\ pairs}} n_{off_i} \Big/ n_{N/N\ pairs}}$$

See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N** → $RRS_{H/H to N/N} = 1.3$
    - **H/N** to **N/N**

See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**

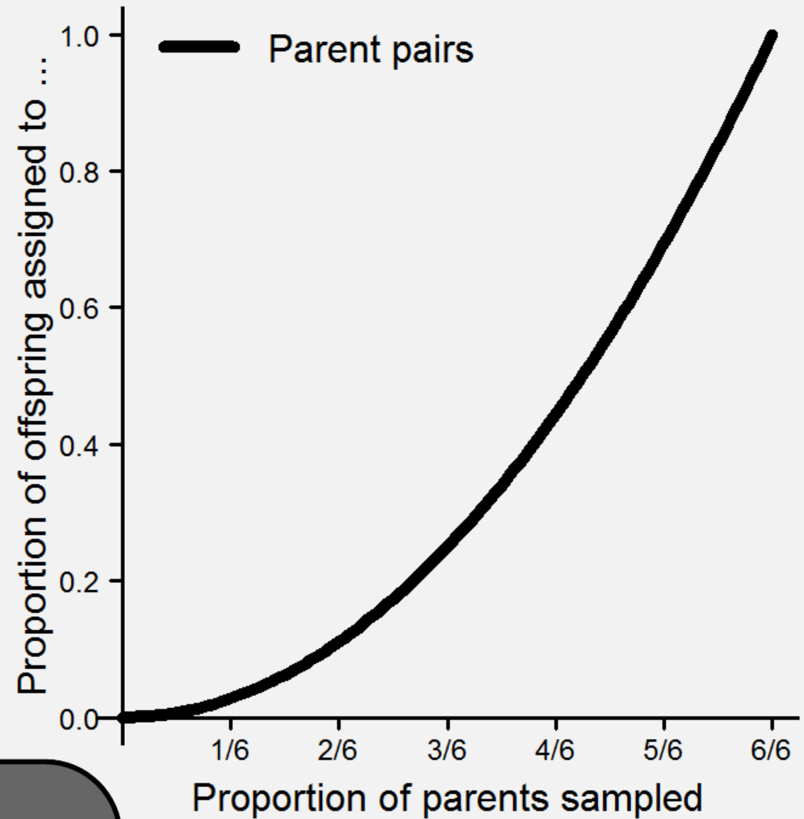
Caveats

- Min # offspring = 1
- Smaller sample size

See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**



<u>Caveats</u>

- Min # offspring = 1
- Smaller sample size

See AHRP Technical Document 5

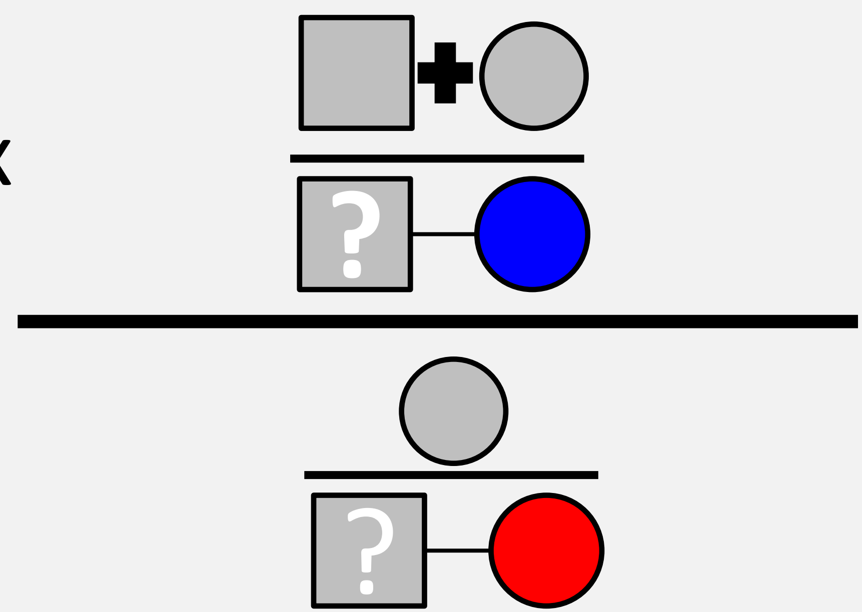
Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**
  - Single parent by sex
    - $\mathbf{H_{female}}$ to $\mathbf{N_{female}}$
    - $\mathbf{H_{male}}$ to $\mathbf{N_{male}}$

See AHRP Technical Document 5

Relative reproductive success

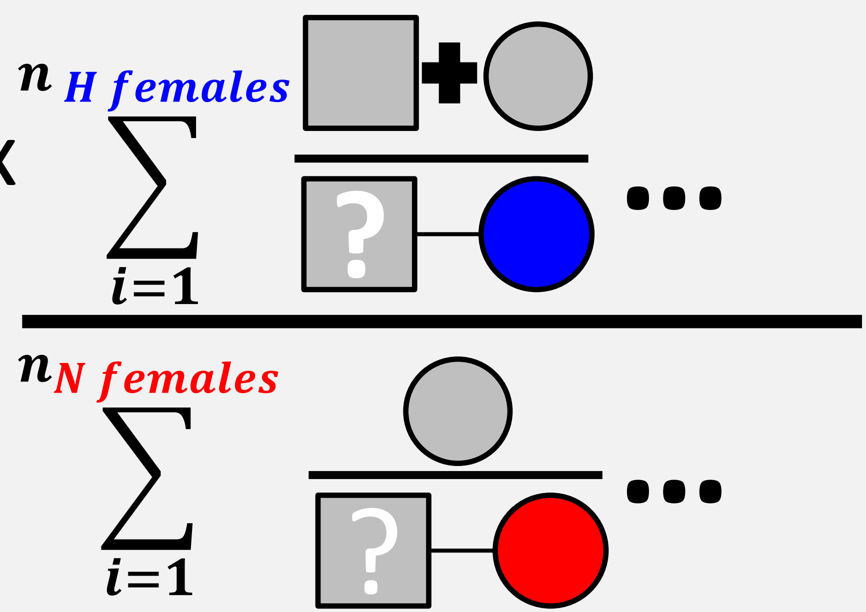
- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**
  - Single parent by sex
    - $\mathbf{H}_{\mathbf{female}}$ to $\mathbf{N}_{\mathbf{female}}$ →
    - $\mathbf{H}_{\mathbf{male}}$ to $\mathbf{N}_{\mathbf{male}}$



See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**
  - Single parent by sex
    - $\mathbf{H_{female}}$ to $\mathbf{N_{female}}$ →
    - $\mathbf{H_{male}}$ to $\mathbf{N_{male}}$



See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**
  - Single parent by sex
    - $\mathbf{H}_{\mathbf{female}}$ to $\mathbf{N}_{\mathbf{female}}$ →
    - $\mathbf{H}_{\mathbf{male}}$ to $\mathbf{N}_{\mathbf{male}}$

$$\frac{\sum_{i=1}^{n_{H\ females}} 0;1;2;1\ \ldots}{\sum_{i=1}^{n_{N\ females}} 0;3;4;1\ \ldots}$$

See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**
  - Single parent by sex
    - **H**$_{\text{female}}$ to **N**$_{\text{female}}$ →
    - **H**$_{\text{male}}$ to **N**$_{\text{male}}$

$$\frac{\sum_{i=1}^{n_{H\,females}} n_{off_i} \Big/ n_{H\,females}}{\sum_{i=1}^{n_{N\,females}} n_{off_i} \Big/ n_{N\,females}}$$

See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**
  - Single parent by sex
    - $\mathbf{H_{female}}$ to $\mathbf{N_{female}}$ →
    - $\mathbf{H_{male}}$ to $\mathbf{N_{male}}$

$$RRS_{H\ to\ N\ female} = 0.5$$

See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**
  - Single parent by sex
    - $\mathbf{H_{female}}$ to $\mathbf{N_{female}}$
    - $\mathbf{H_{male}}$ to $\mathbf{N_{male}}$

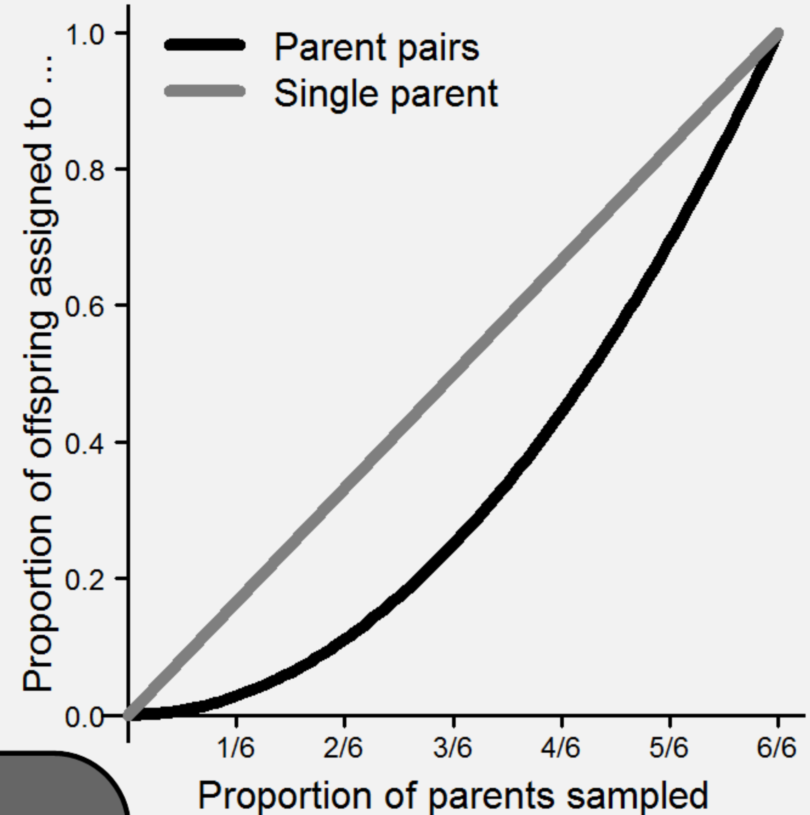
Caveats

- Min # offspring = 0
- Only ½ genetic info

See AHRP Technical Document 5

Relative reproductive success

- Four comparisons
  - By cross type
    - **H/H** to **N/N**
    - **H/N** to **N/N**
  - Single parent by sex
    - H_{female} to N_{female}
    - H_{male} to N_{male}



Caveats

- Min # offspring = 0
- Only ½ genetic info

See AHRP Technical Document 5

Test of fitness differences

- Non-parametric approach (Araki & Blouin 2005)
  - Permutation test

See AHRP Technical Document 5

Test of fitness differences

- Non-parametric approach (Araki & Blouin 2005)
  - Permutation test

Number of offspring	
Hatchery	Natural
1	1
3	2
1	3
0	1
3	5
2	1
0	0
2	2
	2
	3

See AHRP Technical Document 5

Test of fitness differences

- Non-parametric approach (Araki & Blouin 2005)
  - Permutation test

Number of offspring	
Hatchery	Natural
1	1
3	2
1	3
0	1
3	5
2	1
0	0
2	2
	2
	3
$RS_H = 1.5$	$RS_N = 2.0$

See AHRP Technical Document 5

Test of fitness differences

- Non-parametric approach (Araki & Blouin 2005)
  - Permutation test

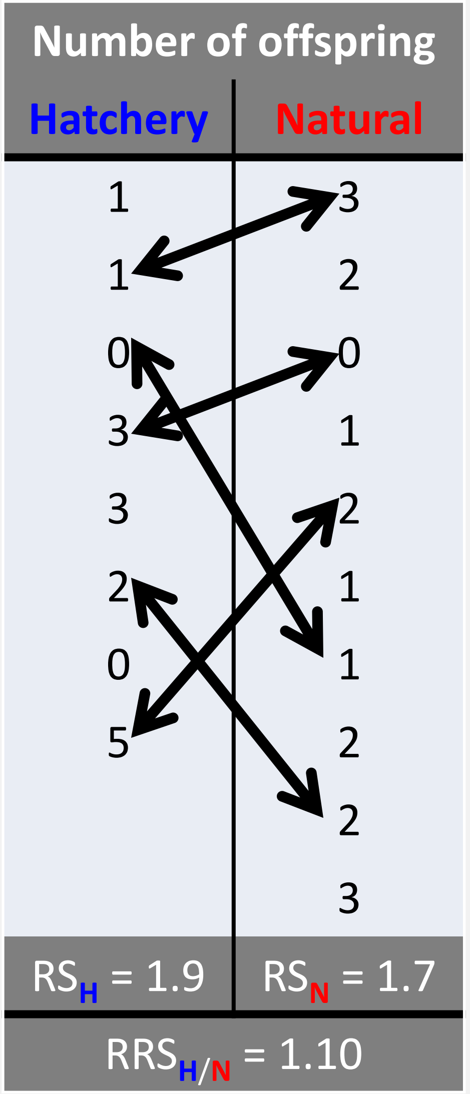
Number of offspring	
Hatchery	Natural
1	1
3	2
1	3
0	1
3	5
2	1
0	0
2	2
	2
	3
$RS_H = 1.5$	$RS_N = 2.0$
$RRS_{H/N} = 0.75$	

See AHRP Technical Document 5

Test of fitness differences

- Non-parametric approach (Araki & Blouin 2005)
  - Permutation test

REPEAT 100,000 TIMES

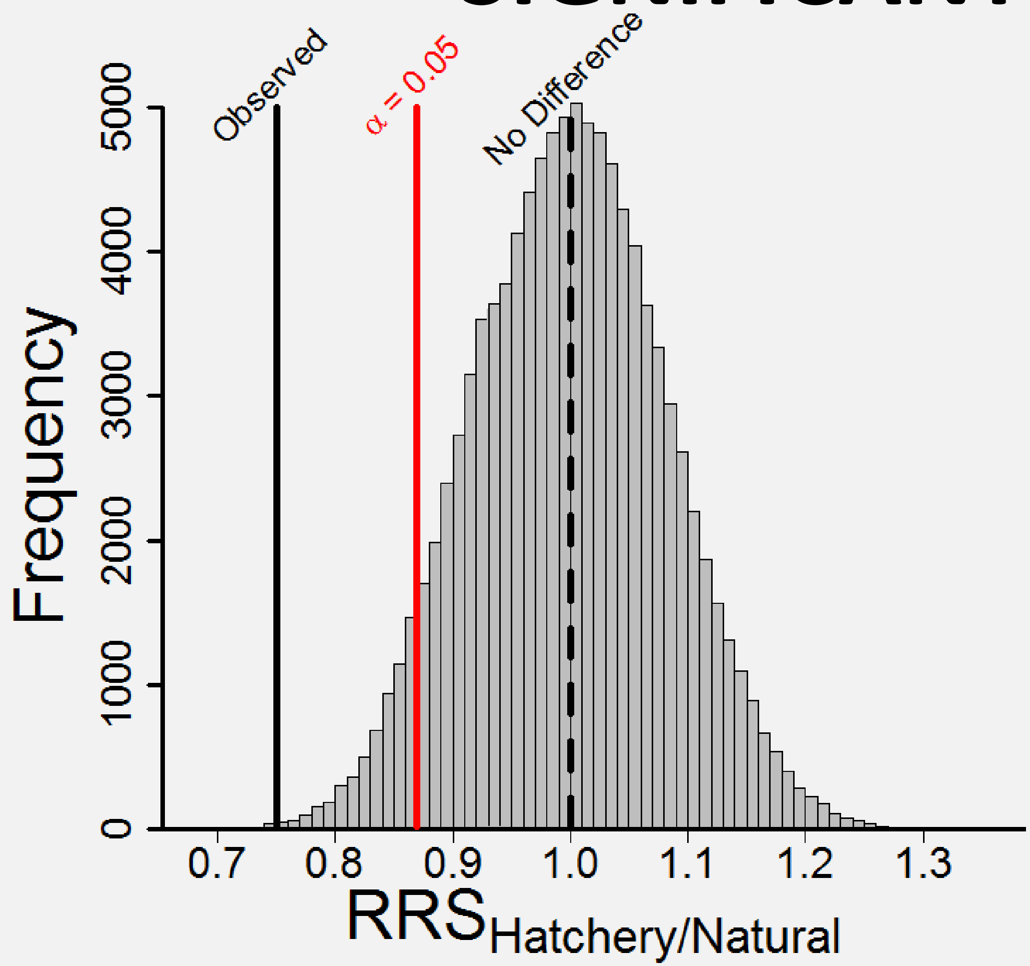


See AHRP Technical Document 5

Test of fitness differences

- Non-parametric approach (Araki & Blouin 2005)
  - Permutation test

SIGNIFICANT



See AHRP Technical D

Test of fitness differences

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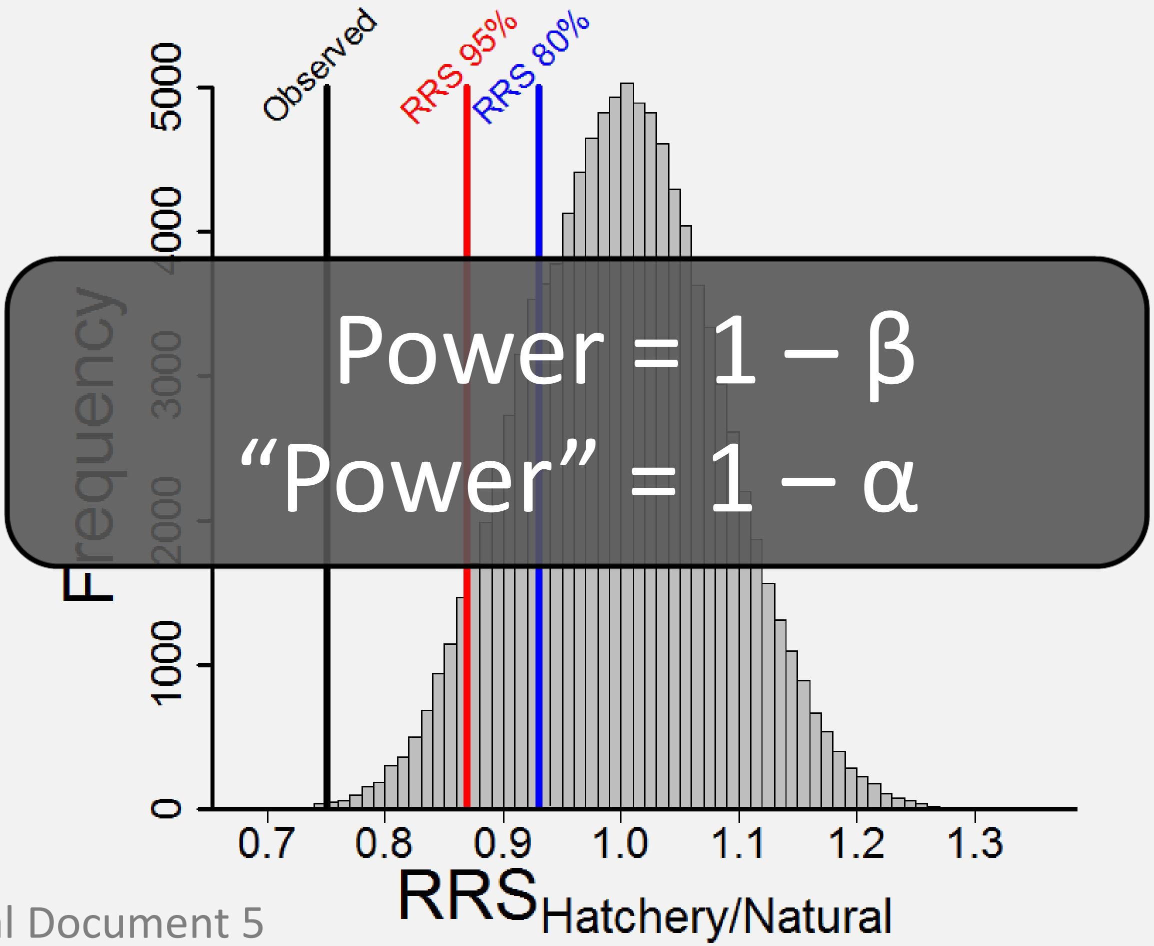
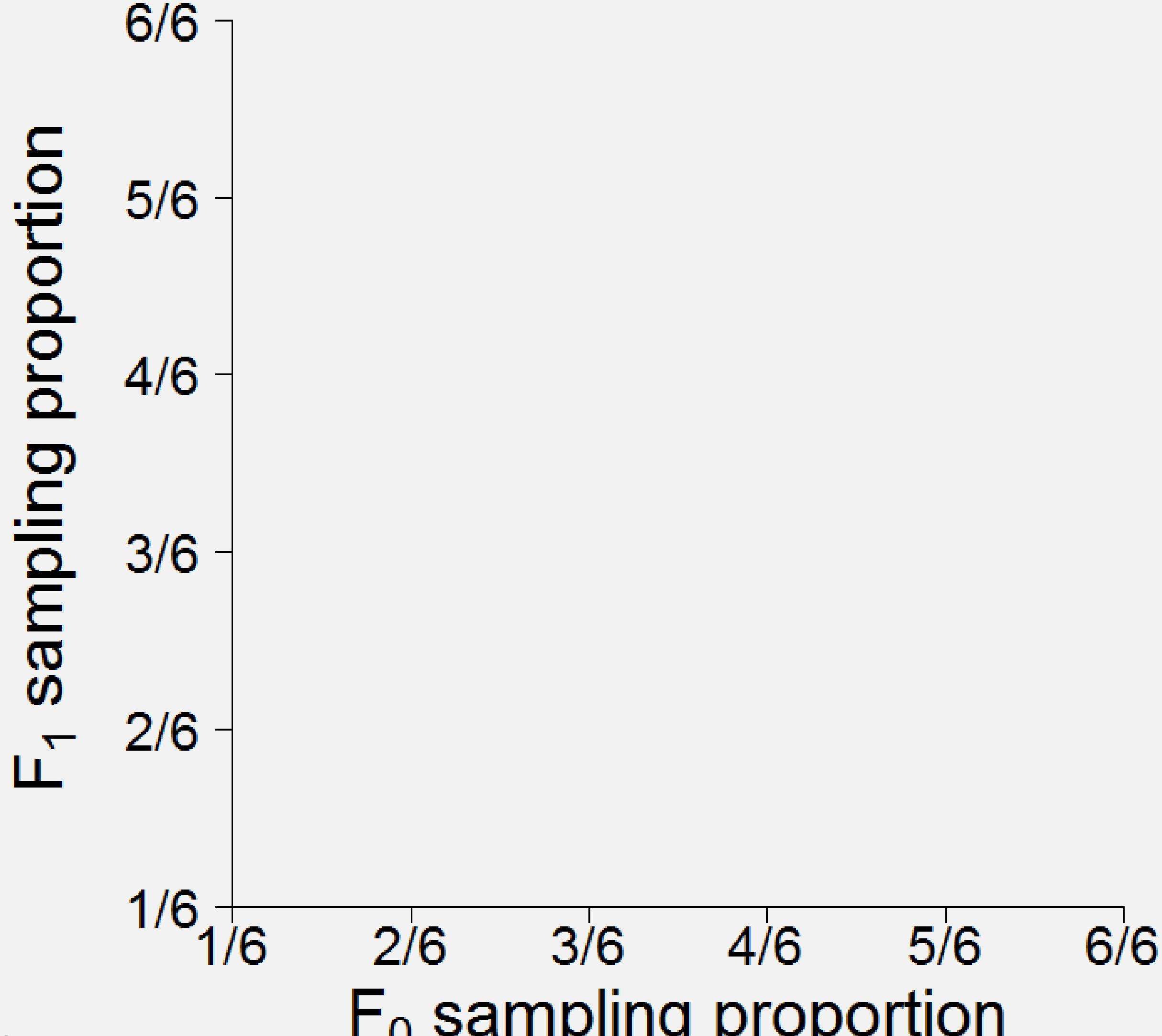


See AHRP Technical Document 5

Single parent results: Permutation test

RRS 95% "Power"

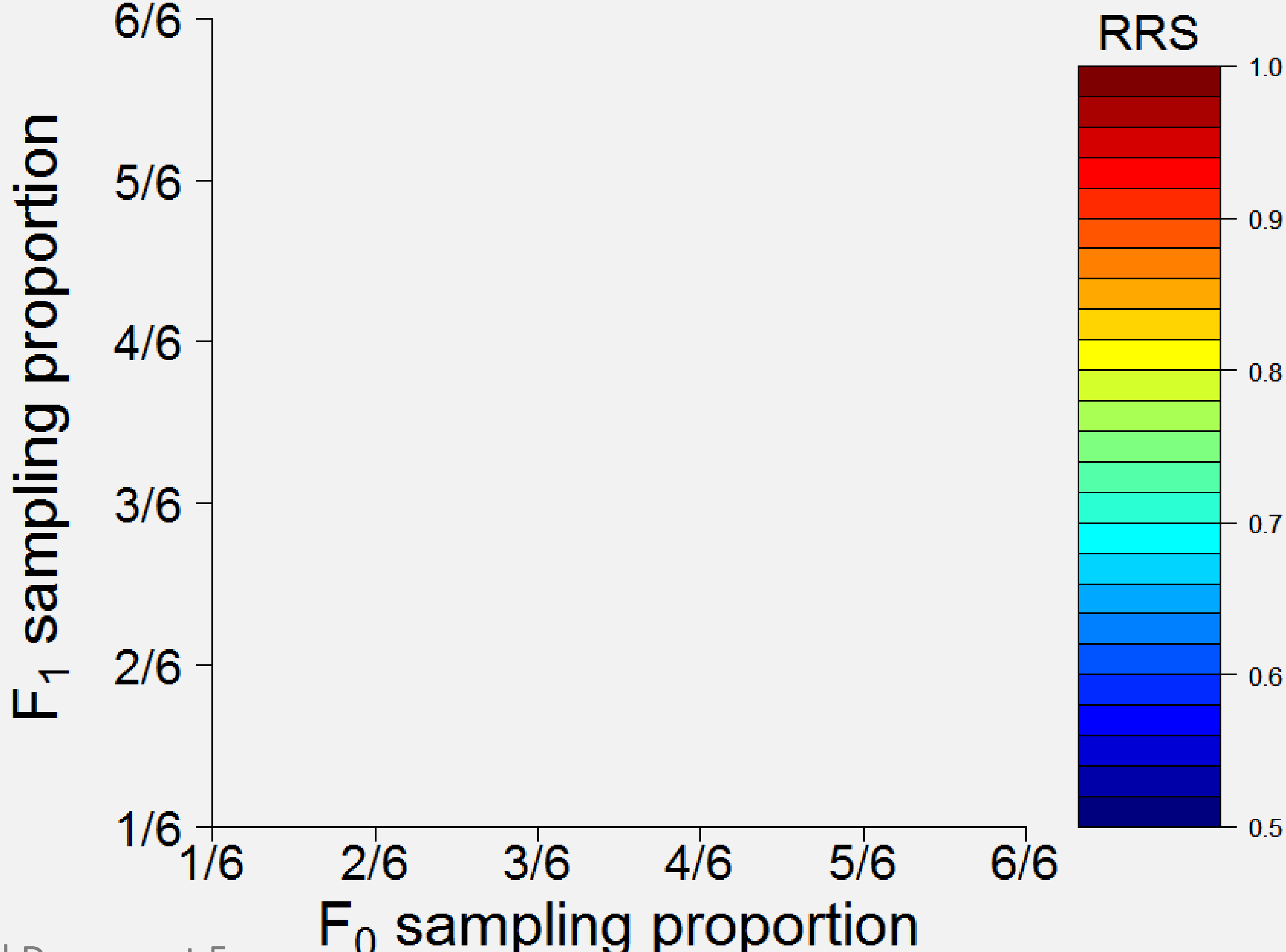
Modeled **RRS**$_{HH/NN}$ = **0. 50**



See AHRP Technical Document 5

RRS 95% "Power"

Modeled **$RRS_{HH/NN}$ = 0. 50**



See AHRP Technical Document 5

RRS 95% "Power"

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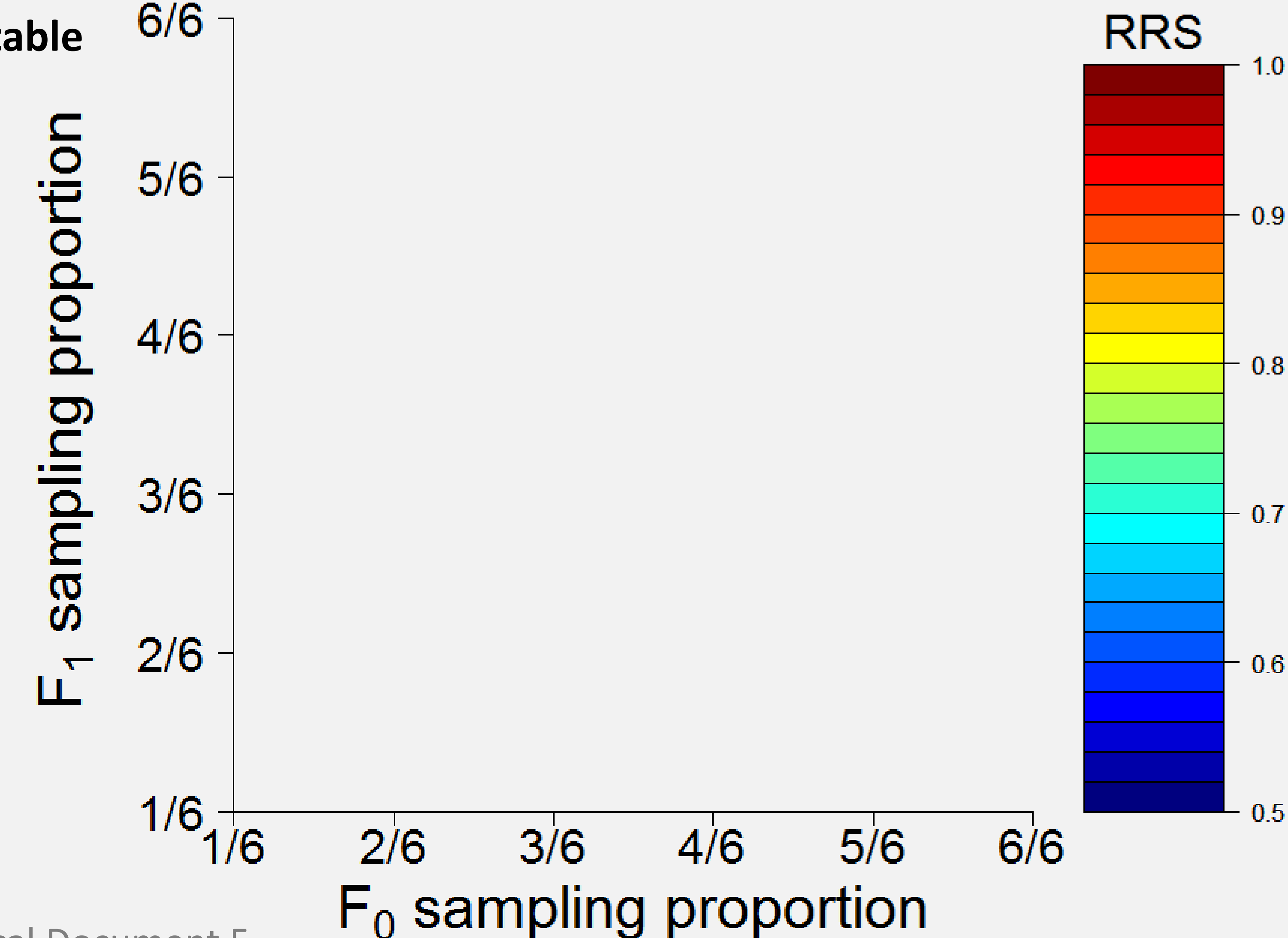
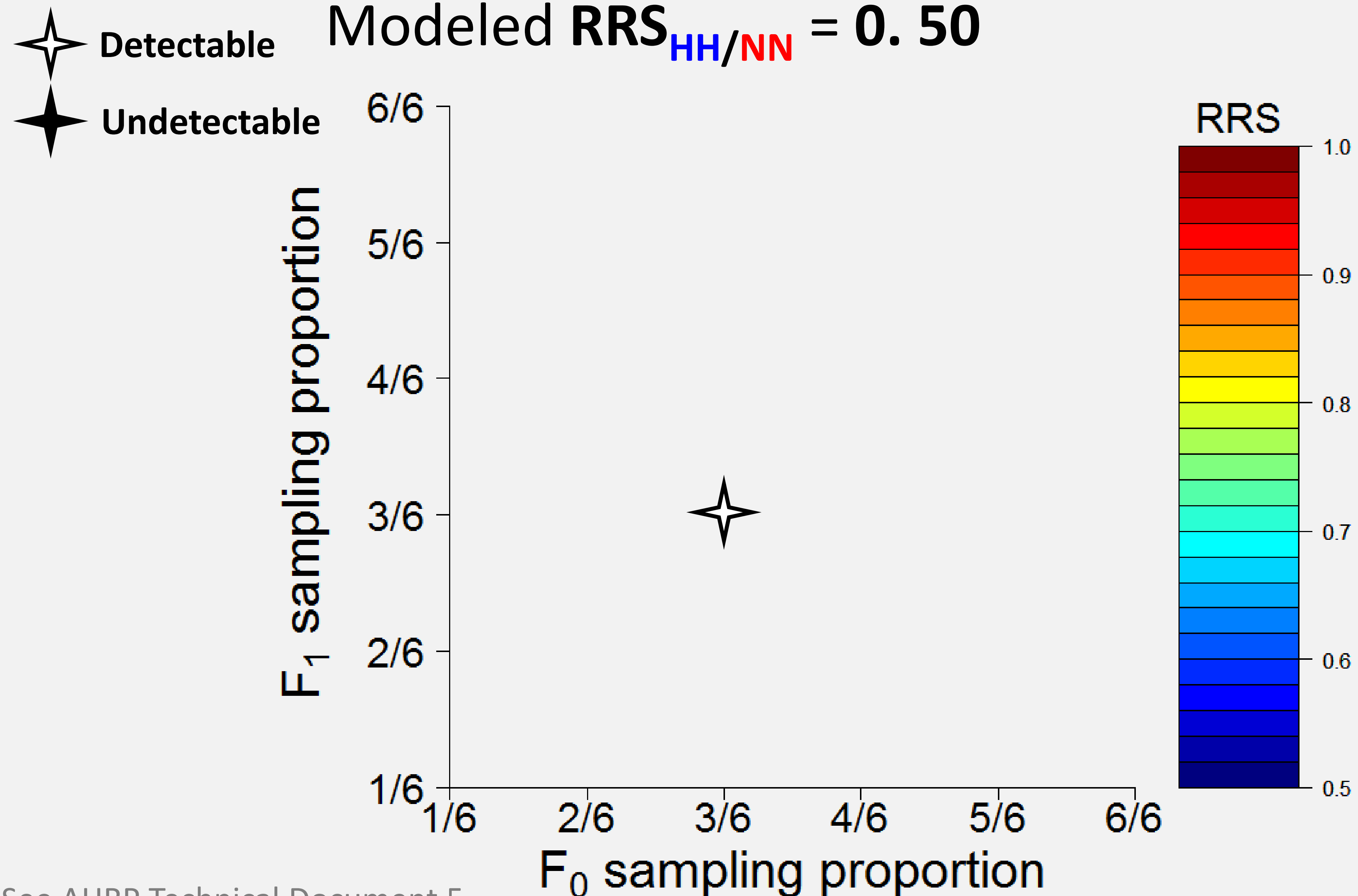


See AHRP Technical Document 5

RRS 95% "Power"

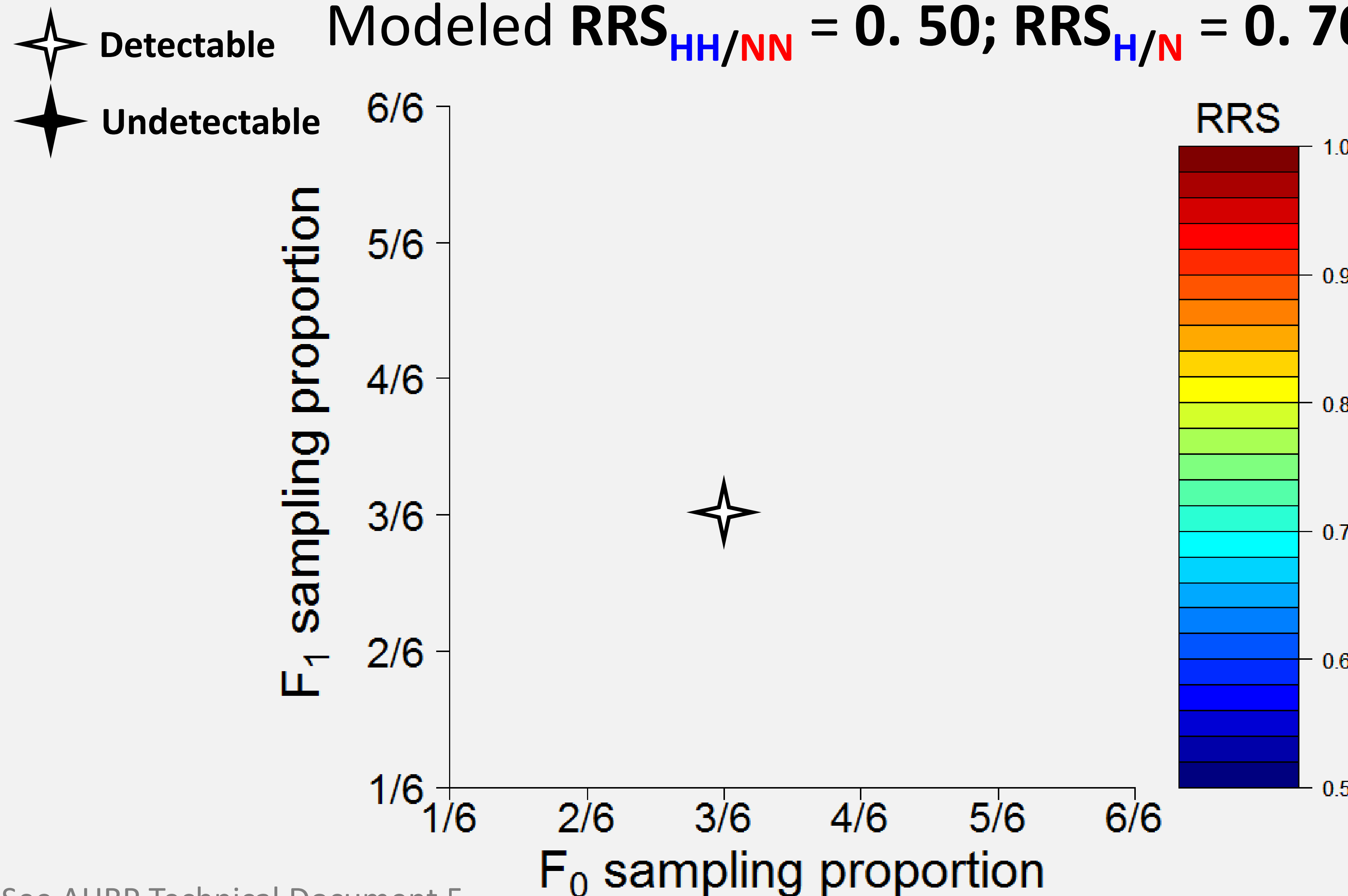
Modeled **$RRS_{HH/NN}$ = 0. 50**



See AHRP Technical Document 5

RRS 95% "Power"

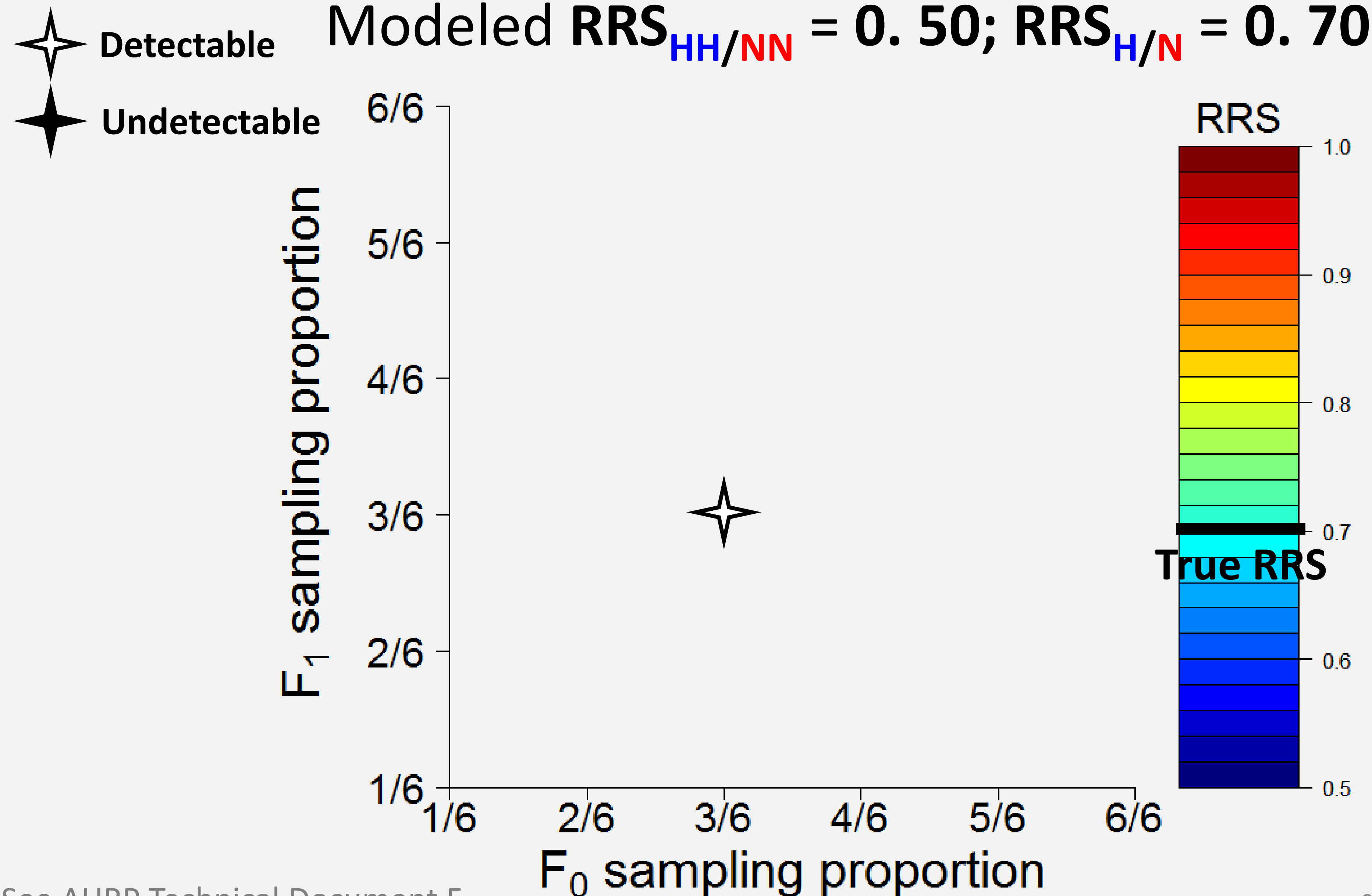
Modeled **$RRS_{HH/NN}$ = 0. 50; $RRS_{H/N}$ = 0. 70**



See AHRP Technical Document 5

RRS 95% "Power"

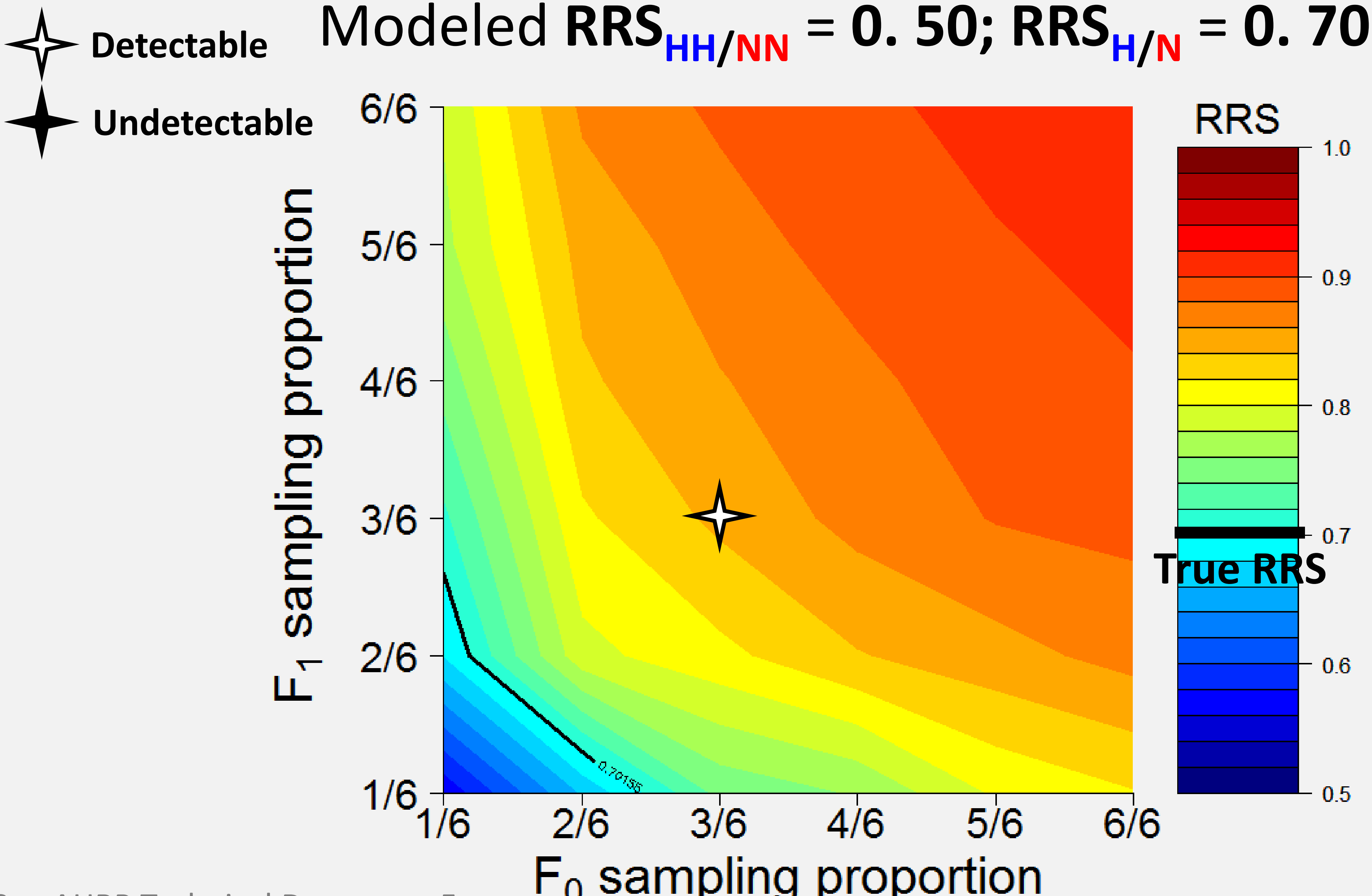
Modeled **$RRS_{HH/NN}$ = 0. 50; $RRS_{H/N}$ = 0. 70**



See AHRP Technical Document 5

RRS 95% "Power"

Modeled **$RRS_{HH/NN}$ = 0. 50; $RRS_{H/N}$ = 0. 70**



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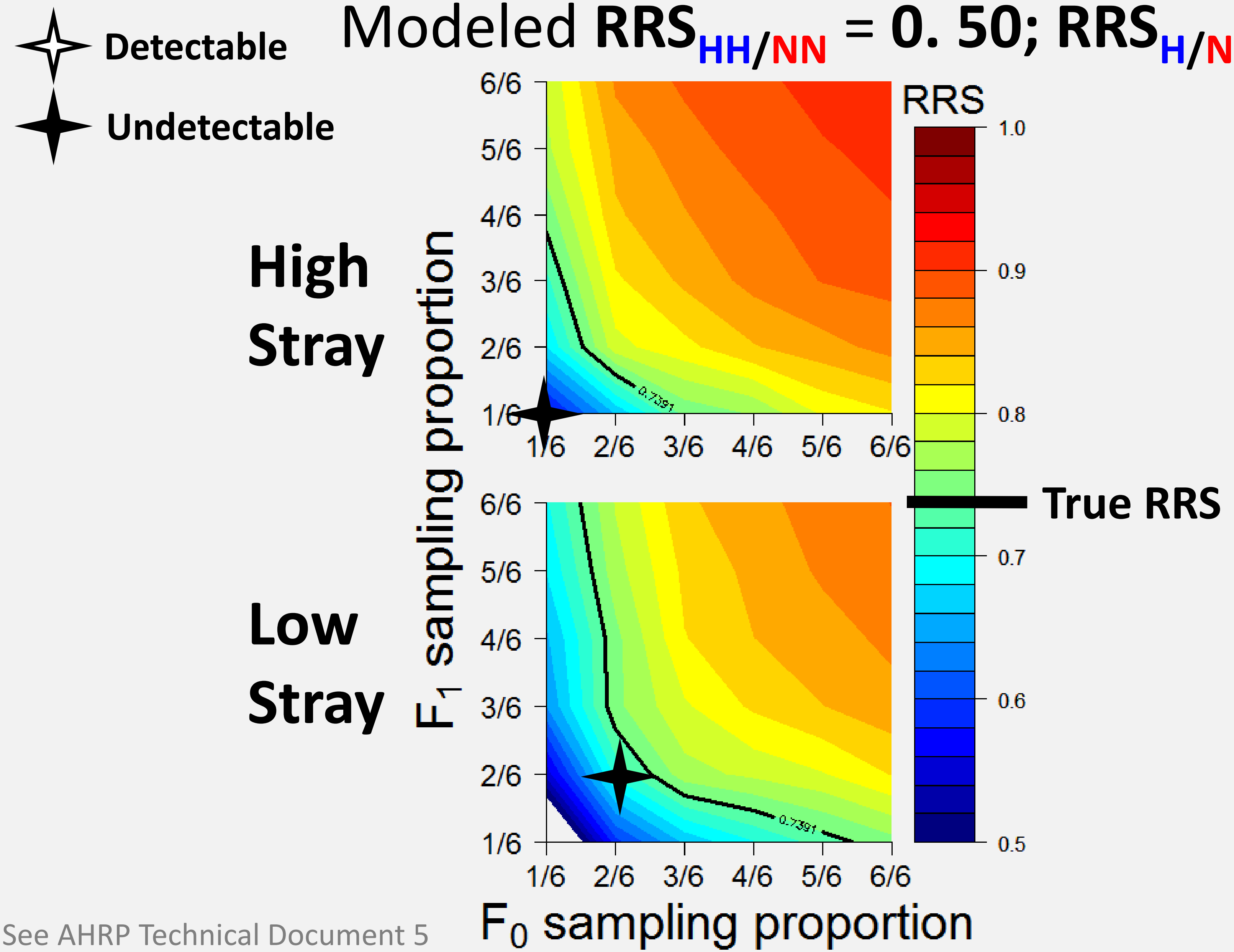
RRS 95% "Power"

Modeled **RRS$_{HH/NN}$ = 0. 50; RRS$_{H/N}$ = 0. 74**



RRS 95% "Power"

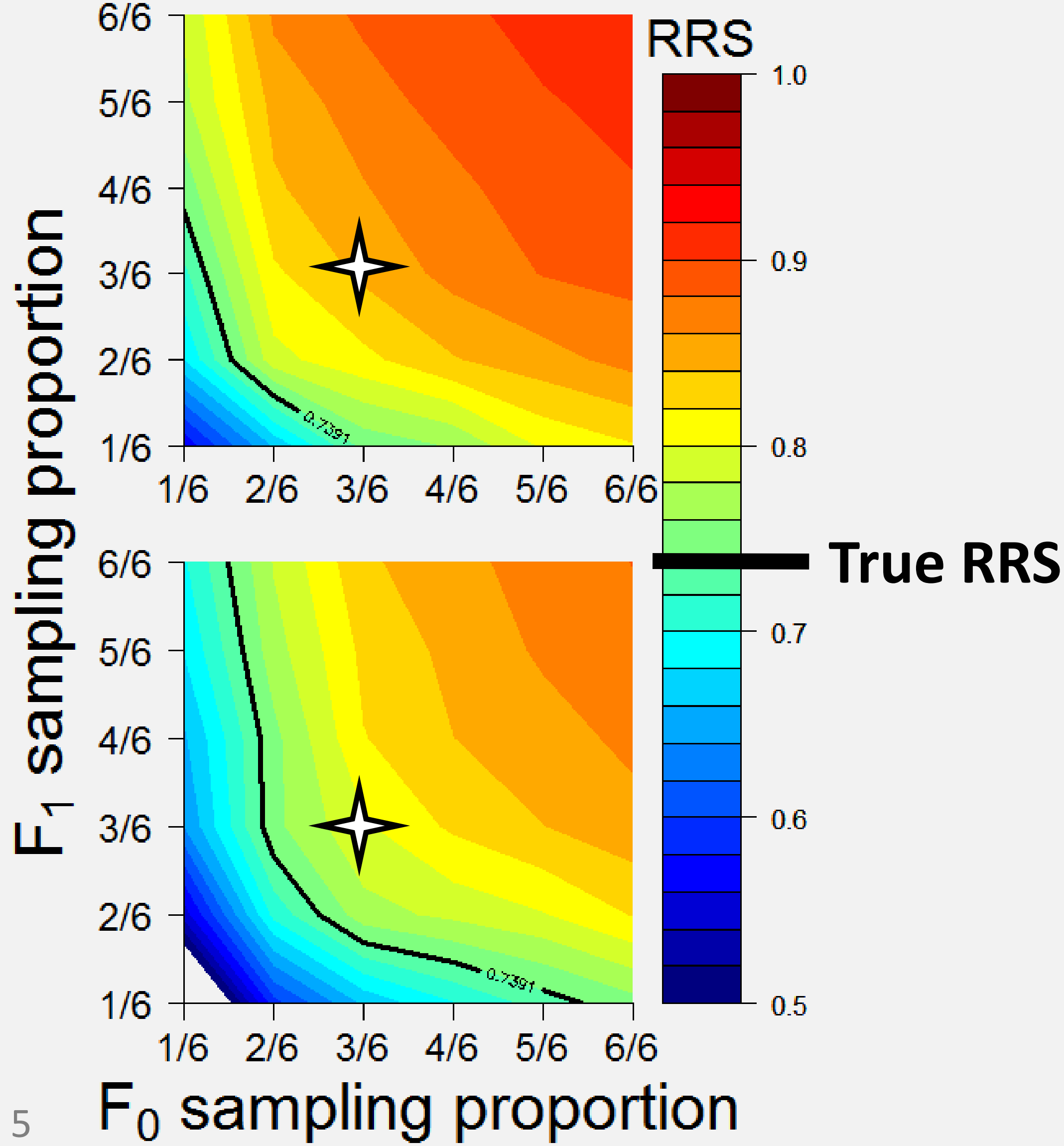
Modeled **RRS$_{HH/NN}$ = 0. 50; RRS$_{H/N}$ = 0. 74**

Detectable

Undetectable

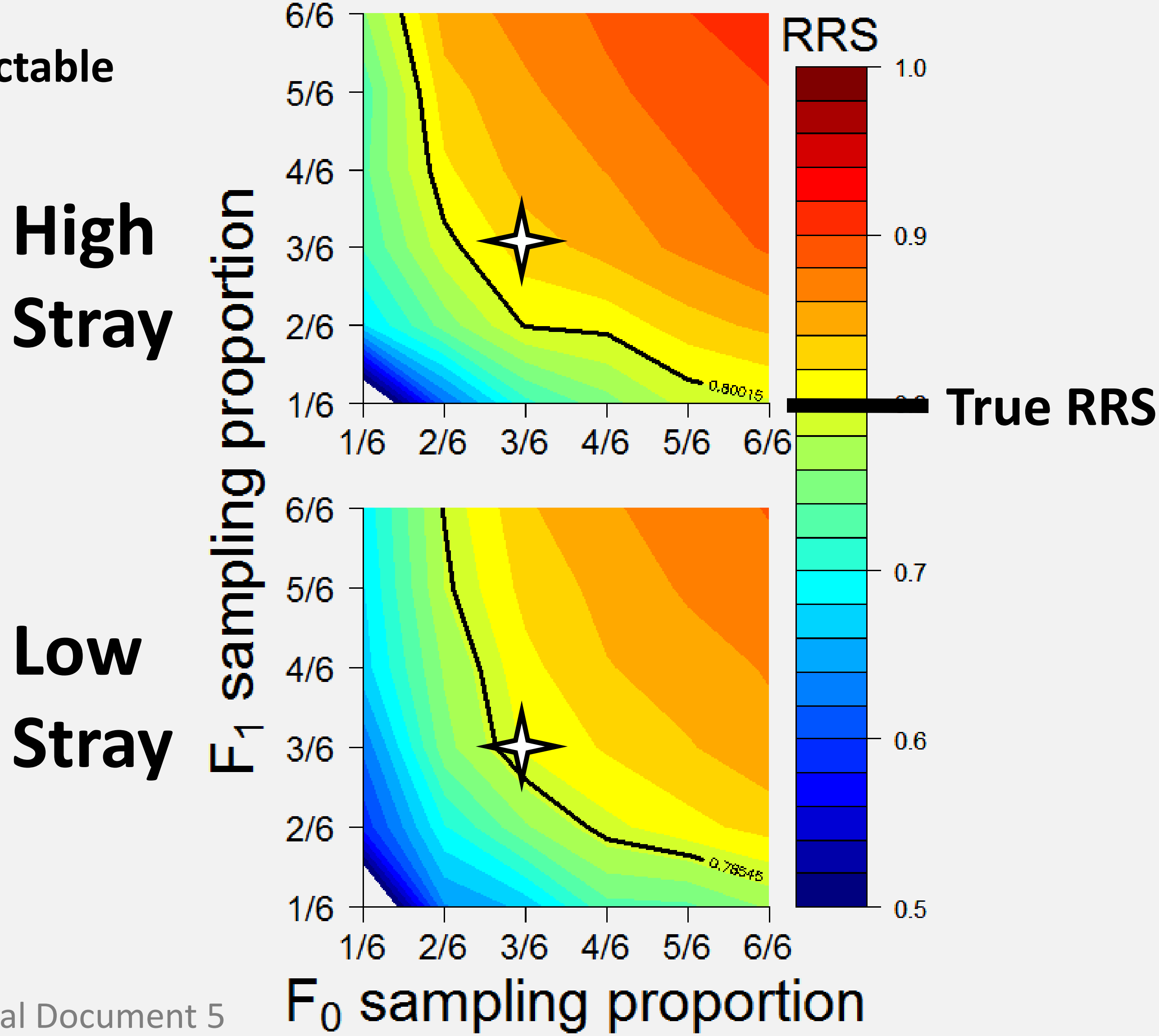
High Stray

Low Stray



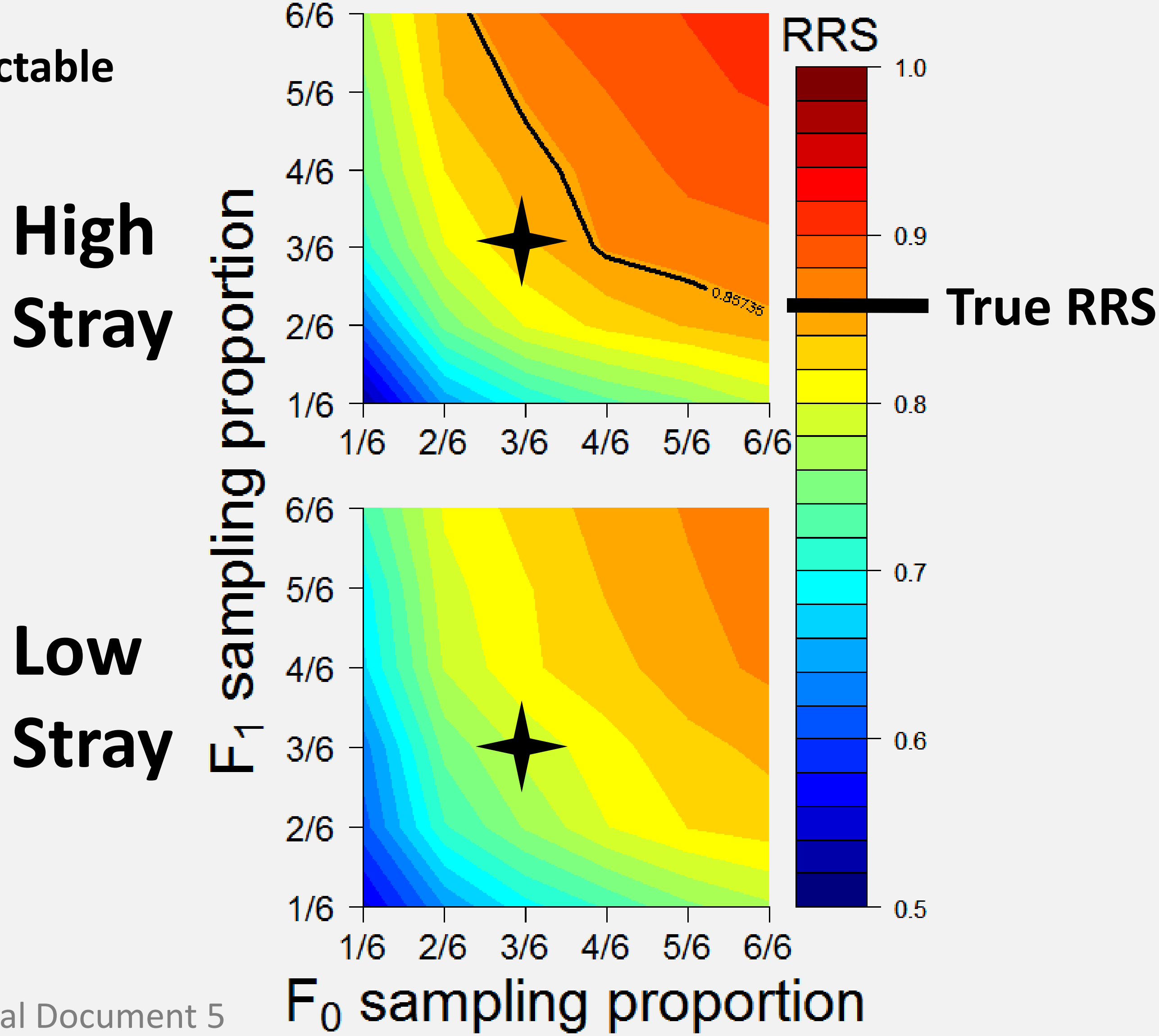
RRS 95% "Power"

Modeled **$RRS_{HH/NN}$ = 0. 63; $RRS_{H/N}$ = 0. 79**



RRS 95% "Power"

Modeled **$RRS_{HH/NN}$ = 0. 75; $RRS_{H/N}$ = 0. 86**



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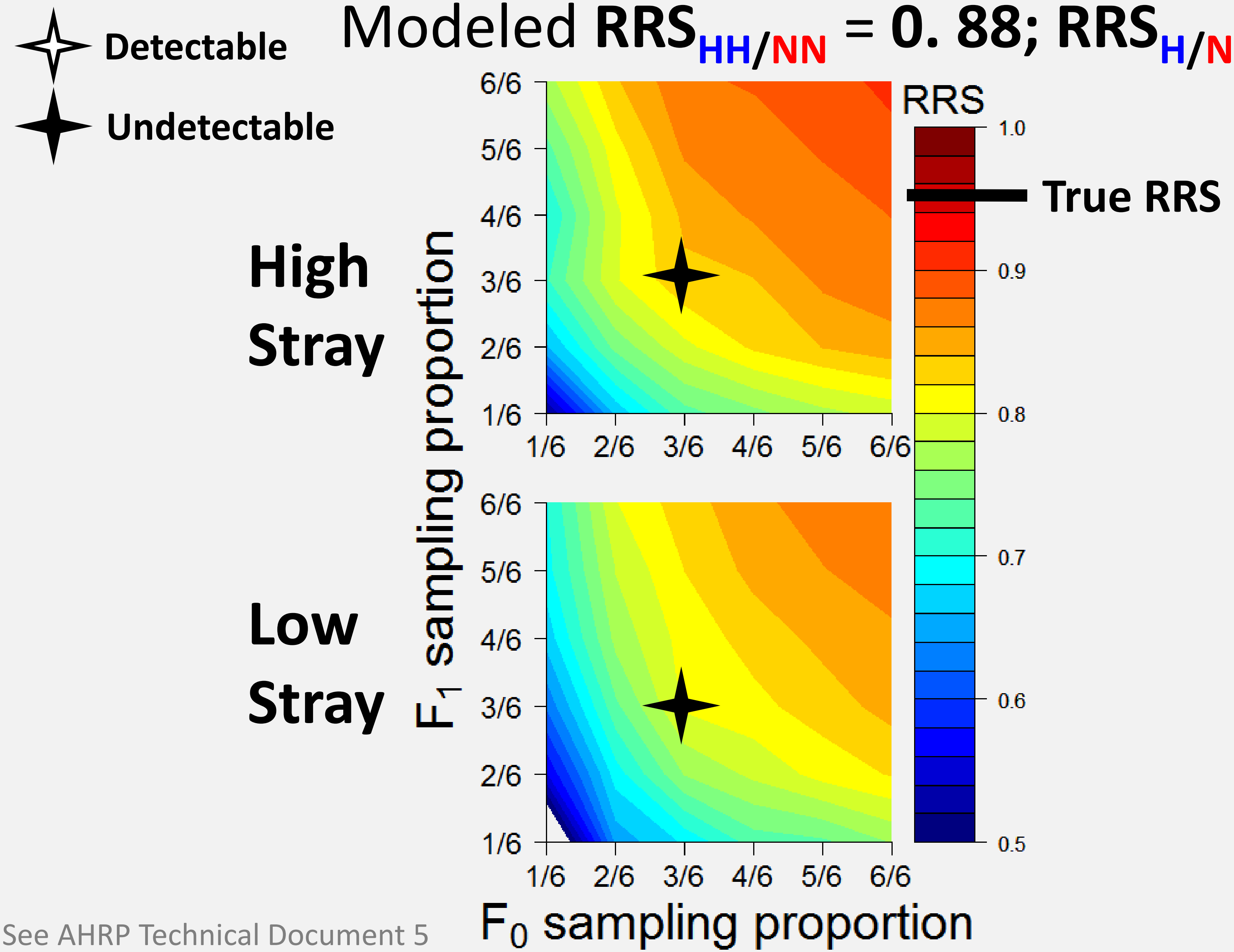
RRS 95% "Power"

Modeled **$RRS_{HH/NN}$ = 0. 88; $RRS_{H/N}$ = 0. 95**



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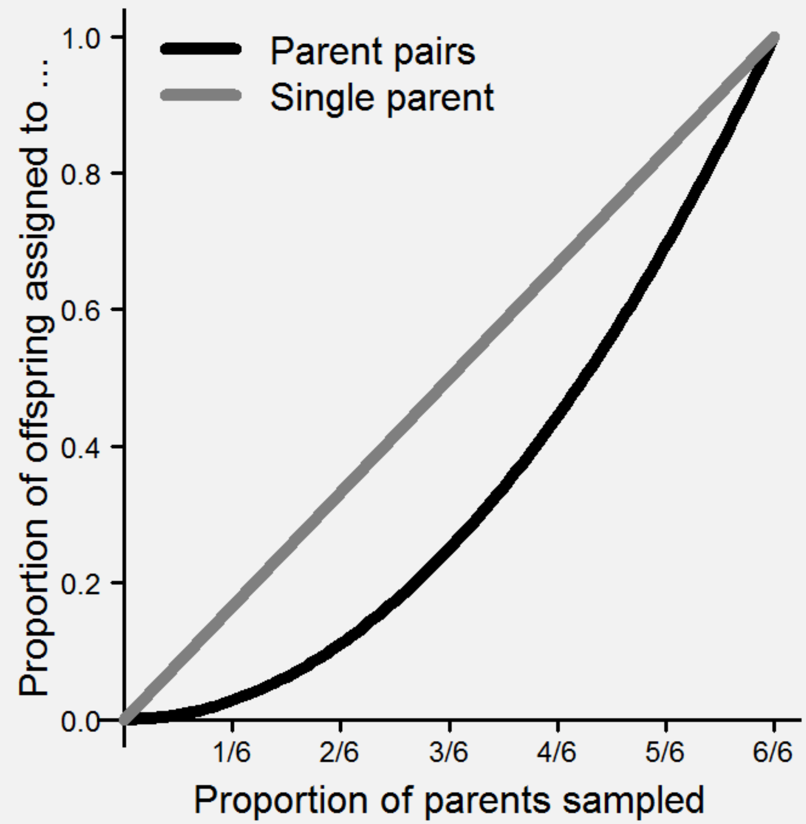
RRS: Single Parents by Sex

- Described in RFP
- Larger sample size
- Greater power



See AHRP Technical Document 5

Test of fitness differences

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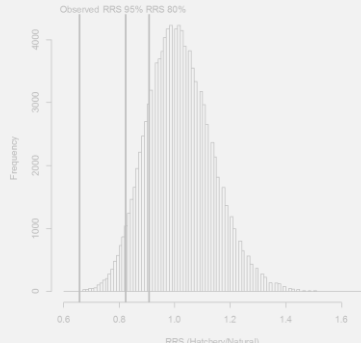
  - Permutation test
    - "Power" - 80% & 95% (Thériault et al. 2011 & Hess et al. 2012)



- Parametric approach (Anderson 2013)
  - Negative binomial general linear model (GLM)

See AHRP Technical Document 5

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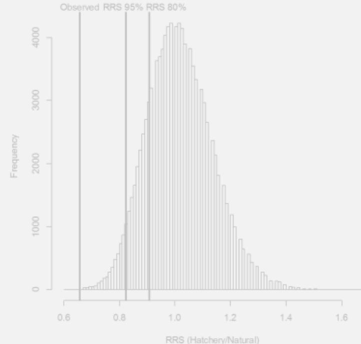

- Parametric approach (Anderson 2013)
  - Negative binomial general linear model (GLM)
    - 90% CI
      - $RRS = {}^{1}/_{e^{\beta}}$

```
Coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept) -1.05022    0.09076 -11.571  < 2e-16 ***
OriginW      0.42128    0.11646   3.617 0.000298 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

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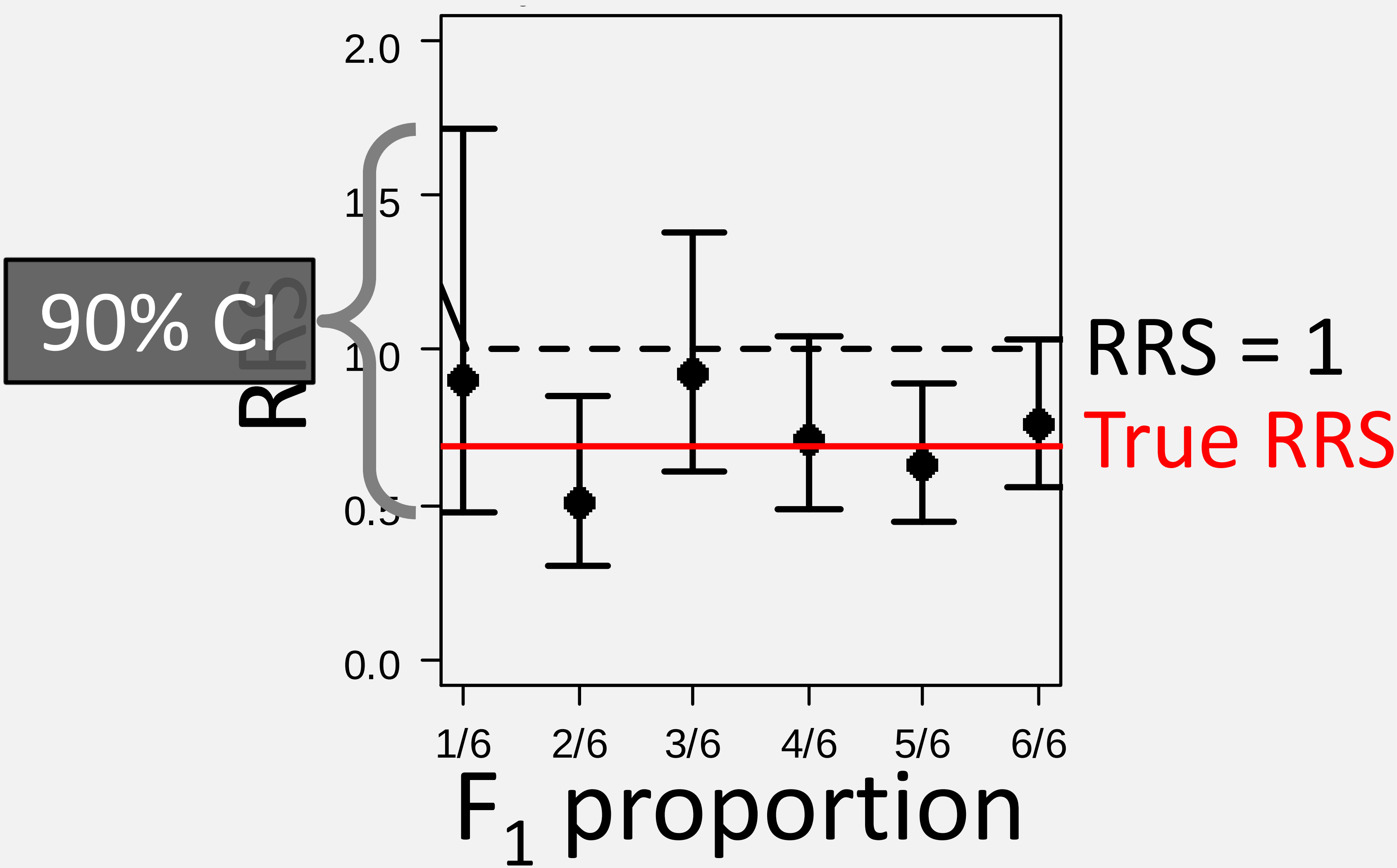
Precision of RRS estimate



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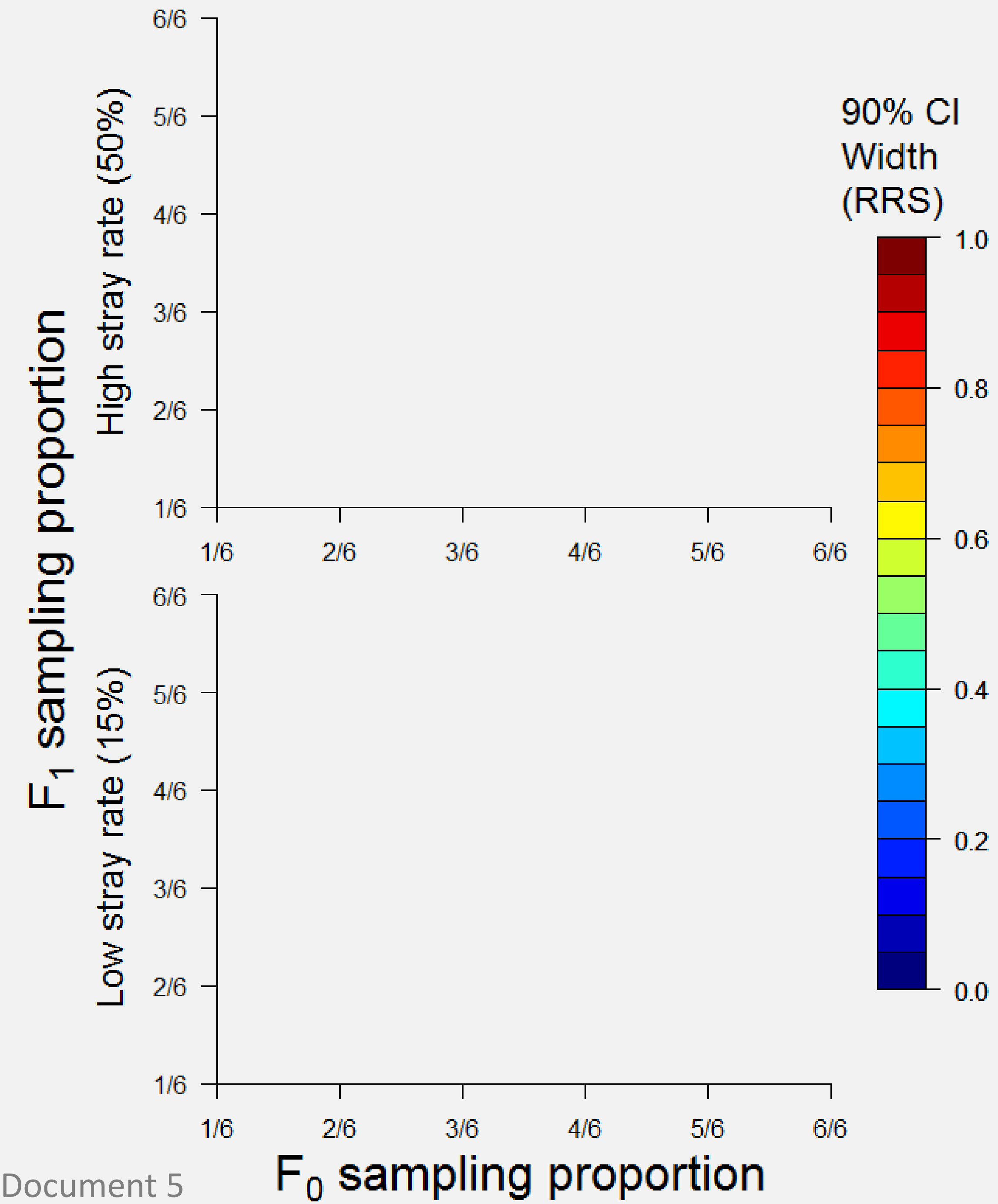
Single parent results:
Negative binomial 90% CI width



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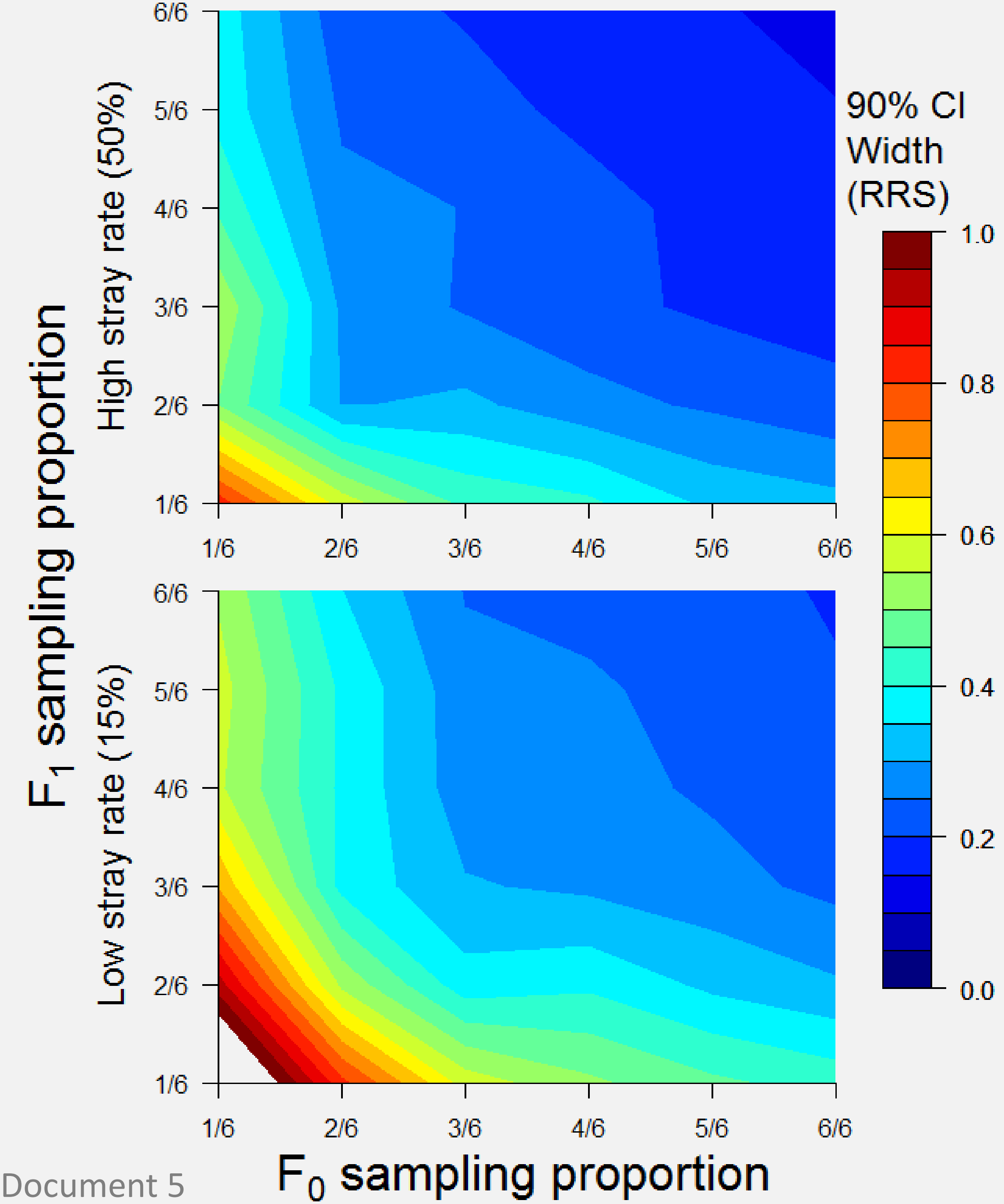
Single parent



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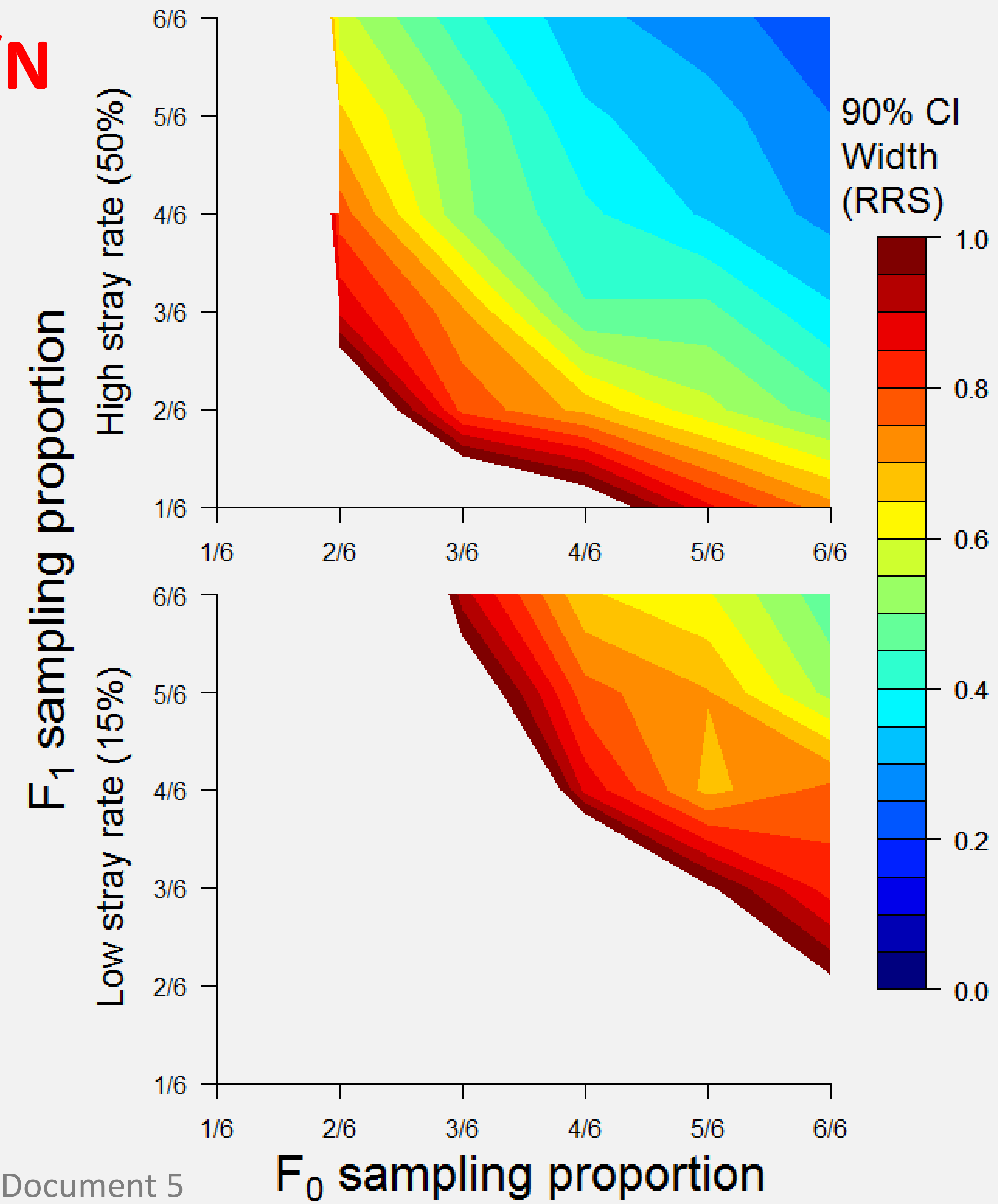
Parent pair results:

Negative binomial 90% CI width

H/H to **N/N** cross type

H/H to N/N cross type



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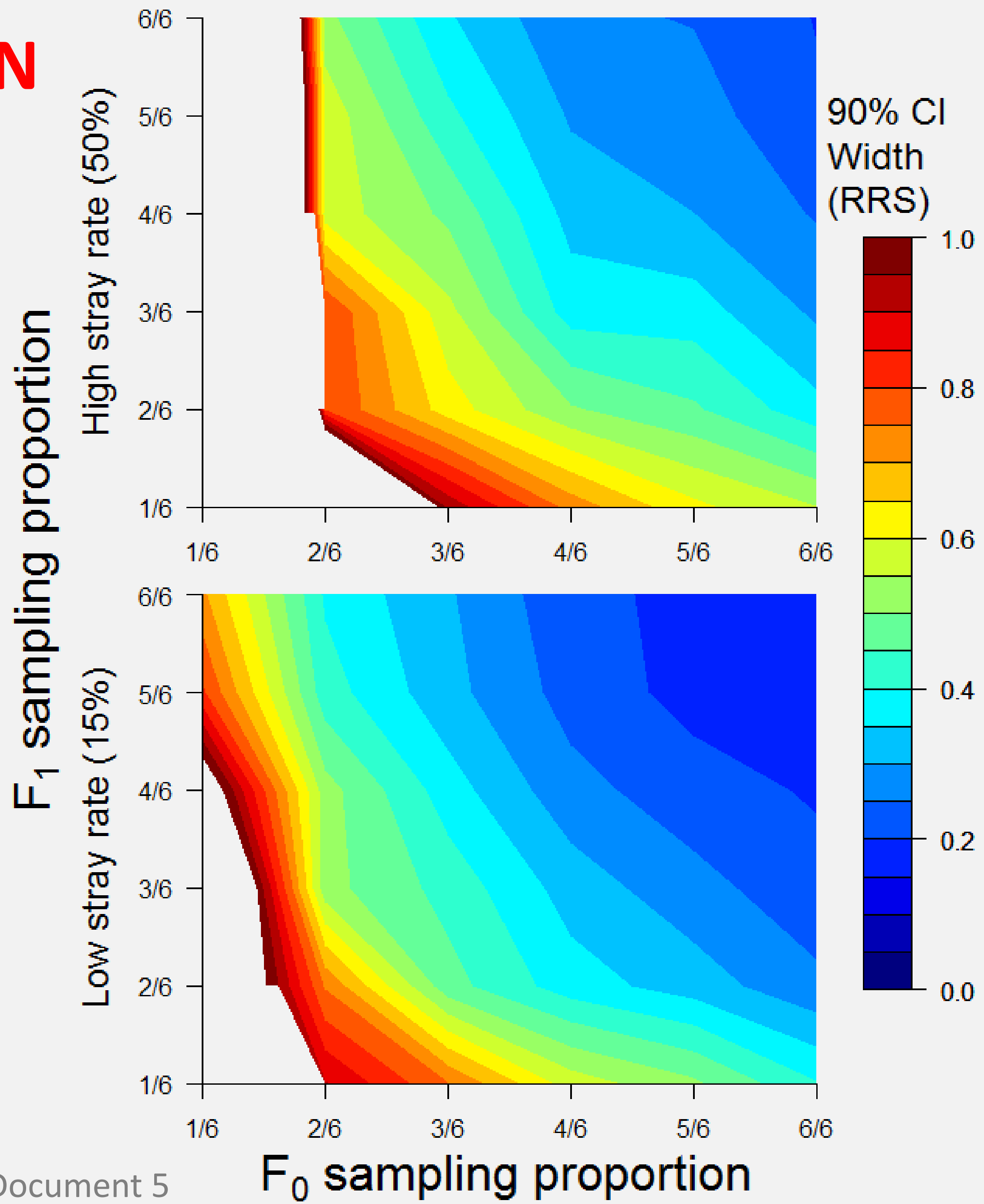
Parent pair results:
Negative binomial 90% CI width
H/N to **N/N** cross type

H/N to **N/N** cross type



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Conclusions from simulations

- Low power with 1/6 sampling
- Lower power for low stray rate
- Lower power for cross type RRS
- Increases faster with F_0 sampling

See AHRP Technical Document 5

BREAK: Questions so far?

Outline

- Background of AHRP
- Parentage and RRS
- Proposed study design
- Simulations
- Power analysis
- Christie et al. 2014 review

Christie et al. 2014

Christie, M. R., M. J. Ford, and M. S. Blouin. 2014. On the reproductive success of early-generation hatchery fish in the wild. Evolutionary Applications:7(8). http://dx.doi.org/10.1111/eva.12183

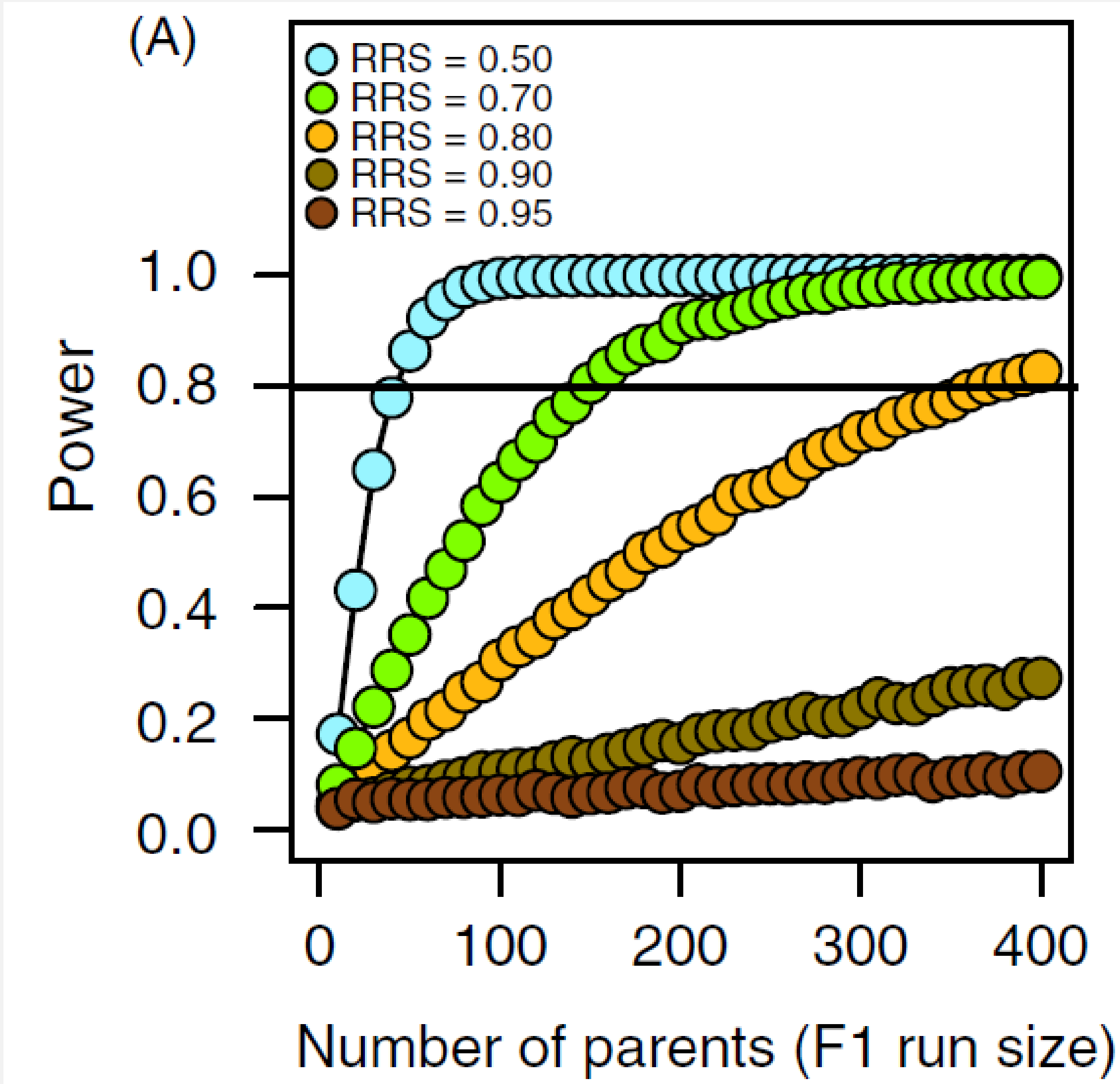
- Review of early-generation RRS studies
- Examine statistical power of RRS studies

Christie et al. 2014 Box 2

- Sample size and power for RRS
  - Vary single parent RRS from 0.5-0.95
  - Sample 5-400 parents
  - 50% stray rate
  - Generate offspring from negative binomial
  - Sample ALL offspring
  - Test for KNOWN fitness difference
  - Repeat 5,000 times
  - Power = % of tests that are “significant”

Christie et al. 2014 Review in Evolutionary Applications

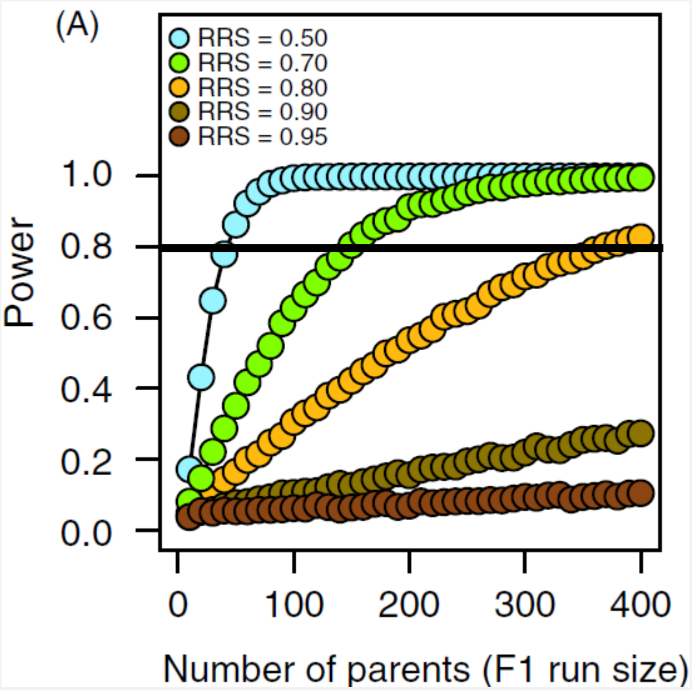
Christie et al. 2014 Box 2

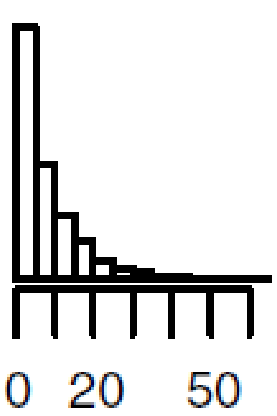


Christie et al. 2014 Review in Evolutionary Applications

Christie et al. 2014 Box 2

- Caveats
  - RRS = 0.5, 0.7, 0.8, 0.9, 0.95
  - Stray rate = 50%
  - # Parents 5-400
  - Sampled ALL offspring
  - Negative binomial of offspring had μ = 8





Christie et al. 2014 Review in Evolutionary Applications

Power analysis

Christie et al. 2014

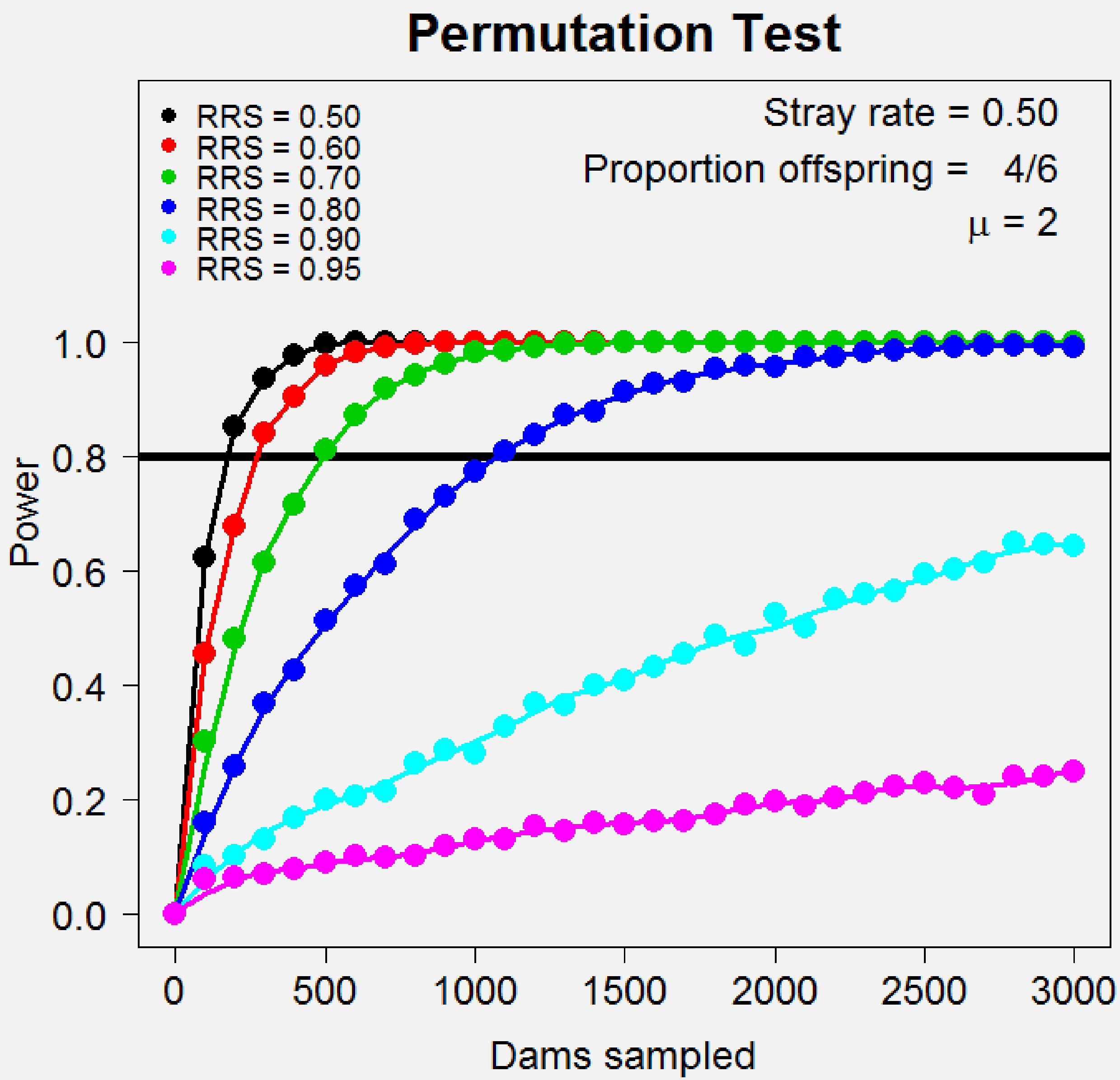
- 5 RRS values
- Sample 5-400 parents
- 50% stray rate
- Negative binomial of offspring μ = 8
- Sample ALL offspring

What I did

- Many RRS values
- Sample 0-3000 parents
- 50% & 15% stray rate
- Negative binomial of offspring μ = 2
- Sample proportions of offspring

See Future AHRP Technical Document

What I did



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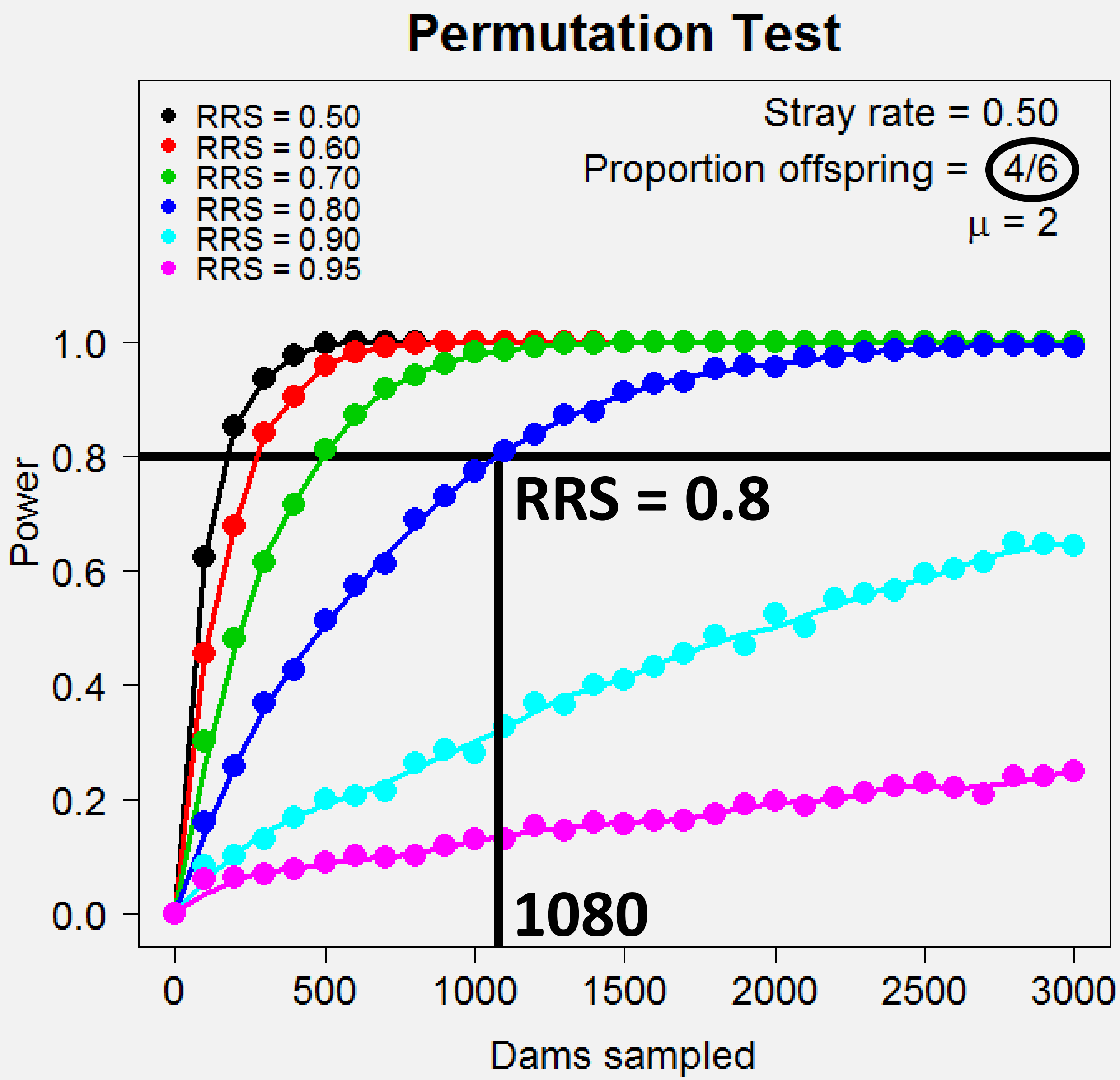
What I did



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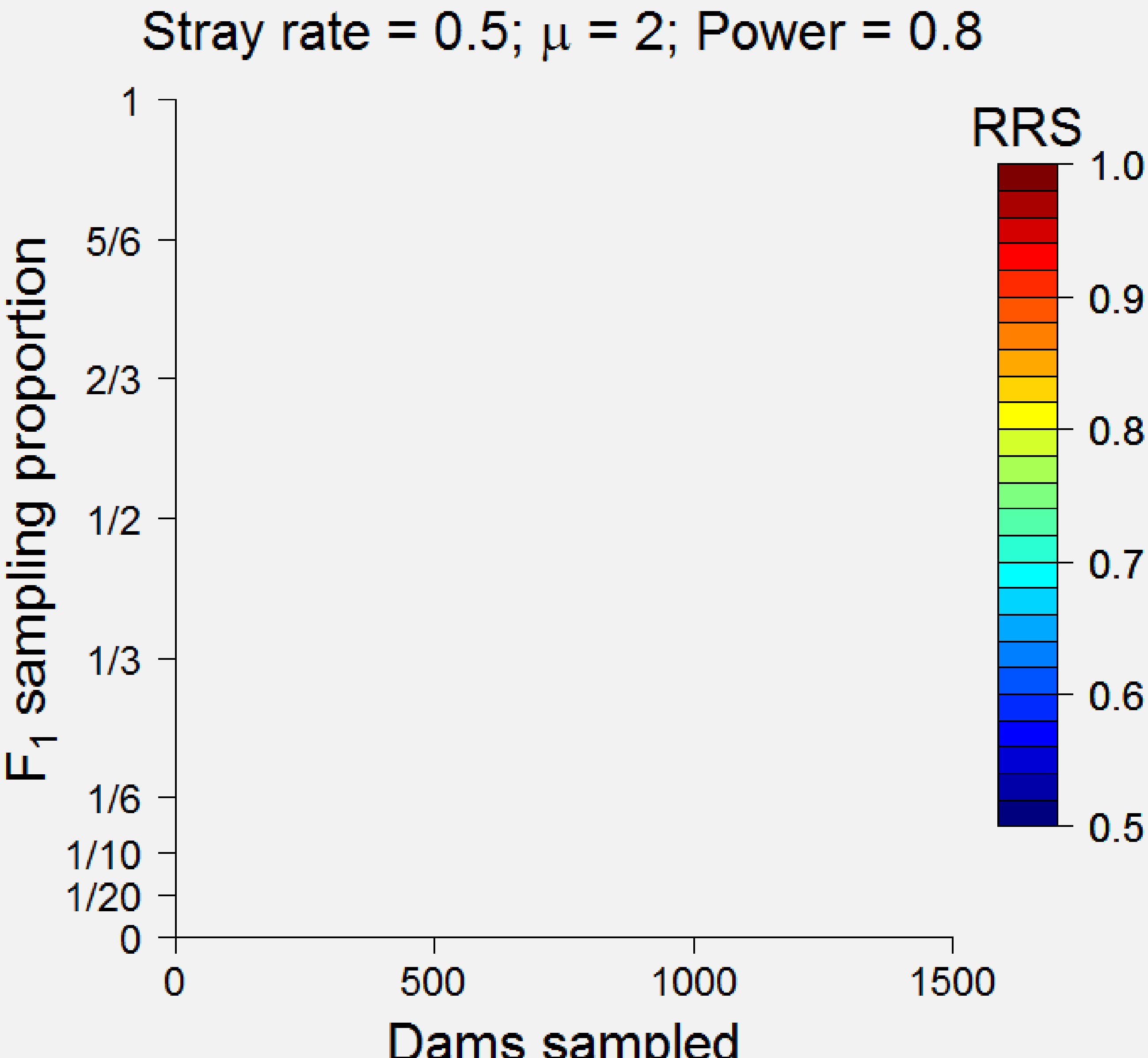
What I did



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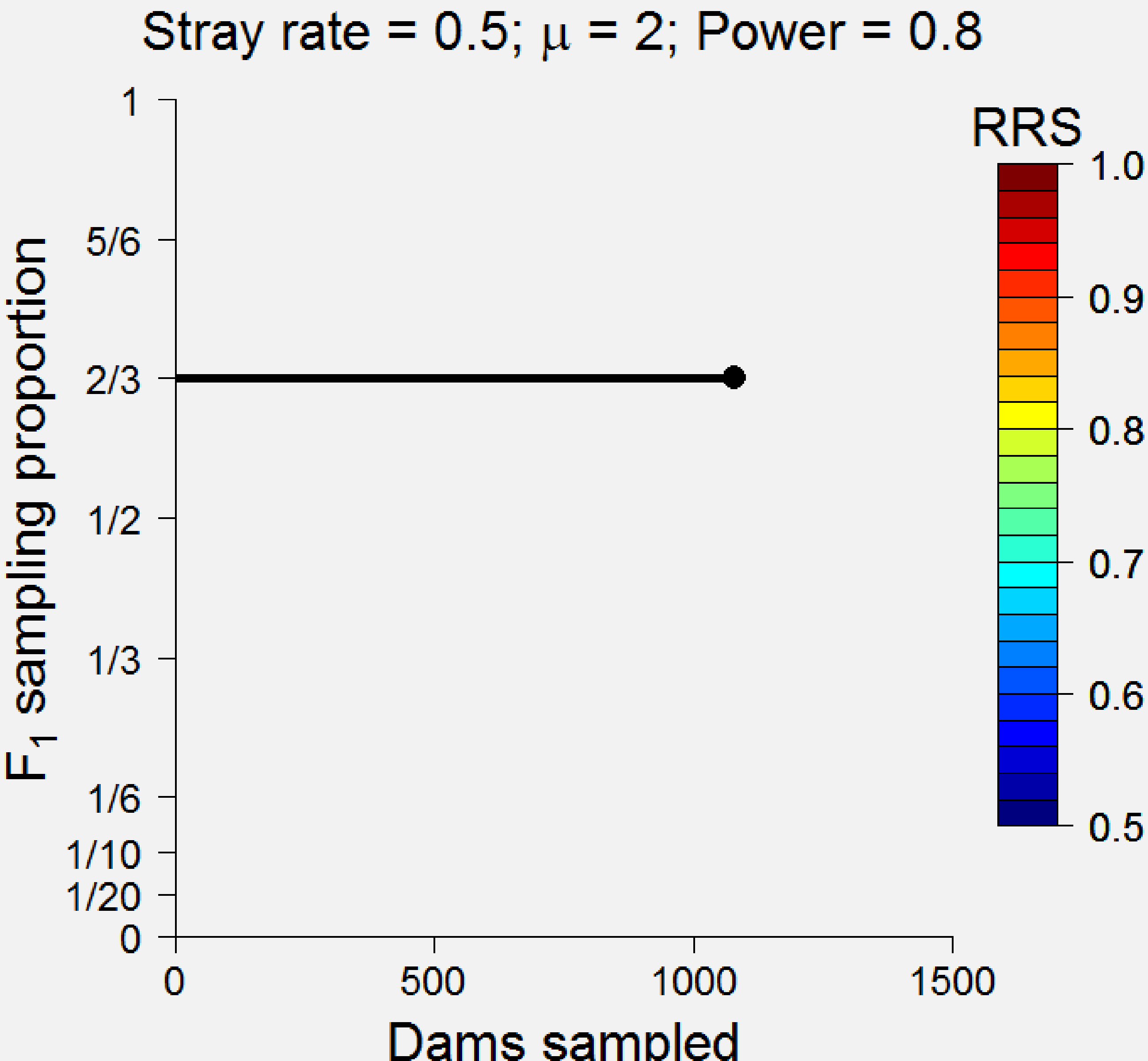
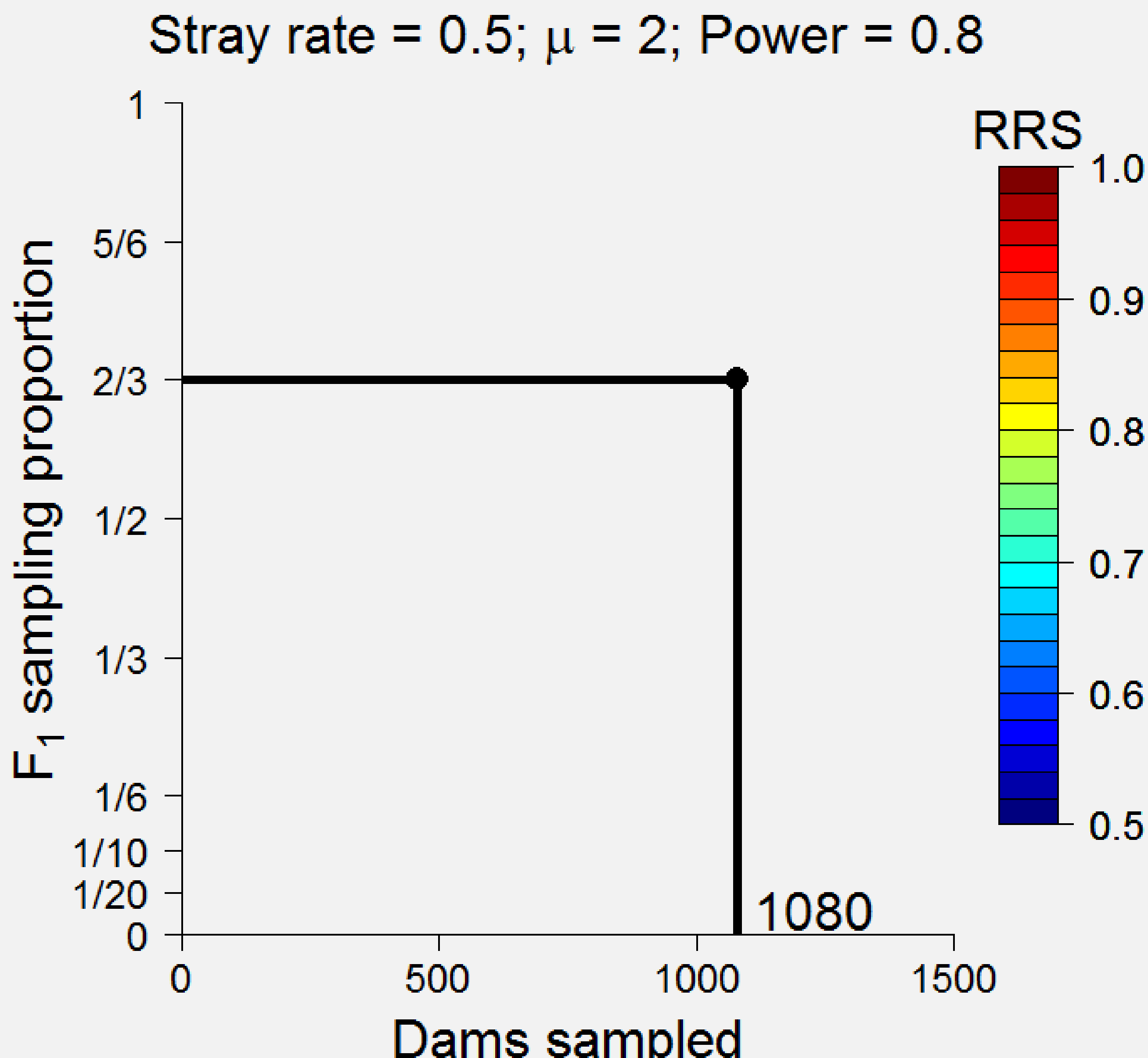
What I did



See Future AHRP Technical Document

What I did



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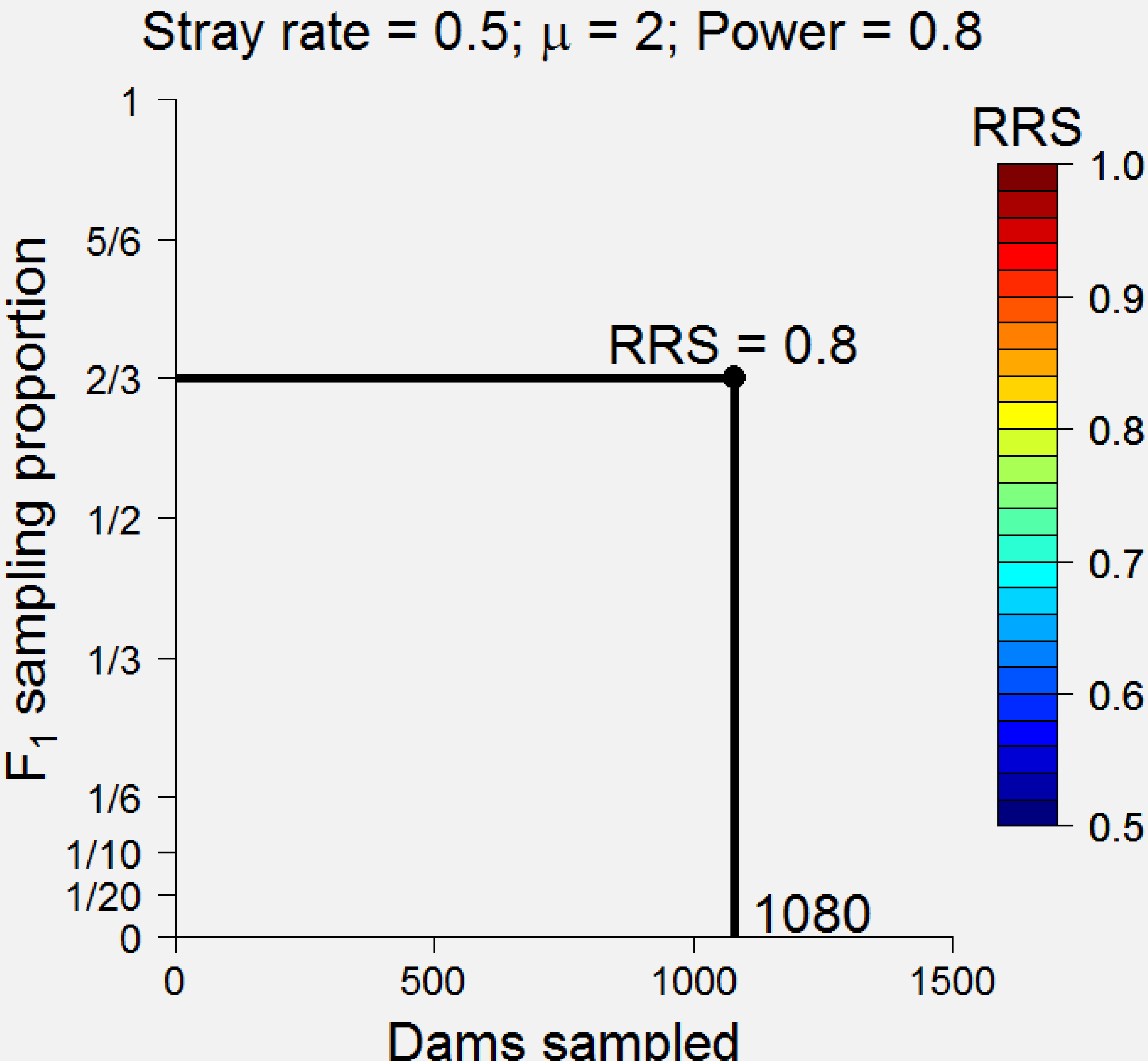
What I did



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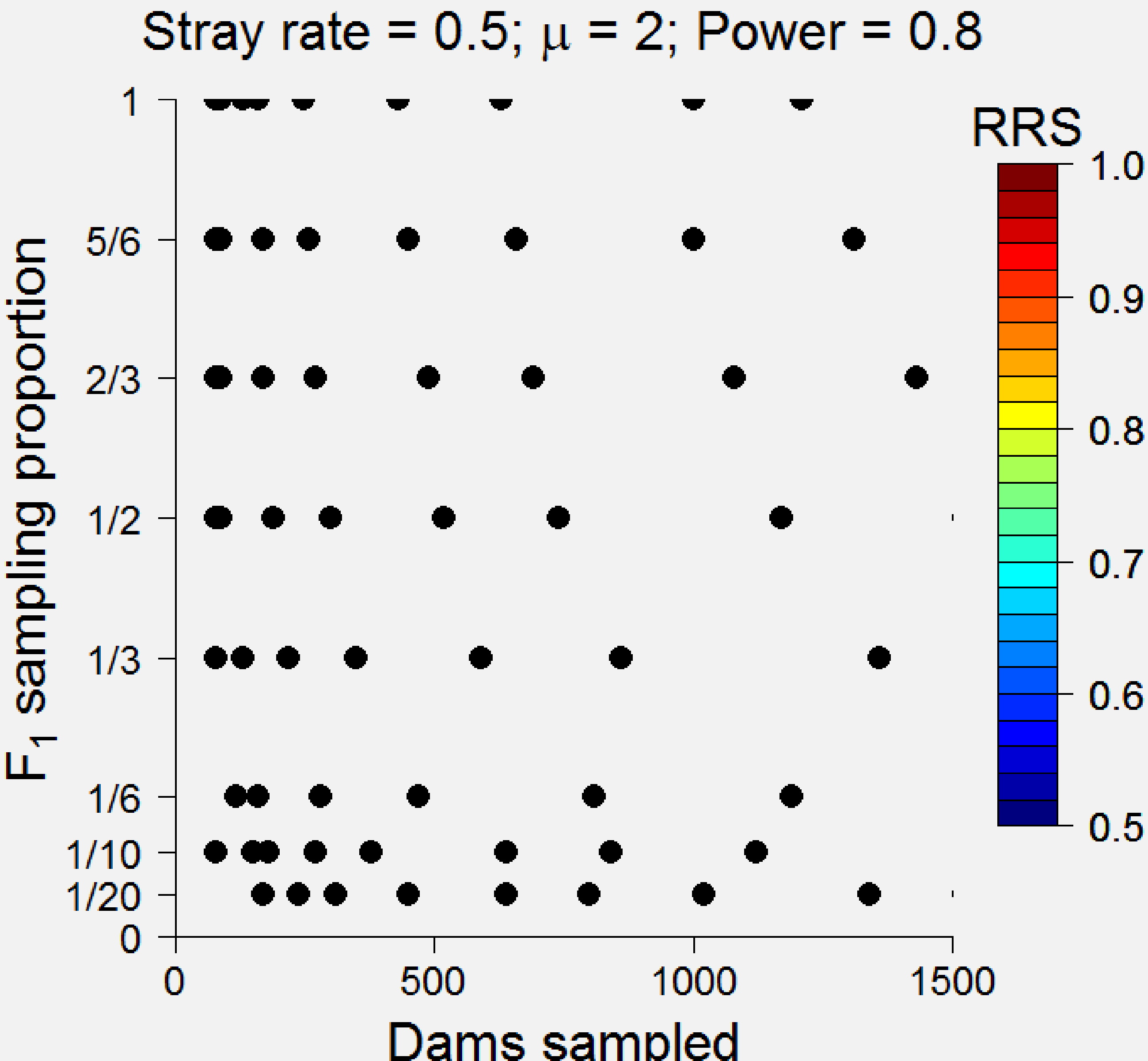
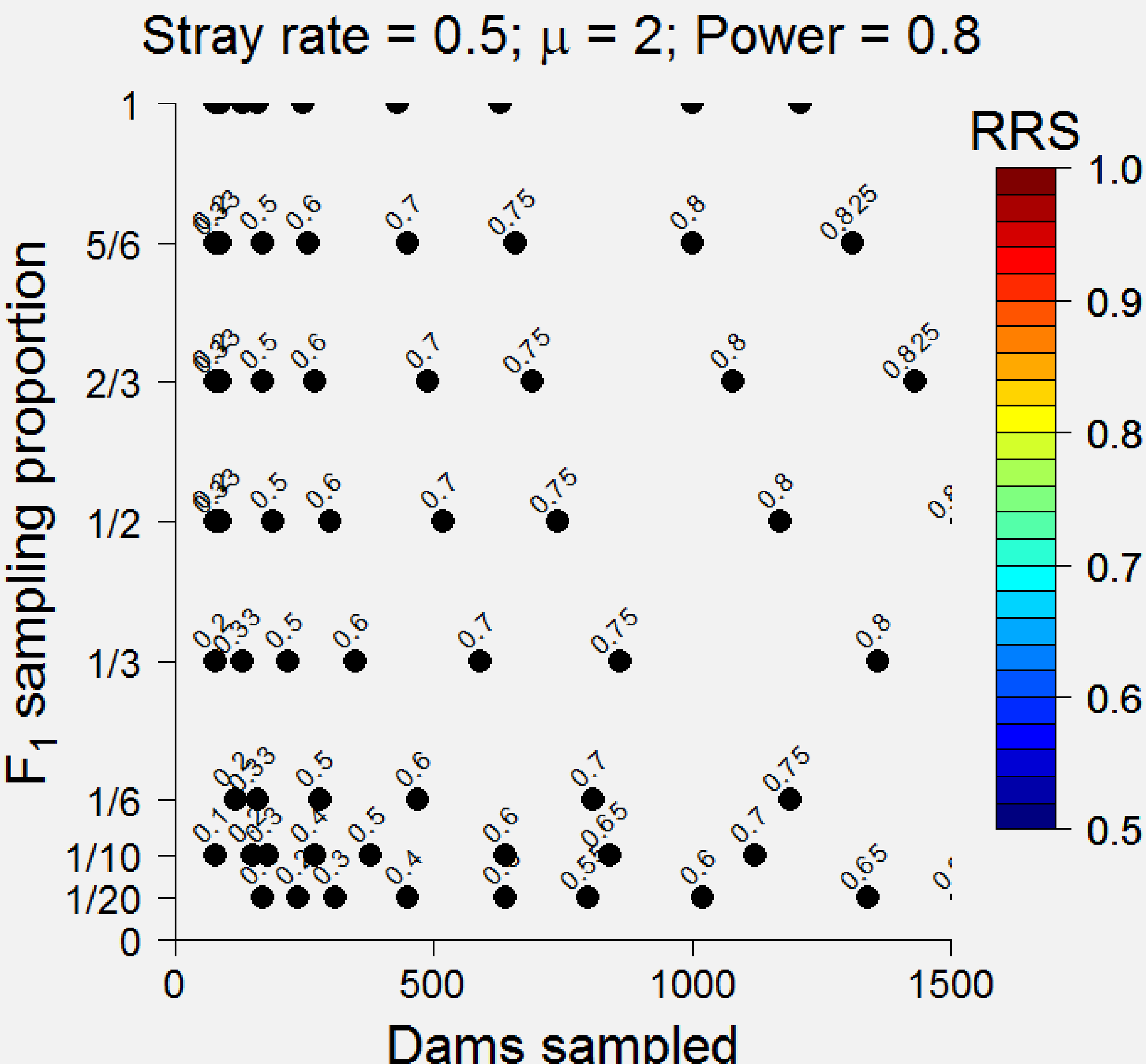
What I did

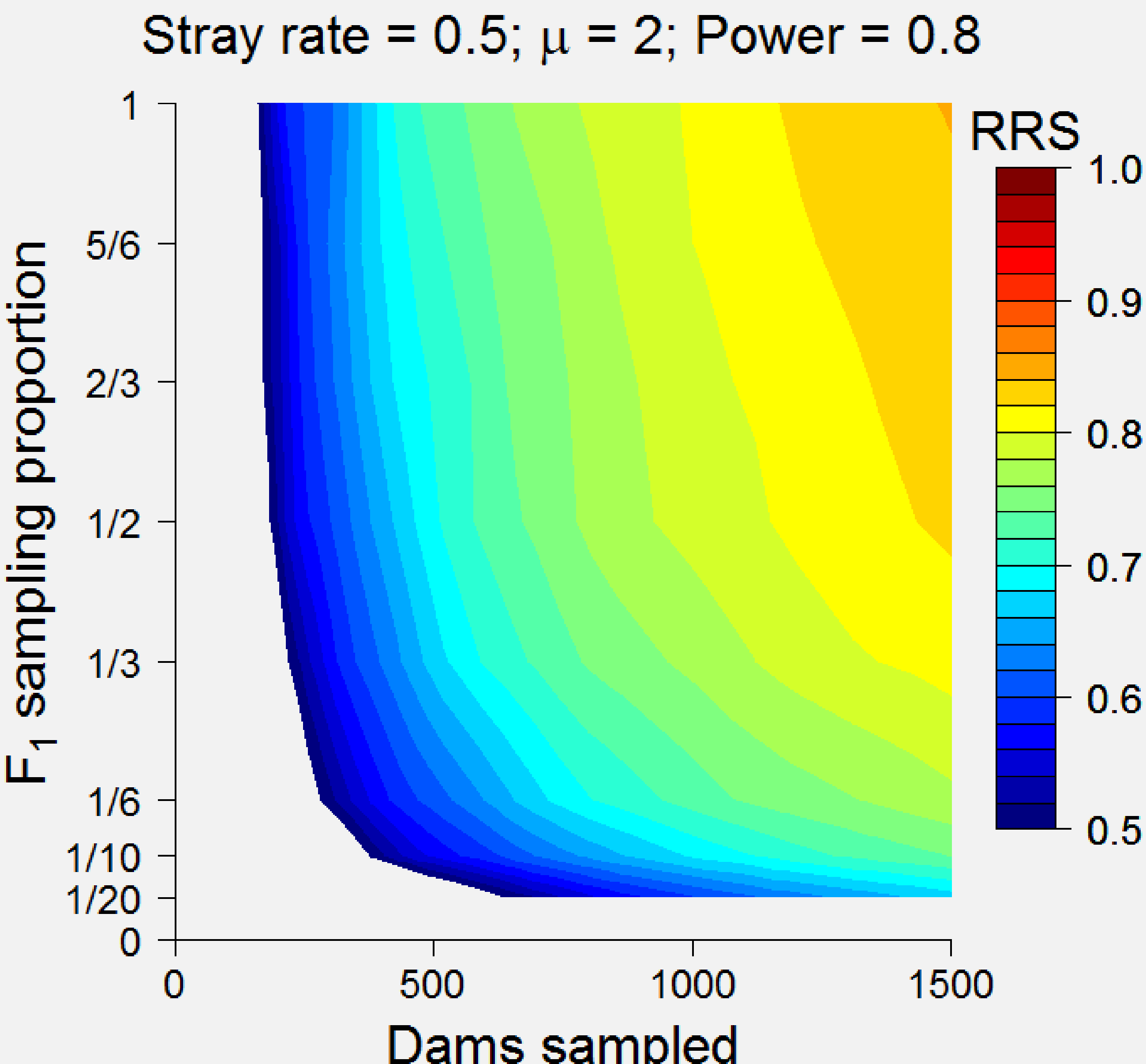


See Future AHRP Technical Document

What I did


Stray rate = 0.5; μ = 2; Power = 0.8
F1 sampling proportion
Dams sampled
RRS
1.0
0.9
0.8
0.7
0.6
0.5
1
5/6
2/3
1/2
1/3
1/6
1/10
1/20
0
500
1000
1500

What I did



See Future AHRP Technical Document

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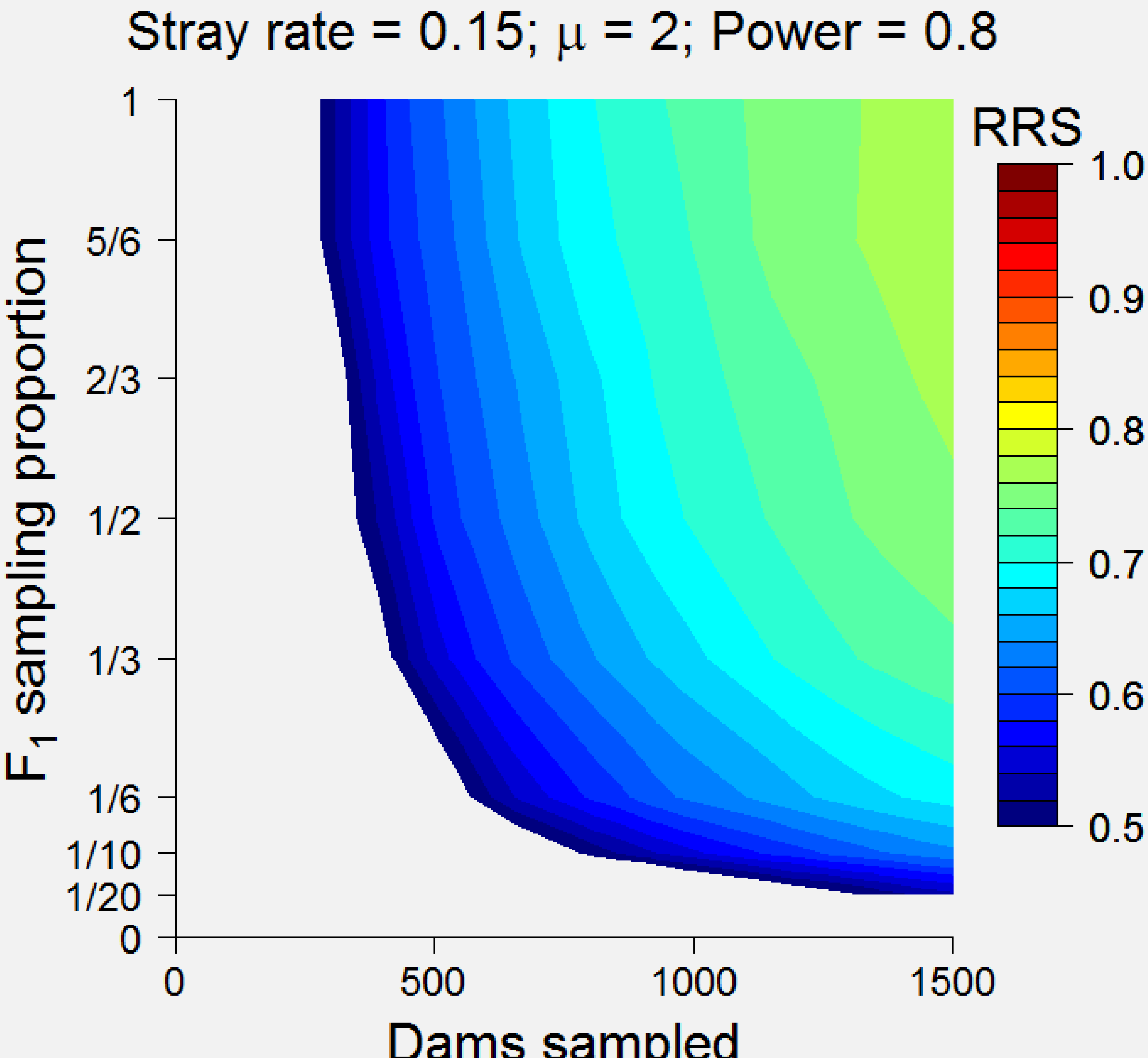


See Future AHRP Technical Document

Recommendations

- Where do we go from here?

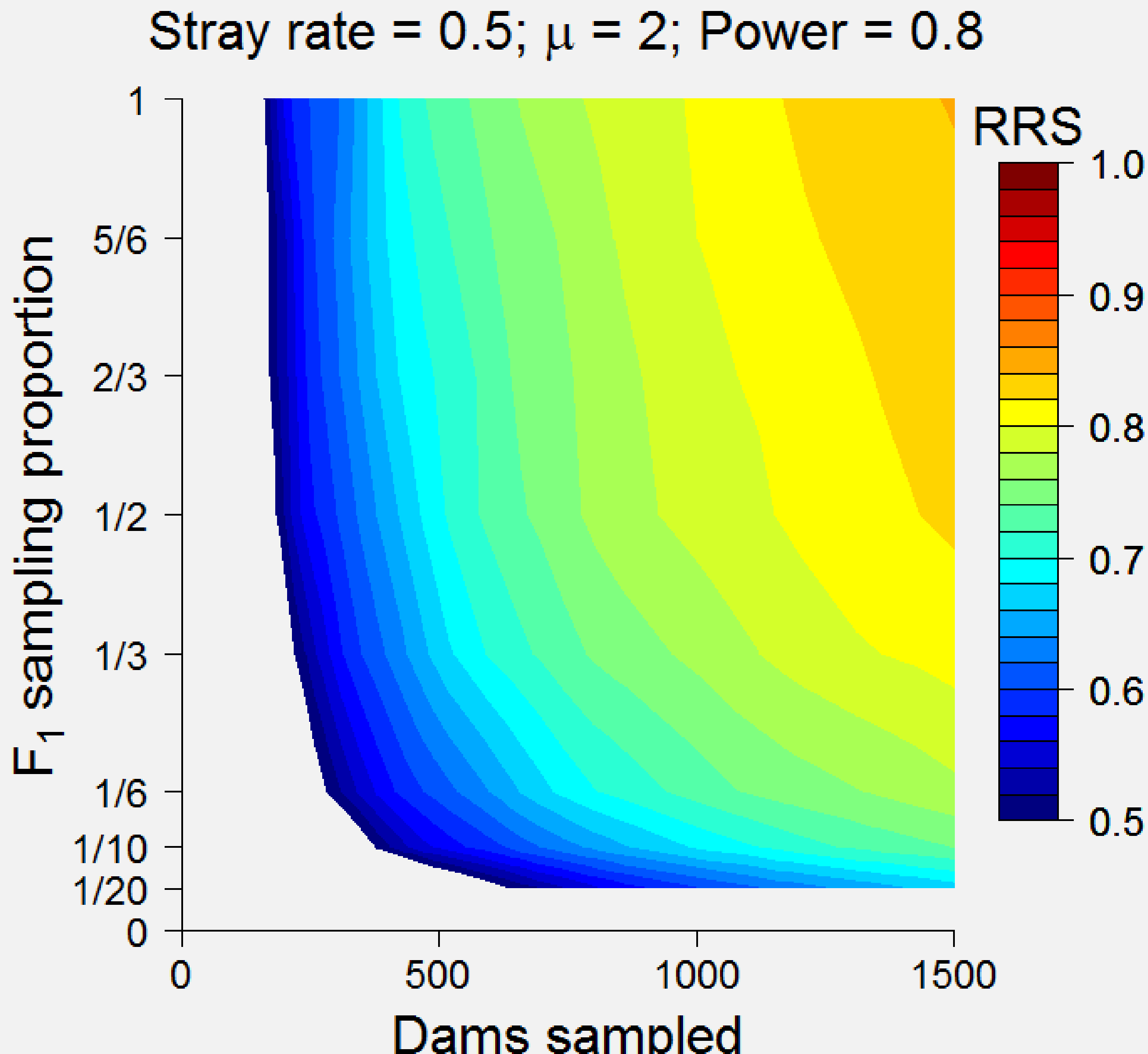
- Where are we?
  - Stray rate?
  - Sample size F_0?
  - Sample proportion of F_1?
    - Use sample proportion of F_0 (2013 & 2014) as proxy

See Future AHRP Technical Document

Sample sizes of F_0 – PWS Pink

Location	Stray	2013	2014
Spring	Low	1,351	151
Stockdale	Low	1,195	1,551
Gilmour	Low	NA	669
Hogan	High	829	2,649
Erb	High	637	1,957
Paddy	High	125	1,158

Sample sizes of F_0 – PWS Pink



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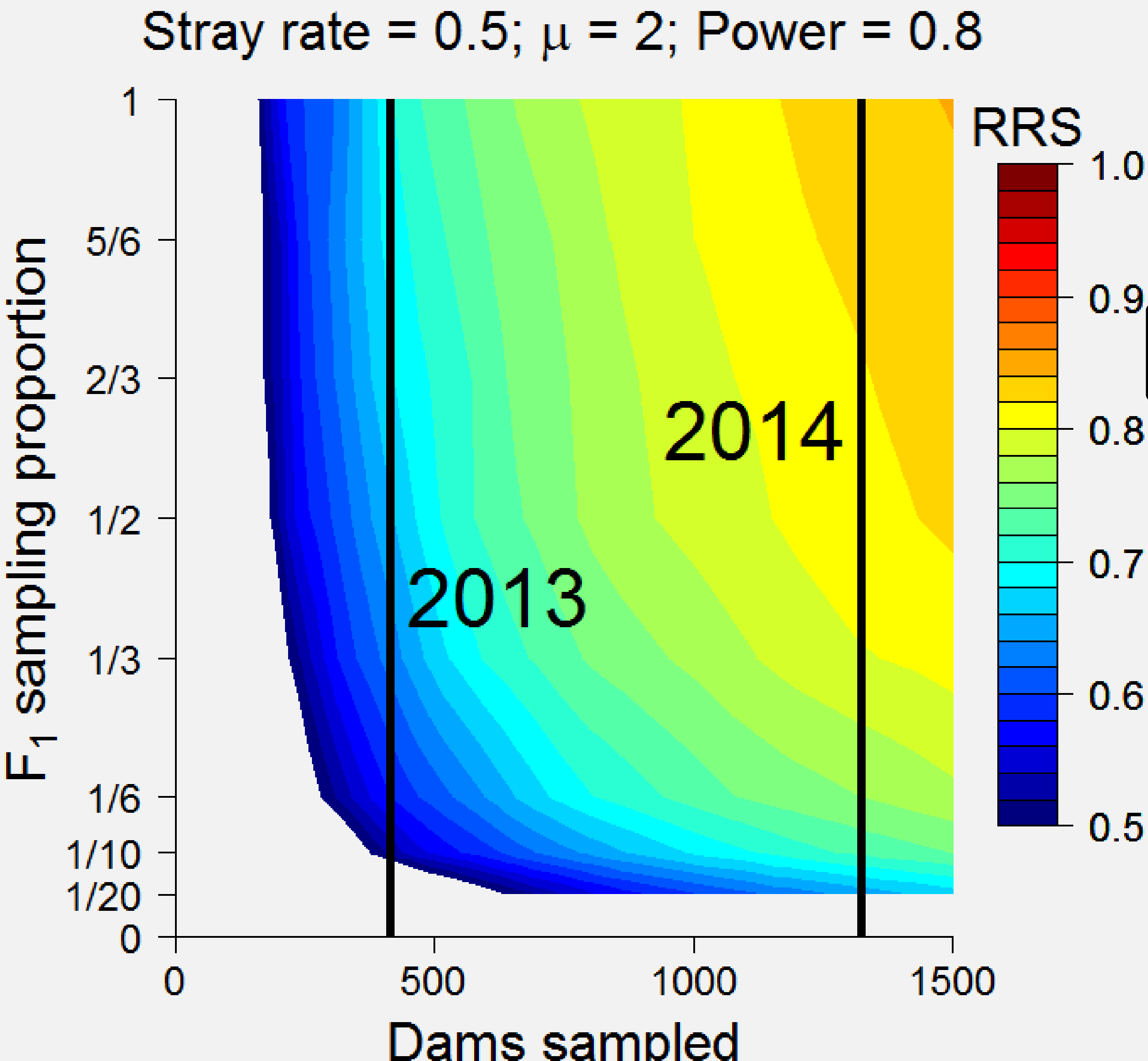

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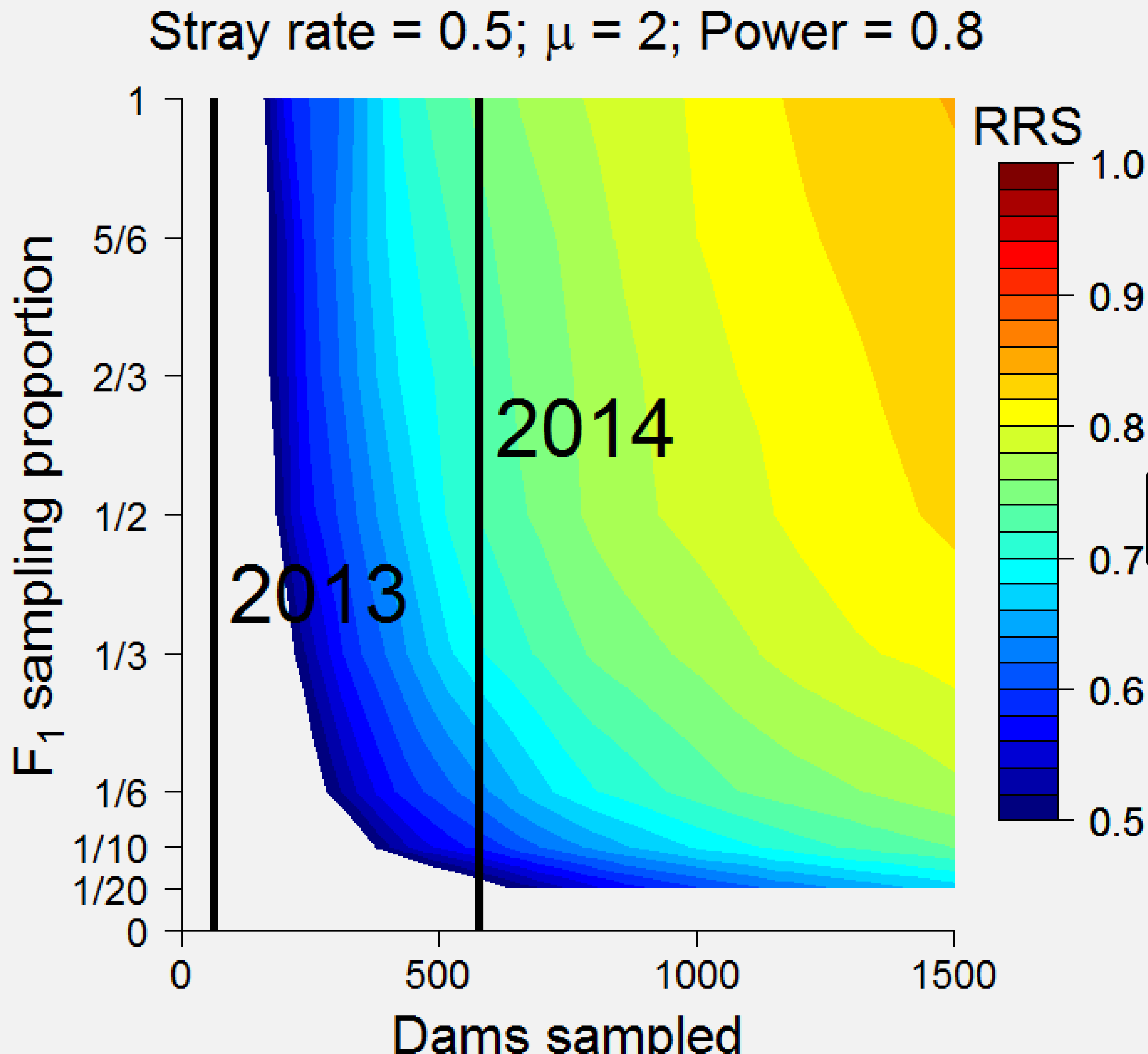

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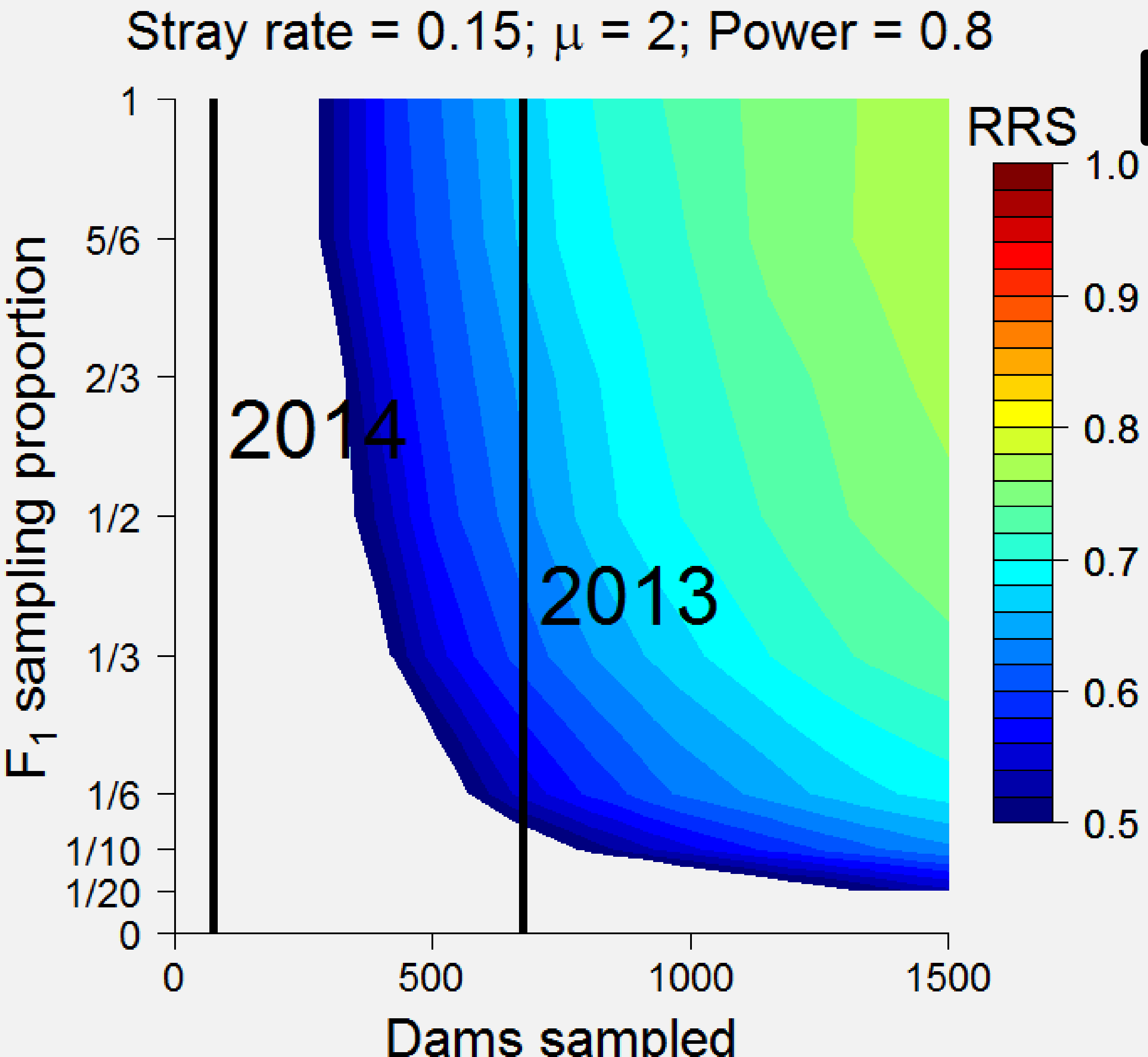

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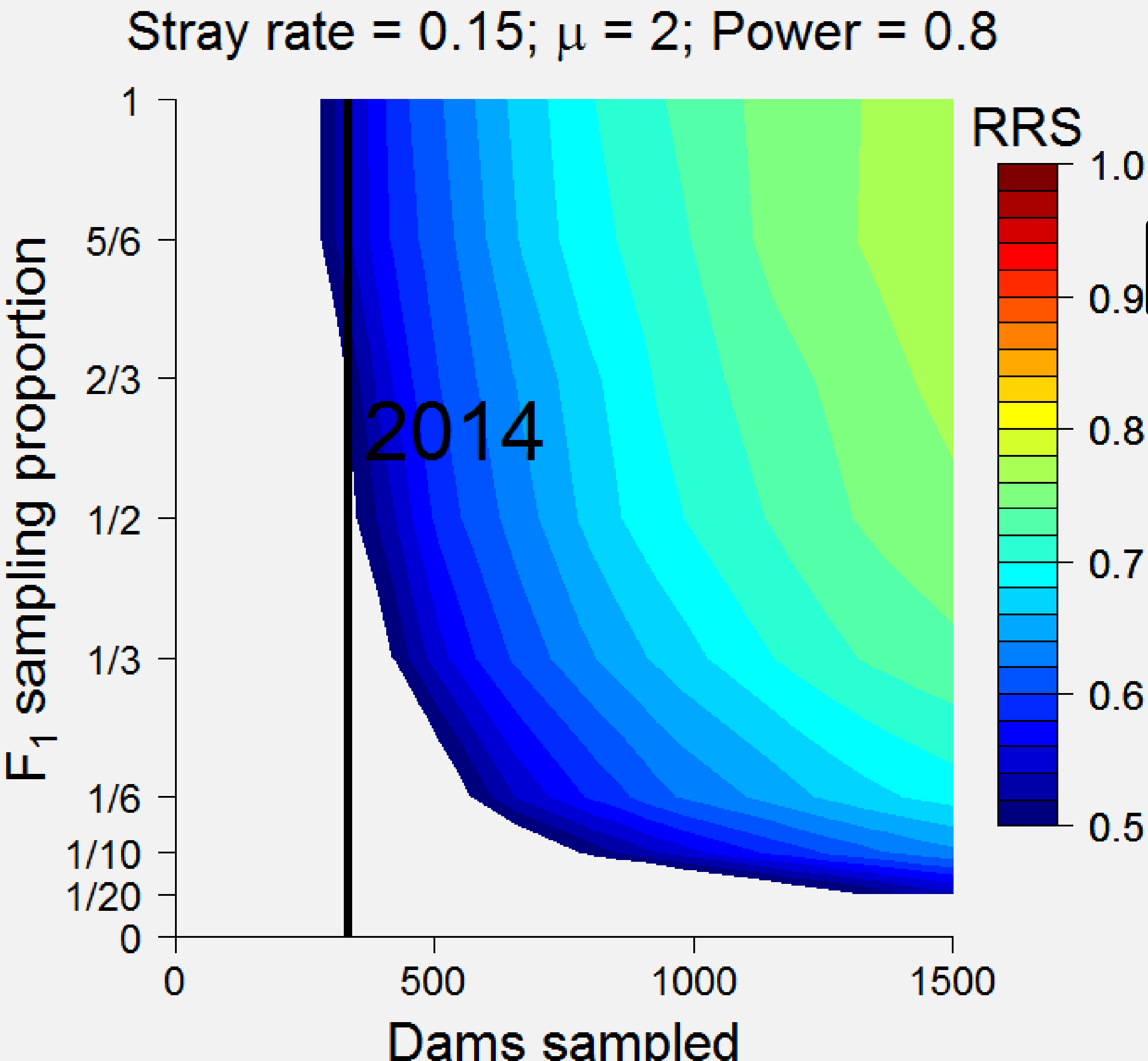

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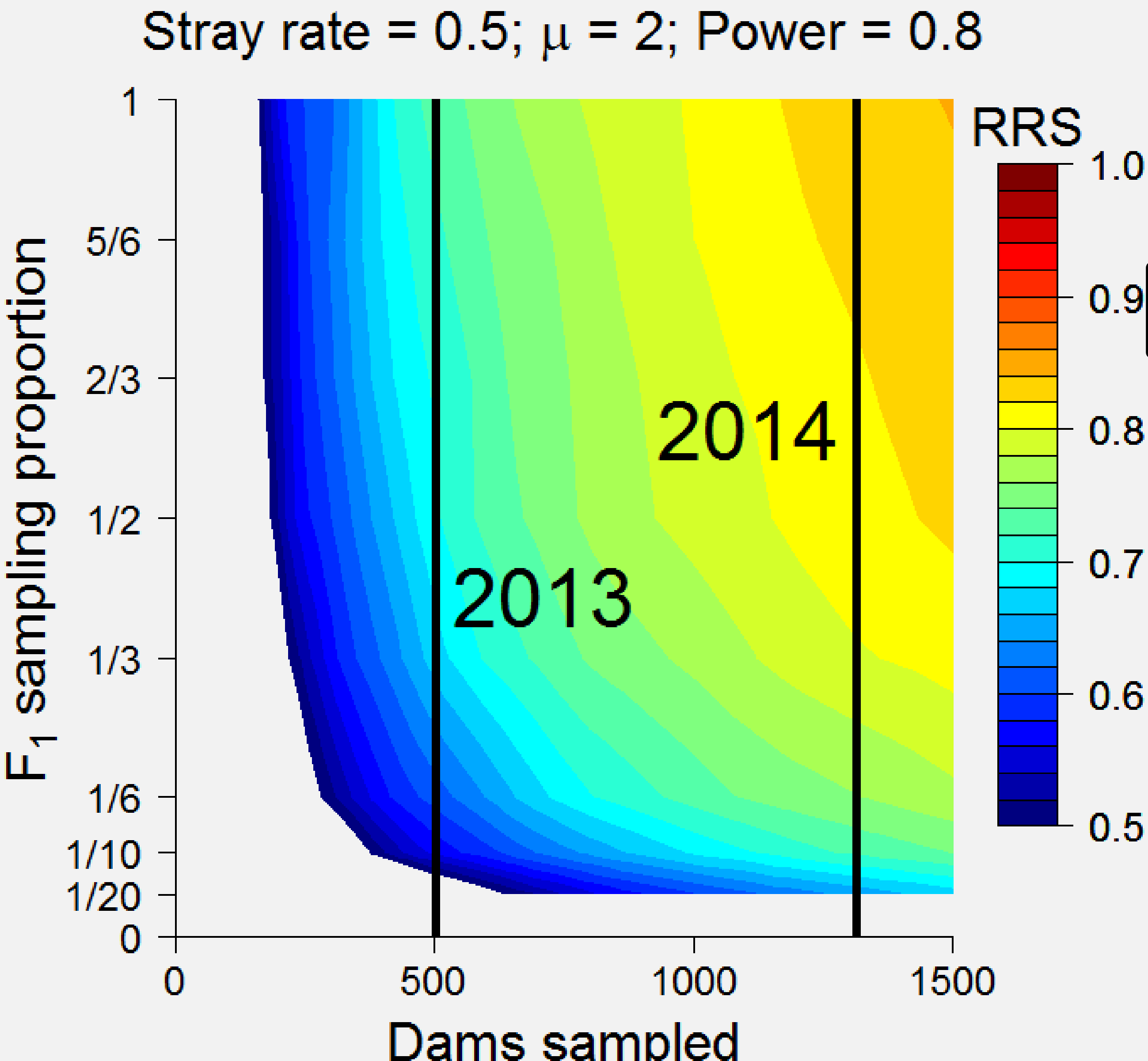
See Future AHRP Technical Document

Sample sizes of F_0 – SEAK Chum

Location	Stray	2013	2014
Admiralty	Low	421	260
Prospect	Low	487	473
Fish	High	1,008	2,626
Sawmill	High	344	124

Sample sizes of F_0 – SEAK Chum



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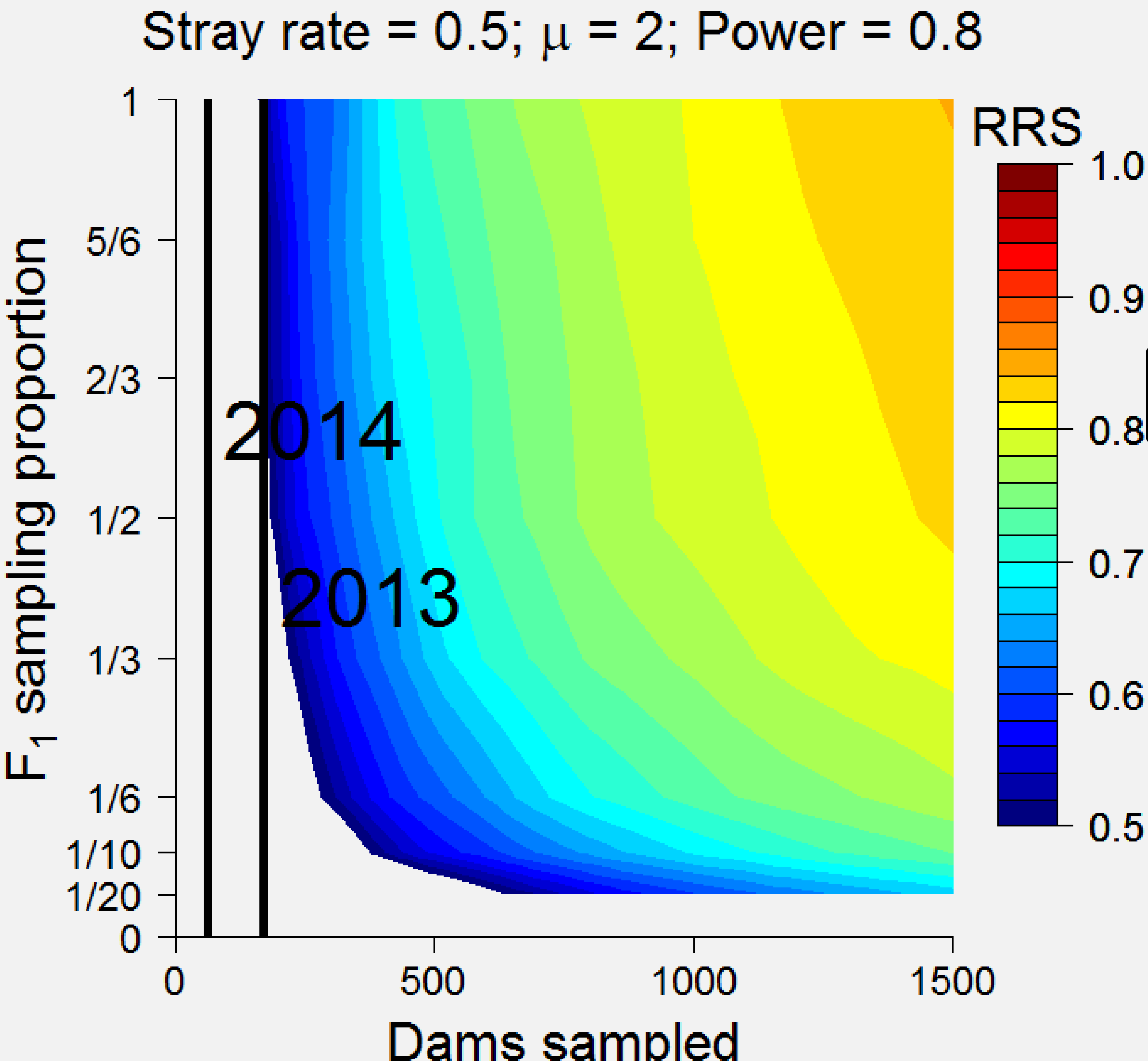

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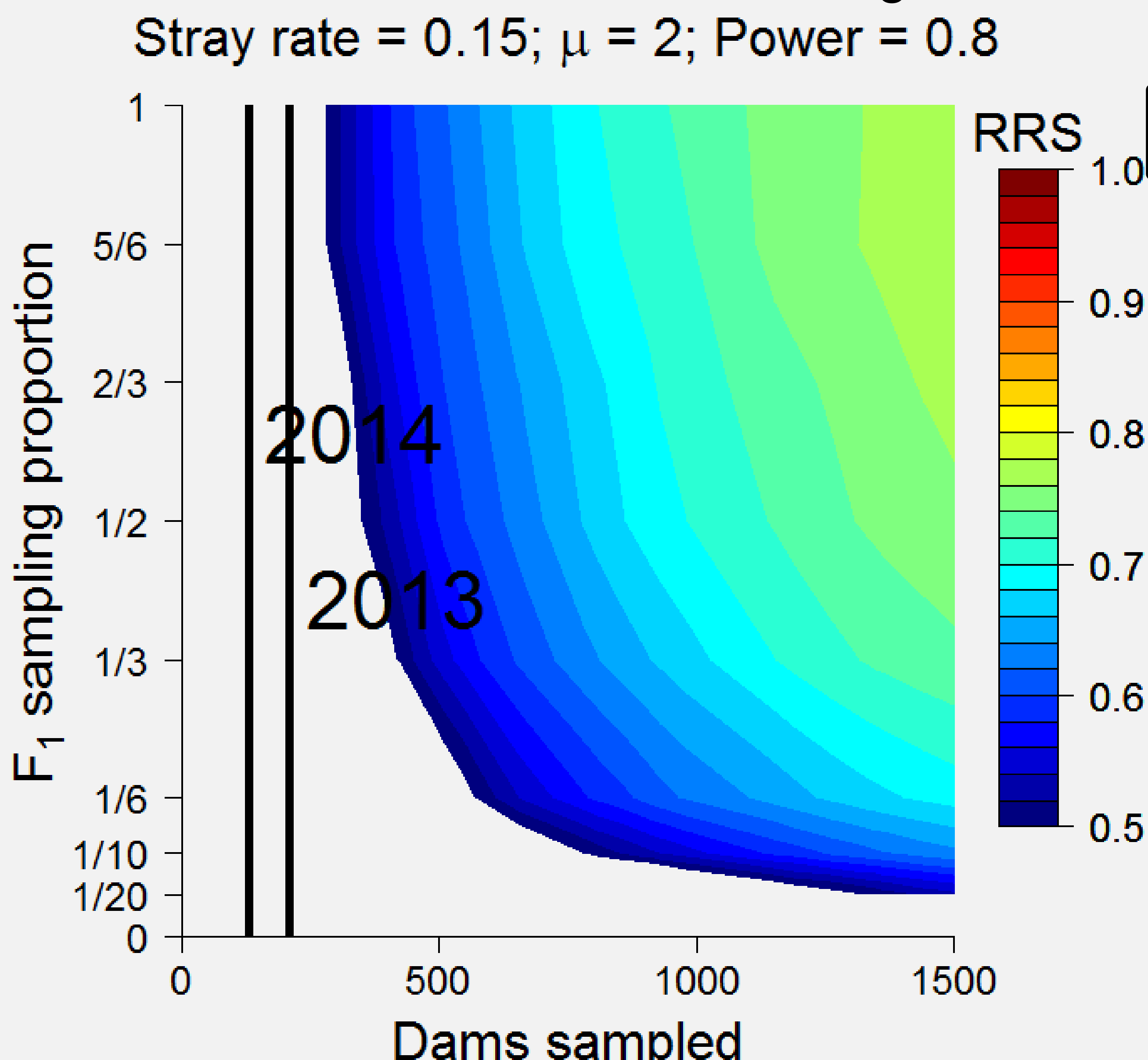

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See Future AHRP Technical Document

Conclusions

Power depends on	**Higher power with**
• Stray rate	50% stray rate
• Distribution of offspring	
– Shape	Low variation
– Mean RS	High Productivity
• Num. families sampled (F_0)	> 500 families
• Prop. offspring sampled (F_1)	High prop. offspring

Questions for Science Panel

- What level of power, in terms of maximum RRS that would likely be detectable, is appropriate for this study?
- What are alternative study designs that could increase the proportion of adults and offspring sampled?

See AHRP Technical Document 5

Acknowledgements

NOAA

PRINCE WILLIAM SOUND
SCIENCE
CENTER

SITKA SOUND
SCIENCE CENTER

Questions?