Supplementation with local, natural-origin broodstock may minimize negative fitness impacts in the wild

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Types of hatchery programs

Supplementation – Prevent extirpation, rebuild natural production (integrated)

Reintroduction – Restore extirpated populations (outside stocks, integrated)

Harvest augmentation – Fish for harvest (often segregated)

Integrated program

- Lower degree of domestication
- Lower genetic risk to natural population

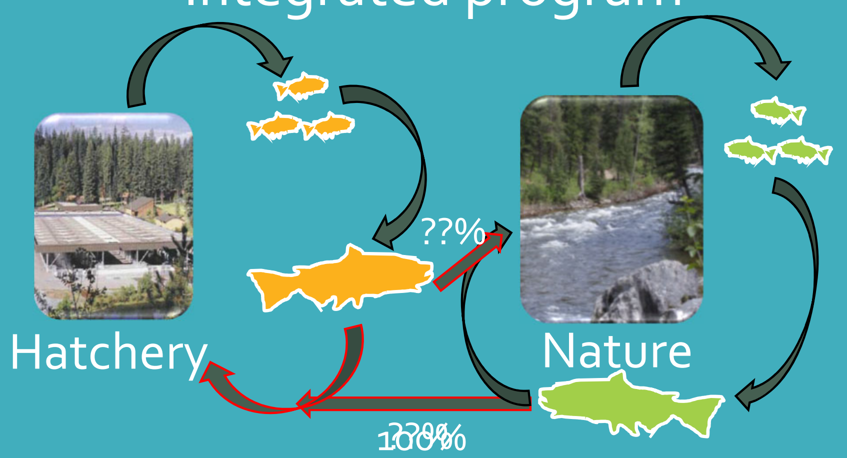
Segregated program

- Higher degree of domestication (“hatchery-adapted”)
- Higher genetic risk to natural population

Types of hatchery programs

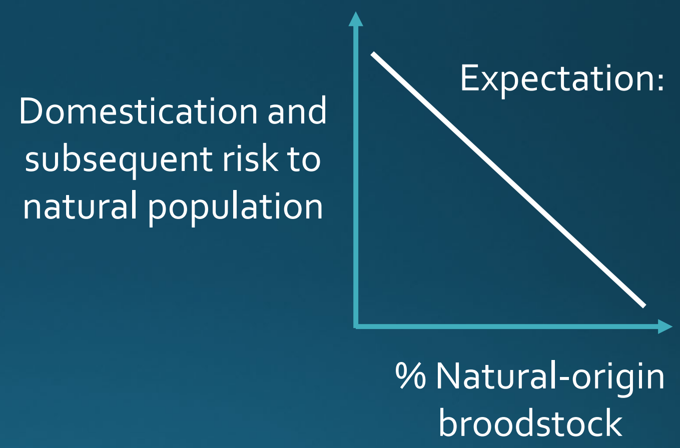
Supplementation – Prevent extirpation, rebuild natural production (integrated)

Integrated program



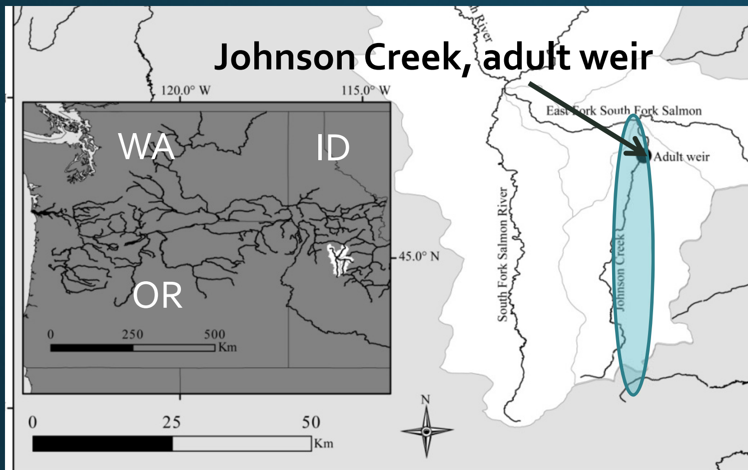
- Lower degree of domestication
- Lower genetic risk to natural population

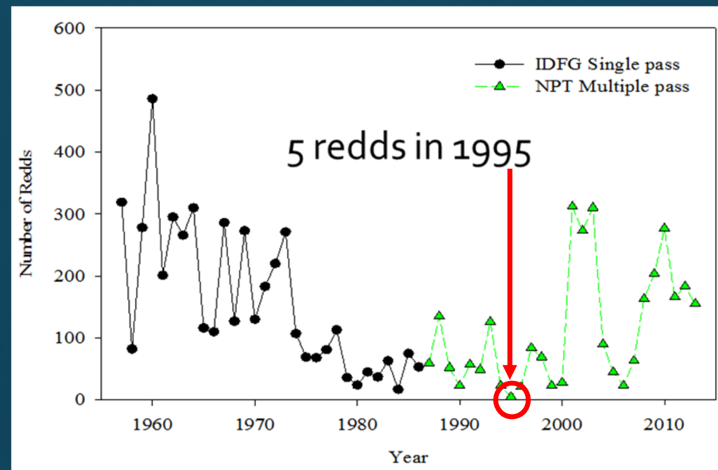
- Proportion of natural-origin fish in broodstock and hatchery-origin fish on spawning grounds varies by program and year



- Johnson Creek supplementation program = 100% natural-origin broodstock every year

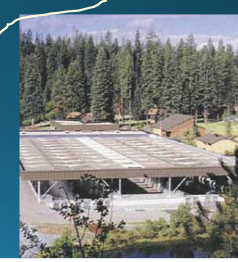
Spring/Summer Chinook Salmon in Johnson Creek





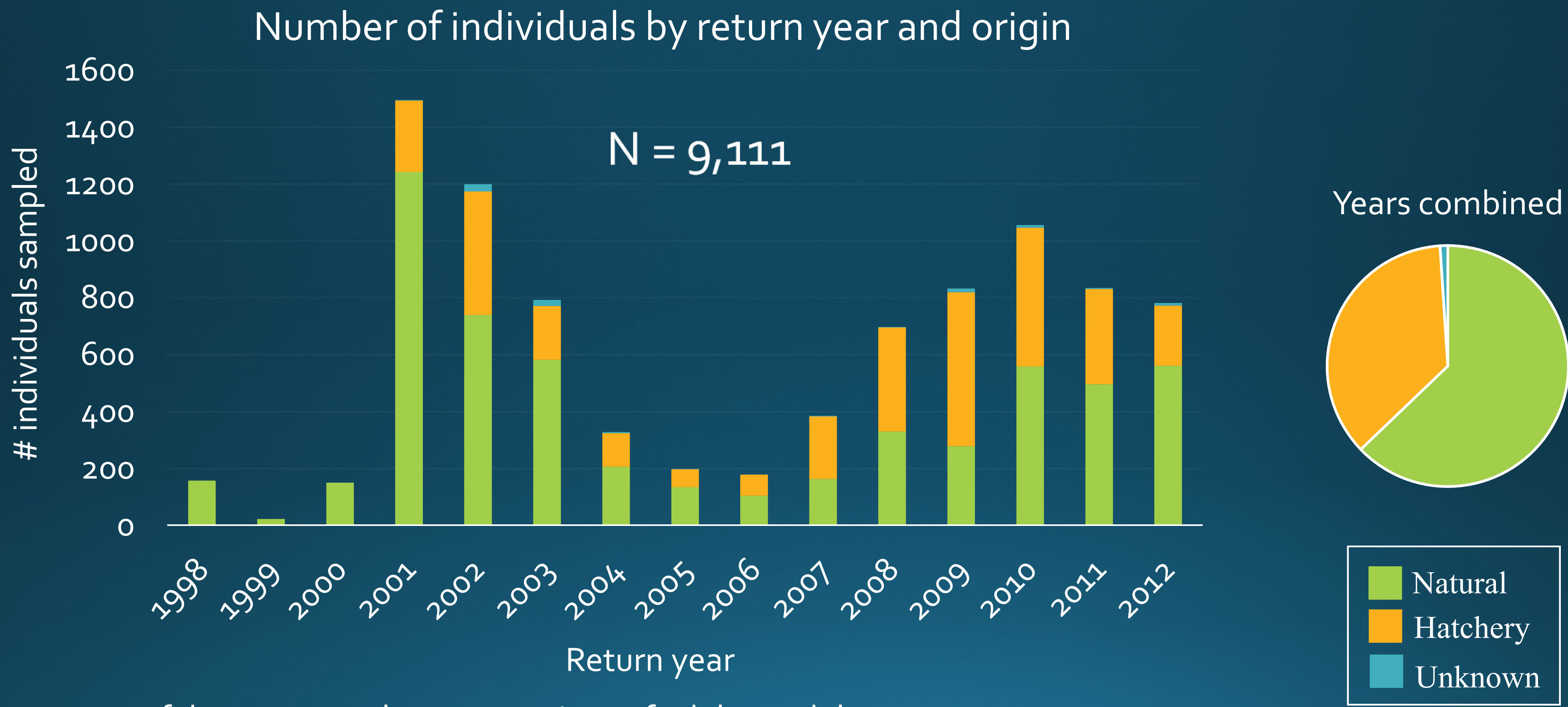
Study system

- Nez Perce Tribe initiated supplementation program in 1998
- Only natural-origin returns used for broodstock



Evaluate lifetime reproductive success of Chinook salmon in the wild at the initiation of supportive breeding (Hess et al. 2012 Molecular Ecology)

Summary of dataset

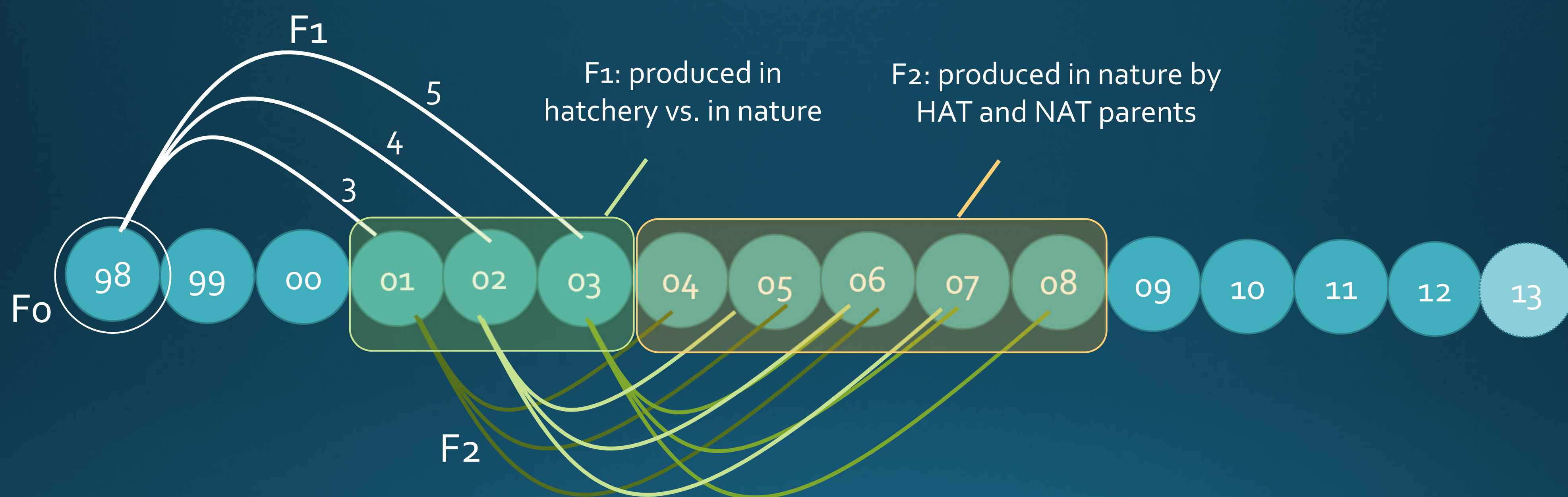


15 years of data = 5 complete generations of adult to adult returns

Sampled high proportion of natural spawners (~90% of fish produced above weir genetically assign to parents)

Methods

i.) Use DNA to reconstruct genetic pedigrees

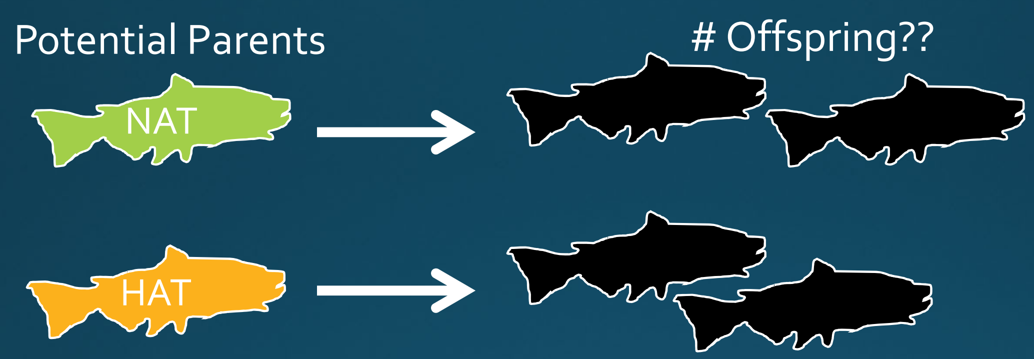


- 5 Fo broodyears of adult to adult returns over 2 generations

Methods

ii.) Use genetic pedigrees to quantify reproductive success

- Reproductive success = How many offspring did each individual produce?



- Comparison of reproductive success (RS) between hatchery and natural

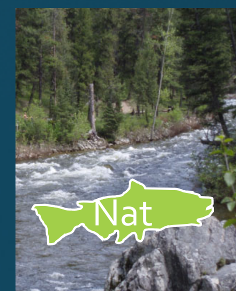
$$RRS = \frac{\text{Avg \# offspring produced by a hatchery fish}}{\text{Avg \# offspring produced by a natural fish}}$$

Objectives

1.) Demographic boost provided by the hatchery over two generations?

Hatchery environment

Offspring & Grand-offspring



Wild environment

Objectives

1.) Demographic boost provided by the hatchery over two generations?

Hatchery environment

Offspring
Grand-offspring

Wild environment

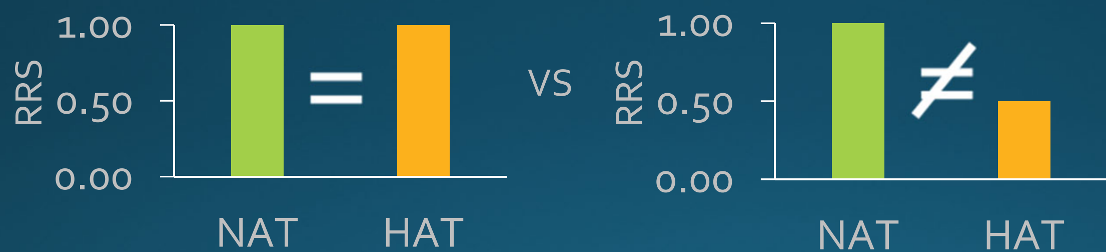
2.) Differences in reproductive success between hatchery-reared and natural-origin fish spawning naturally?

VS

Objectives

1.) Demographic boost provided by the hatchery over two generations?

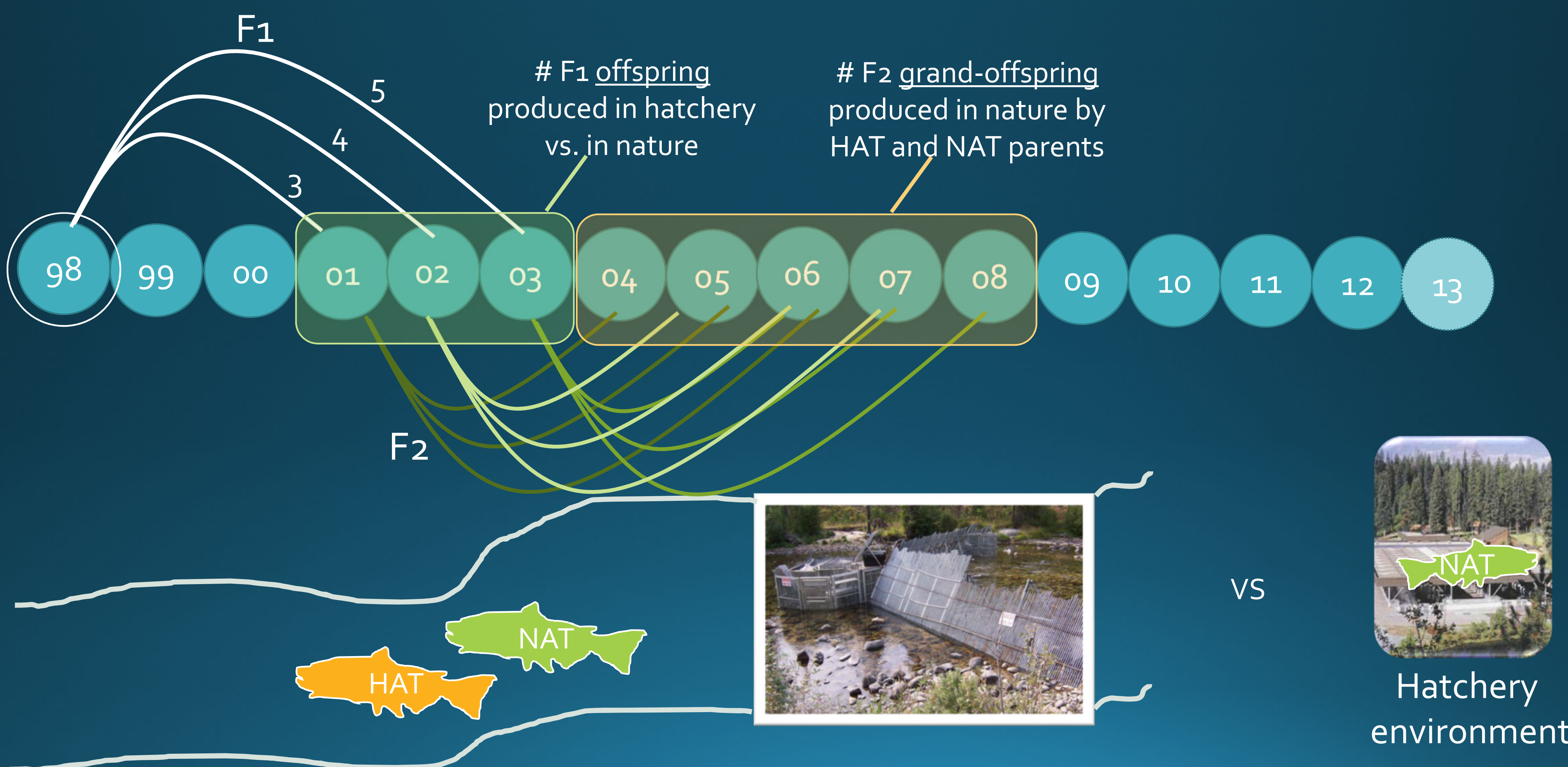
2.) Differences in reproductive success between hatchery-reared and natural-origin fish spawning naturally?



3.) Do hatchery-reared fish reduce the fitness of natural-origin fish?

Objective 1

i.) Demographic boost provided by the hatchery?



Objective 1

i.) Demographic boost provided by the hatchery?

Brood year	Adult offspring produced relative to wild	Adult grand-offspring produced relative to wild
1998	2.79	1.22
1999	n/a	n/a
2000	1.20	0.89
2001	5.22	3.64
2002	5.40	4.76
2003	7.94	9.99*
2004	5.25	tbd
2005	4.41	tbd
2006	3.40	tbd
2007	4.70	tbd
Mean	4.48	2.63+

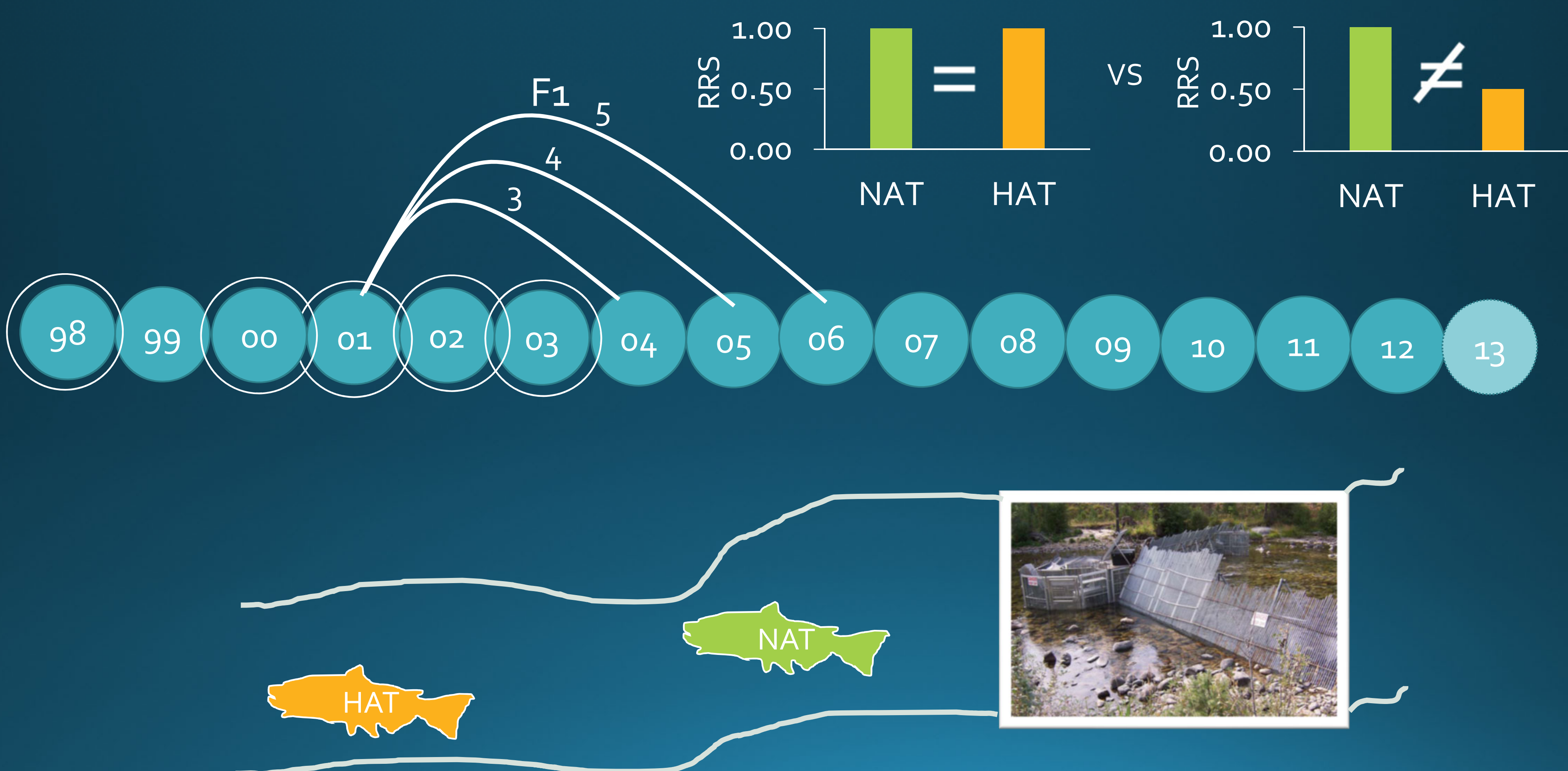
- Survival advantage in the hatchery environment
- Demographic boost continues into second generation

* BY2003 grand-offspring doesn't yet include BY2008 F2 assignments from 2013

+ Mean for BYs 1998-2002

Objective 2

Reproductive success differences between hatchery and natural spawning in nature?

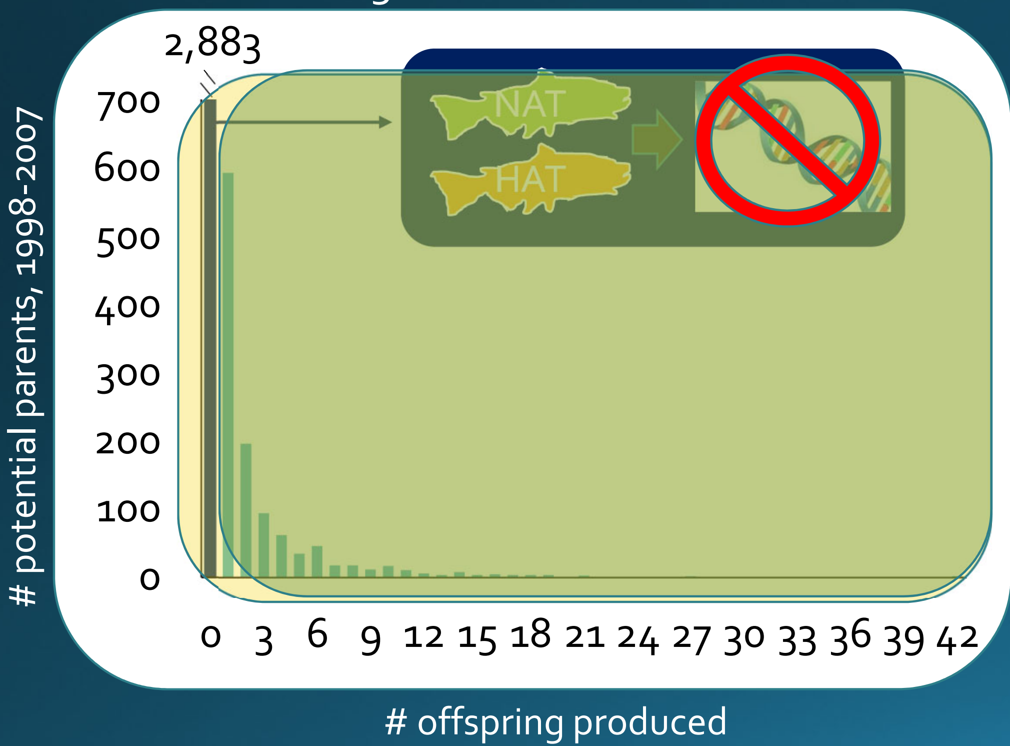


Objective 2

Reproductive success differences between hatchery and natural spawning in nature?

High variance in reproductive success - most produce zero returning adult offspring

Those that produce zero offspring, have no direct genetic effect on fitness

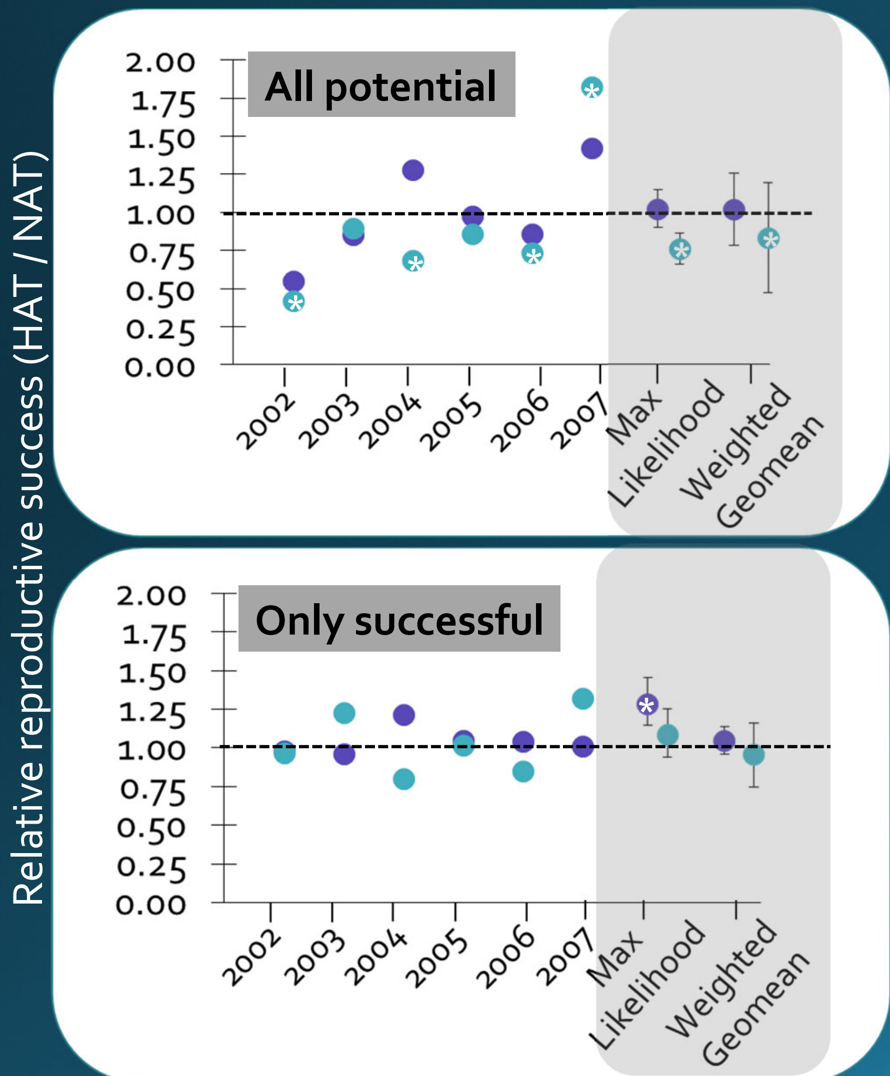


Evaluate reproductive success in two ways

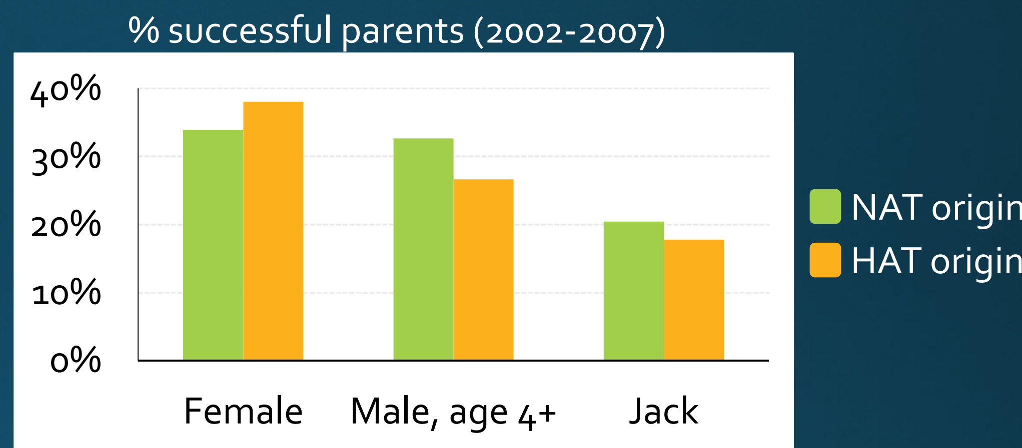
a.) Include all potential spawners regardless of whether they produced returning adult offspring or not

b.) Include only successful spawners (produced at least 1 returning adult offspring)

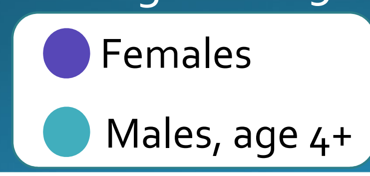
Reproductive success differences between hatchery and natural spawning in nature?



- Hatchery rearing yielded fewer males that reproduced (possible sexual selection in action)



- Many hatchery jacks present, likely poor spawn success
- RRS estimates similar between hatchery and natural fish, no statistical differences (recognize some years with low power due to sample size; average annual 95% CIs ranged ~0.65 and 1.50)



Objective 3

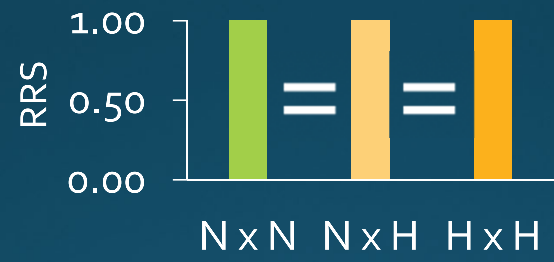
Do hatchery-reared fish reduce the fitness of natural-origin fish?

Parents ← → Offspring

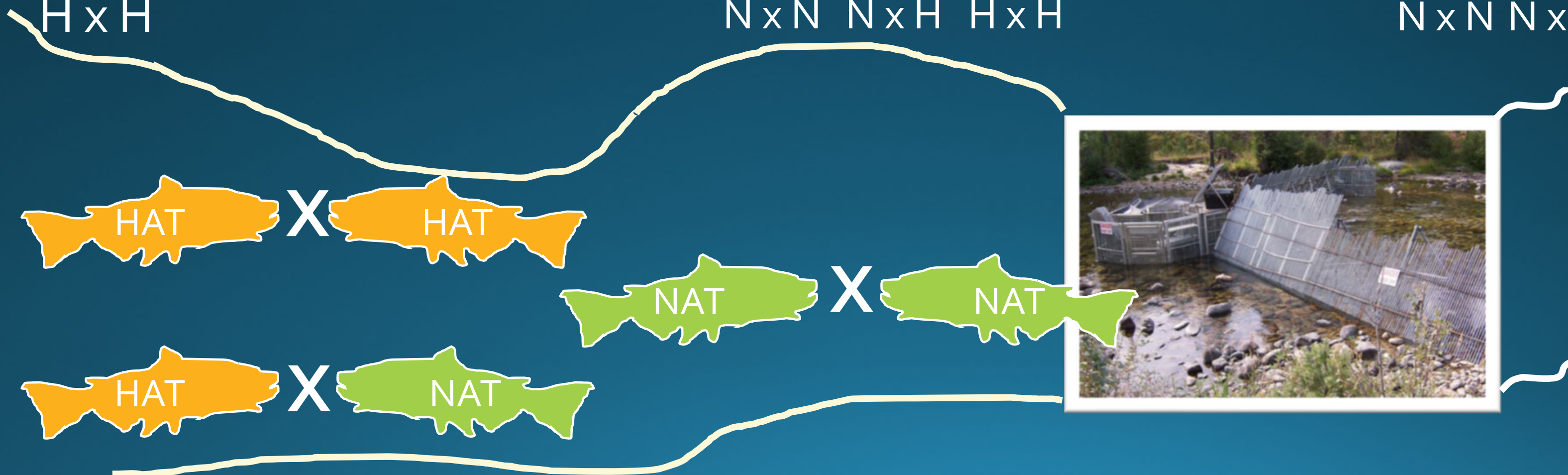
98 99 00 01 02 03 04 05 06 07 08 09 10 11 12

3 types of matings in nature:

N x N
H x N
H x H



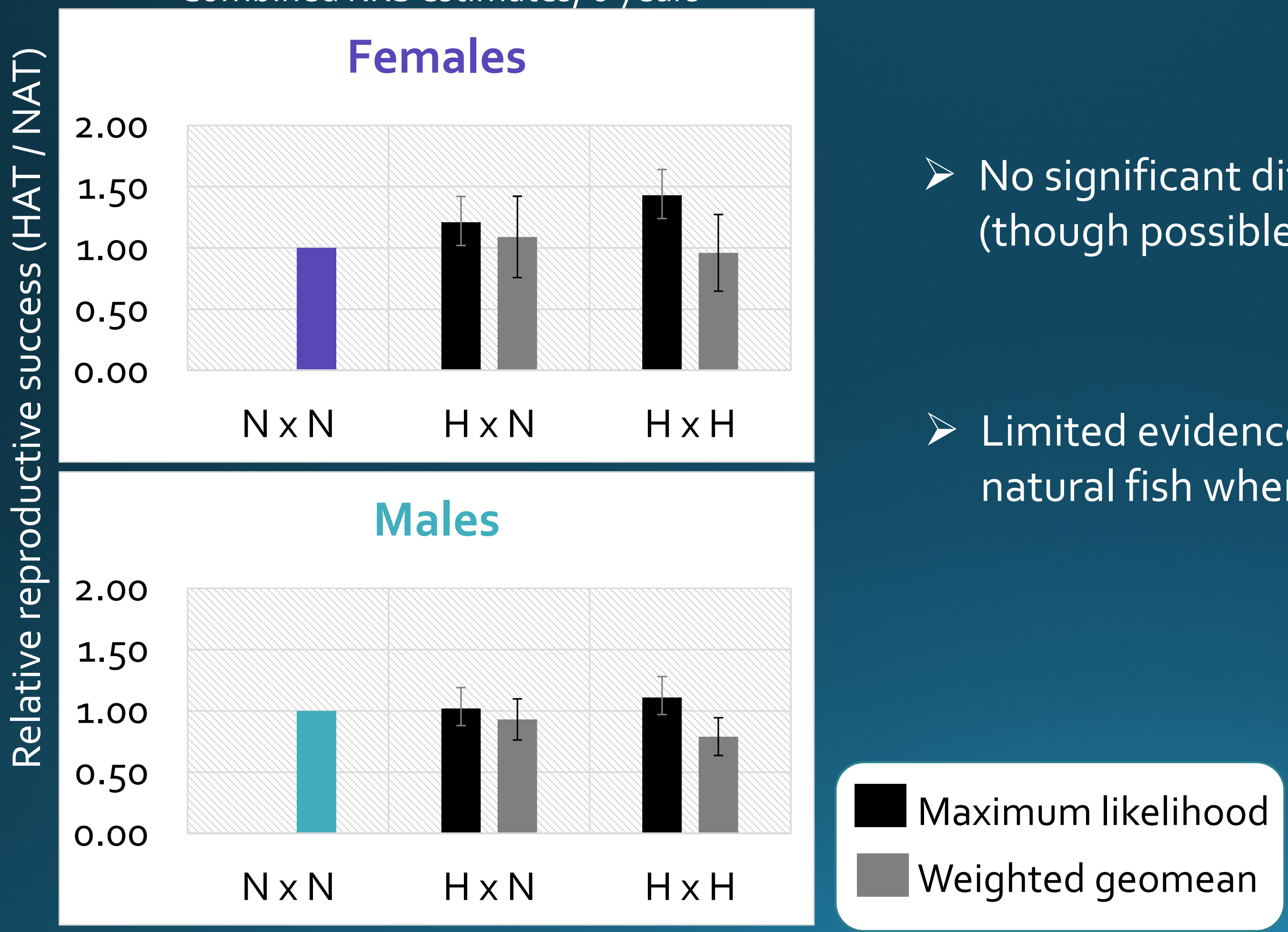
VS



Objective 3

Do hatchery-reared fish reduce the fitness of natural-origin fish?

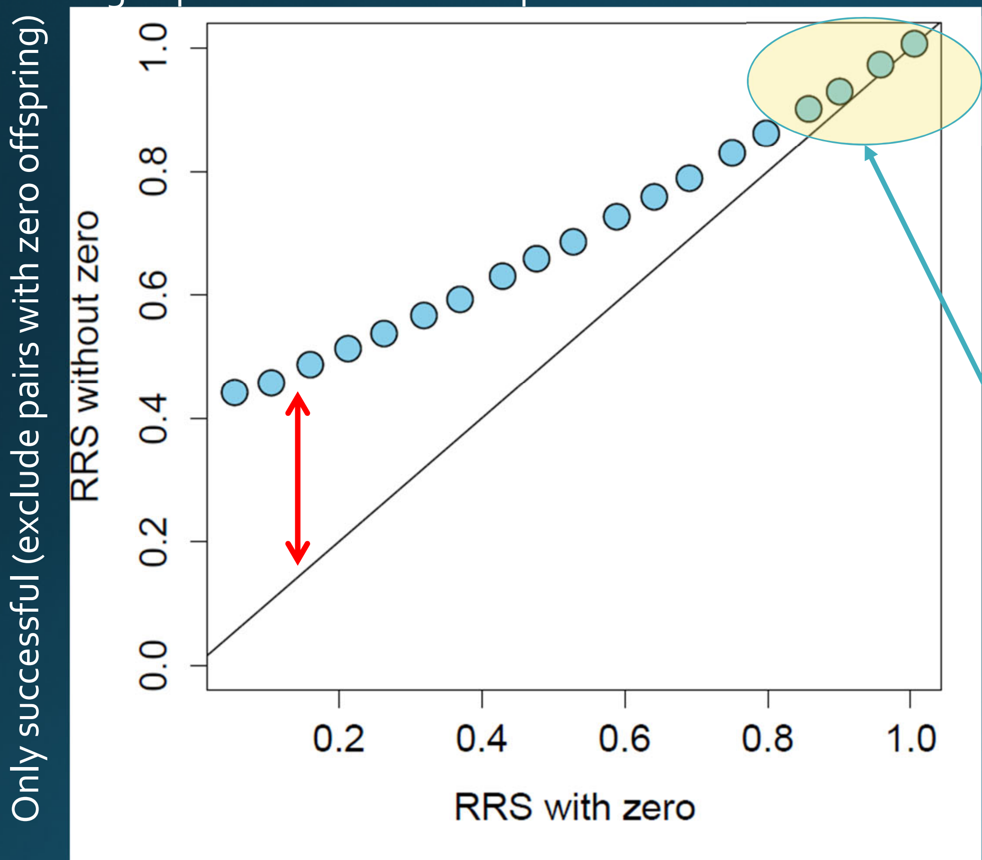
Combined RRS estimates, 6 years



- No significant difference in RS of H x N and N x N (though possible interaction effect of HxH males)
- Limited evidence of reduction in fitness of natural fish when they mate with hatchery fish

Estimating RRS from cross type data (e.g. NxN vs. HxN)

Fig. S4 in Christie et al. 2014



All potential (including pairs with zero offspring)

- RRS analyses of mating types cannot identify pairs that produce zero offspring
- At lower RRS estimates, there is a larger difference between estimates with or without zeros
- In reality, true RRS of salmon pops is likely in the middle – zeros represent both fish that didn't spawn and fish that spawned but offspring didn't return

Johnson Creek RRS estimates were ≥ 0.79 ; so <u>little difference or directional bias</u> in estimates of RRS

Conclusions

- Objective 1 - **Demographic Boost:** Supplementation program provides a boost to the natural population

- Objective 2 - **Fitness Differences:**

  a.) Lower RS of hatchery fish; primarily in jacks and males that do not appear to have mated successfully

  b.) Generally, equal reproductive success of H and N fish contributing offspring to the next generation

- Objective 3 - **Fitness Effects:** No significant difference in reproductive success of HxH, HxN, and NxN mating types

- Suggests Chinook salmon reared for a single generation in the hatchery had a limited and undetectable effect on the fitness of natural-origin fish in Johnson Creek

Photo credit: Bill Young

Why limited evidence of reduced RRS in Johnson Creek in the short-term?

- Low statistical power in some annual estimates
  - Inability to detect significant differences does not equate to no fitness effects on natural population
- Differences in hatchery rearing practices and management of broodstock

HOW can programs be managed to minimize potential for negative effects on wild fish?

One small piece of this puzzle, but likely important way to reduce negative impacts:

~100% natural-origin in broodstock