Comparisons of reproductive success between hatchery and natural fish: Current research and perspectives

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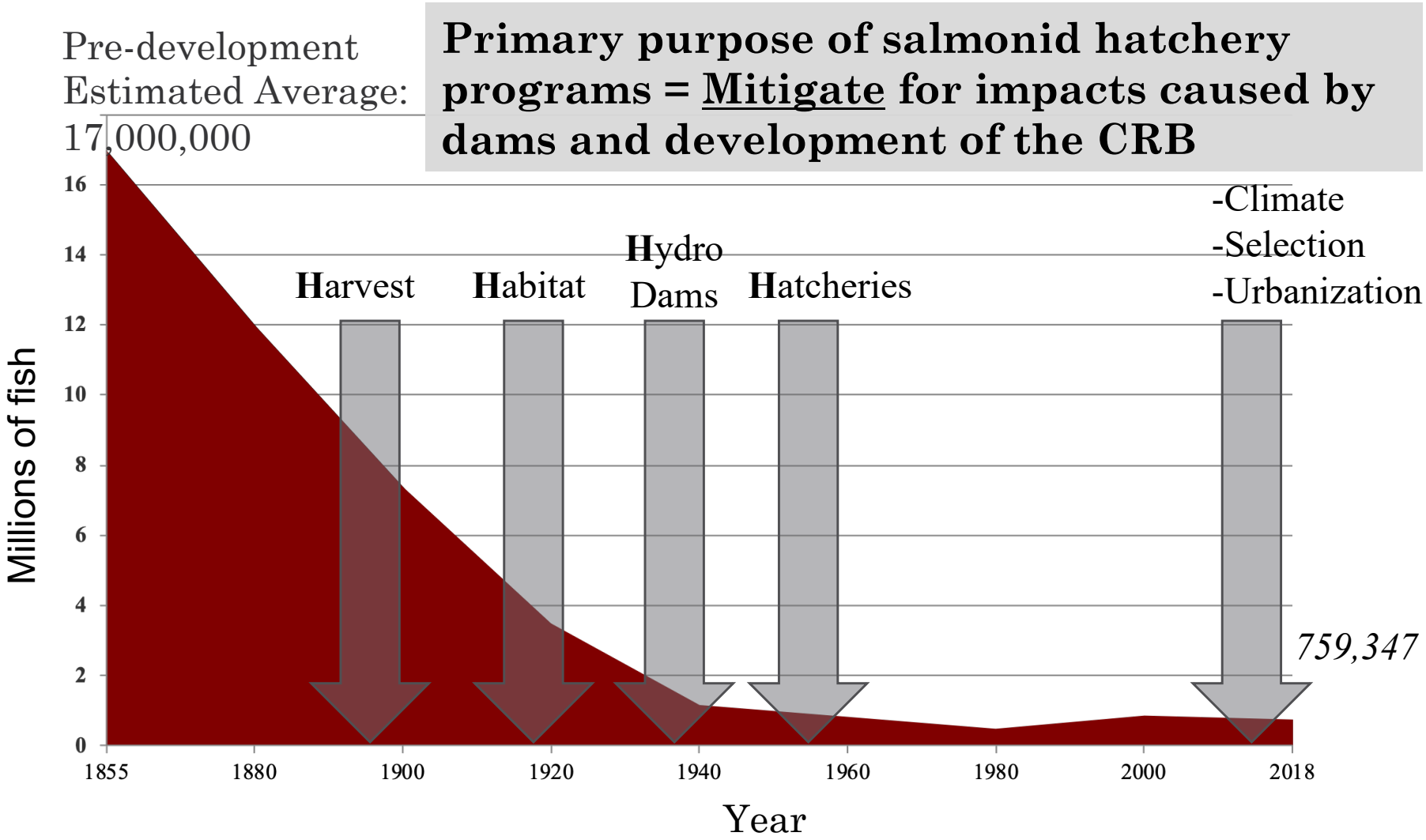
Major Decline in Salmonid Abundance in Columbia River

Returning Columbia River salmon (chinook, steelhead, sockeye, coho)



1855: NPCC historical run extrapolation estimate; 1880-1920 data points extrapolated from Columbia River cannery output; 1940-present: dam counts and river mouth estimates

Tribes and Hatchery Risks

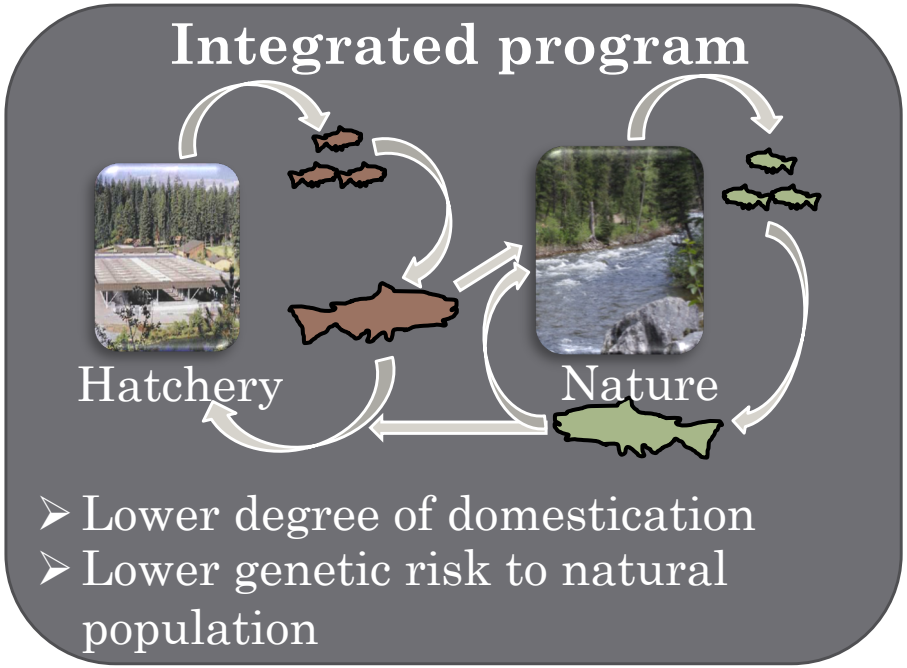
- "The tribes recognize that there is significant risk to wild fish associated with the production of hatchery fish."
- "The job at hand is to manage that risk, with sound hatchery practices."
- "The tribes insist that hatcheries must remain a tool to benefit recovery of imperiled wild stocks and help rebuild populations for both reproduction and harvest."
- "As long as we have dams we'll have hatcheries to provide mitigation for heavy losses."

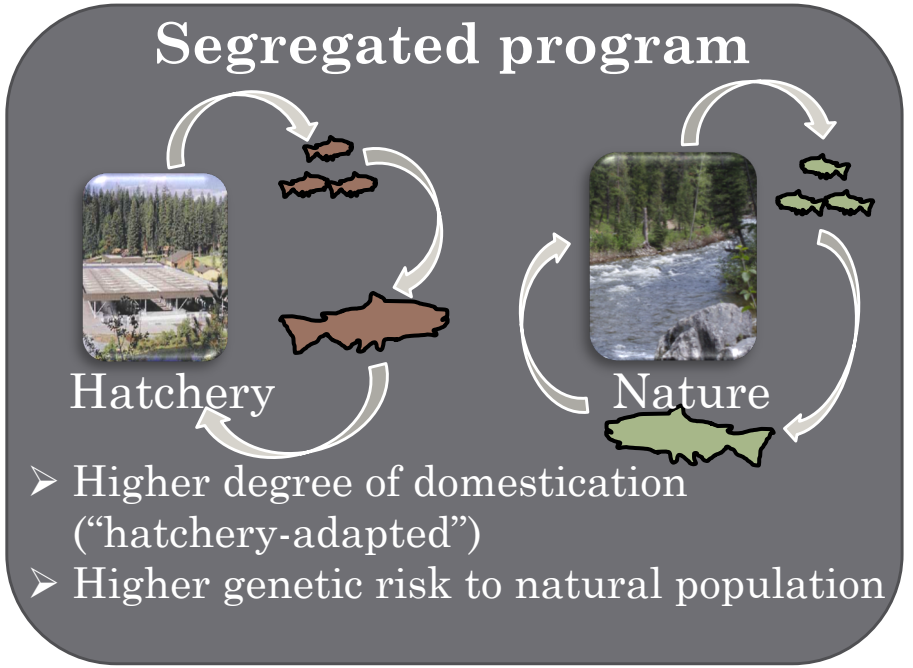
Source: Paul Lumley, CRITFC executive director, 2008-2016

Management of Hatchery Programs

- Supplementation – Prevent extirpation, rebuild natural production (integrated)
- Reintroduction – Restore extirpated populations (outside stocks, integrated)
- Harvest augmentation – Fish for harvest (often segregated)

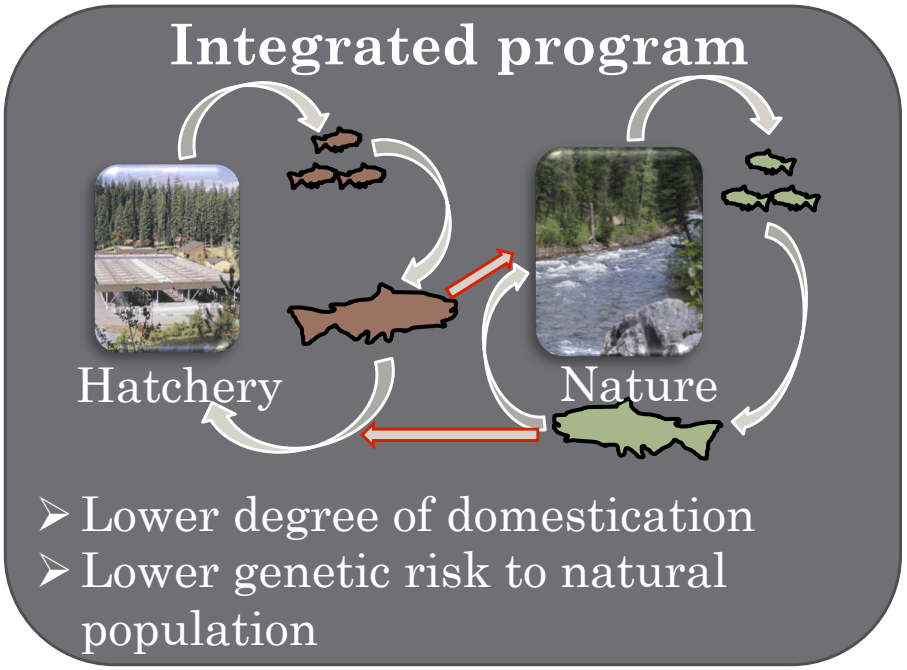
Two different management approaches

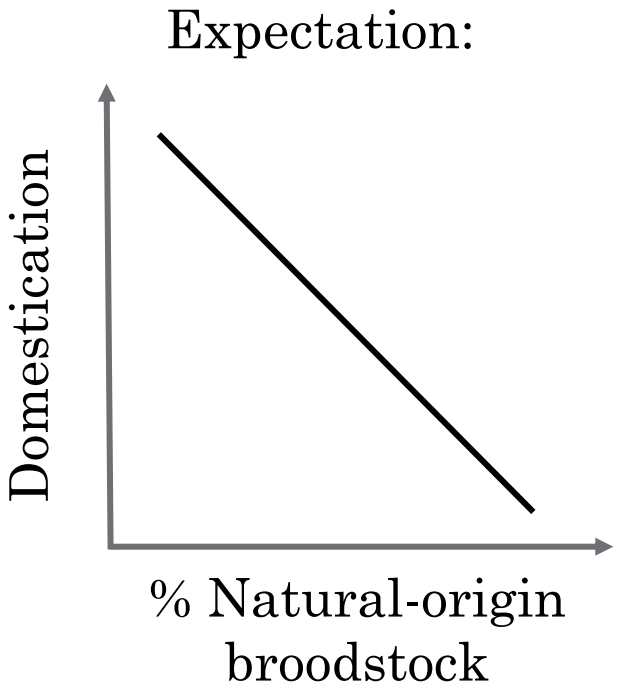




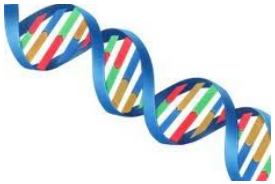
Integrated Supplementation Programs

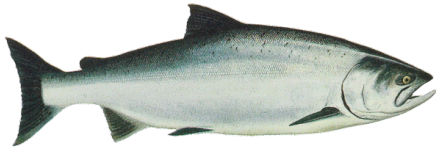
- Supplementation – Prevent extirpation, rebuild natural production (integrated)
  - Proportion of natural-origin fish in broodstock and hatchery-origin fish on spawning grounds varies by program and year
  - Intended to maintain diversity necessary for long-term persistence
  - Domestication expected to decrease with high proportion of natural-origin broodstock





The Role of Genetic Sampling in Supportive Breeding





- Genetic sampling can provide insight into numerous individual and population-level assessments:
  - Diversity within and among populations
  - Connectivity among populations
  - Genes underlying traits (i.e. migration timing)
  - Parentage Analyses (i.e. Parentage Based Tagging; PBT)
- Parentage analyses can provide insight into fitness differences (reproductive success; RS) between hatchery- and natural-origin fish.

Relative Reproductive Success (RRS)

$$\textbf{RRS} = \frac{\text{Avg \# offspring (Hatchery origin)}}{\text{Avg \# offspring (Natural origin)}}$$

Equal Fitness

$$\textbf{RRS} = \frac{\text{2 offspring (Hat.)}}{\text{2 offspring (Nat.)}} = \textbf{1.0}$$

Lower Fitness

$$\textbf{RRS} = \frac{\text{1 offspring (Hat.)}}{\text{2 offspring (Nat.)}} = \textbf{0.5}$$

Studies In Salmonids and Risks to Natural-Origin Fish

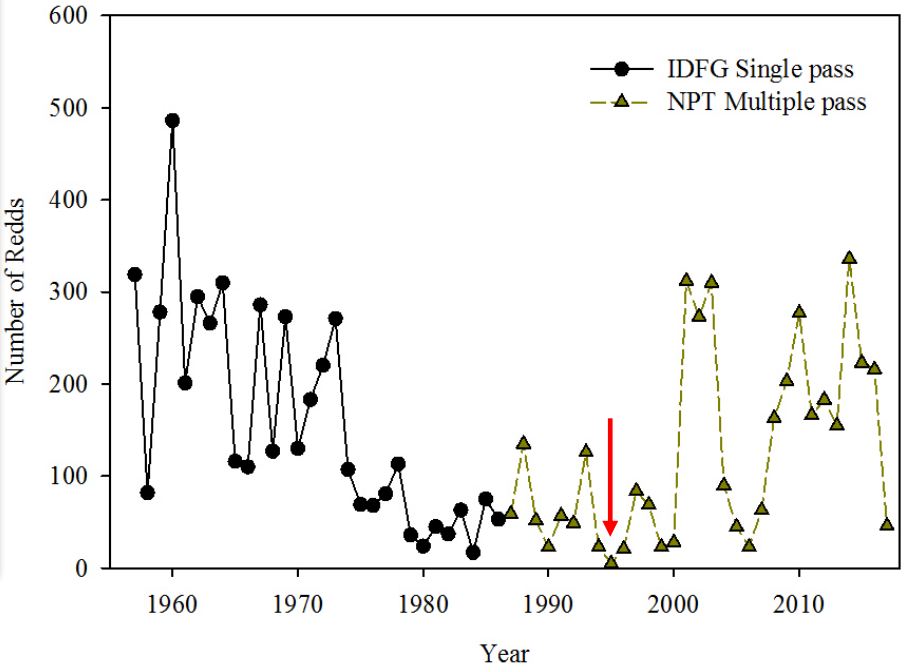
- Steelhead 
  - Lower success of hatchery-origin compared to natural-origin fish[1]
  - Success of natural-origin fish reduced when mating with hatchery-origin fish[1]
  - Natural-origin broodstock produce offspring that reproduce better in nature[2]
- Coho 
  - No differences in success between hatchery- compared to natural-origin fish[3]
  - Lower success of hatchery-origin compared to natural-origin fish, except for jacks[4]
- Chinook 
  - Lower success of hatchery-origin compared to natural-origin fish[5,6]
  - More generations in hatchery leads to lower success in the wild for males[6]
  - No effect detected when natural-origin fish mate with hatchery-origin fish[5]

Summary: Results vary by species and hatchery program

[1]Kostow et al. 2003; McClean et al. 2003, 2004; Araki et al. 2007, 2009; Berntson et al. 2011
[2]Ford et al. 2016
[3]Ford et al. 2006; O'Malley et al 2015
[4]Theriault et al. 2011
[5]Hess et al. 2012; Janowitz-Koch et al. 2019
[6] Williamson et al. 2010; Ford et al. 2012; Anderson et al. 2013; Evans et al. 2015

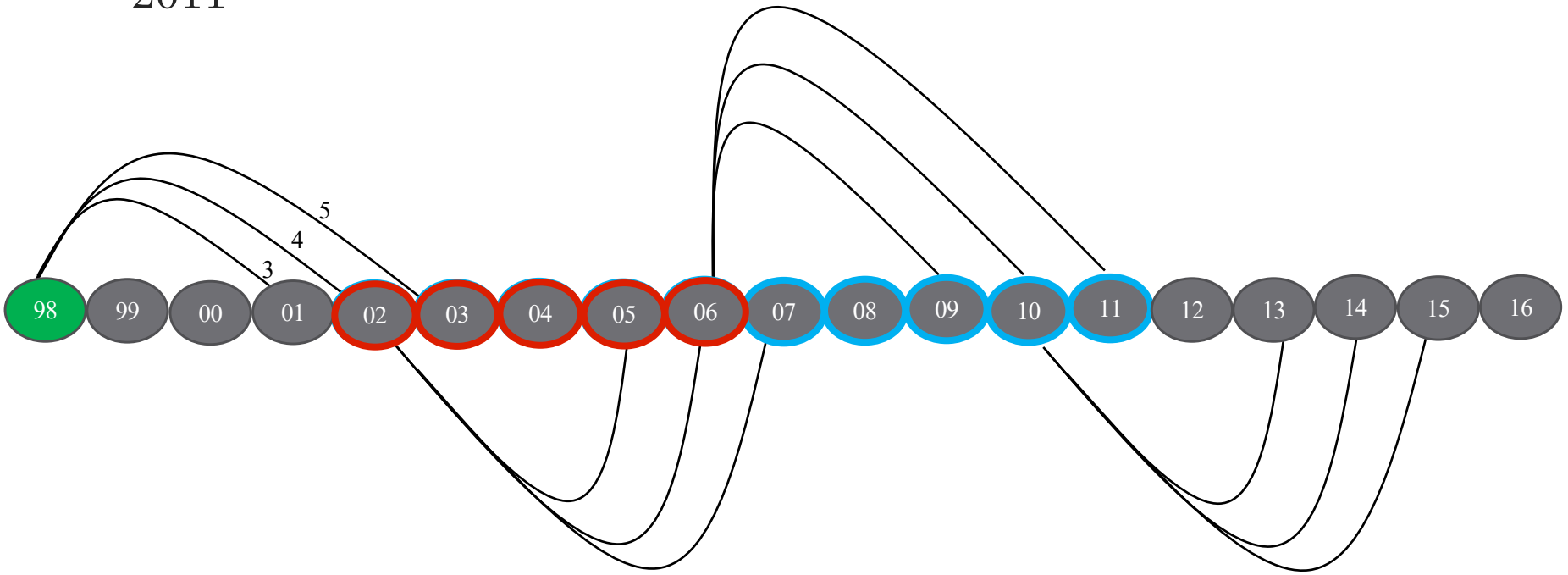
Spring/Summer Chinook salmon (*Oncorhynchus tshawytscha*)

- Threatened or endangered in many locations
- **Johnson Creek:** spawning tributary in interior watershed of Salmon River Basin (Idaho)
  - All fish are passed above the weir for natural spawning.
  - Only natural-origin fish are used for broodstock.



Methods: Sample Collection

- Fin tissue sample collected and data recorded from all fish at Johnson Creek weir (~93% of spawning adults)
- Samples genotyped for parentage analyses
- Tissue samples from approximately 14,500 fish between 1998-2016
  - 19 collection years and 10 brood years examined in this study: 2002-2011



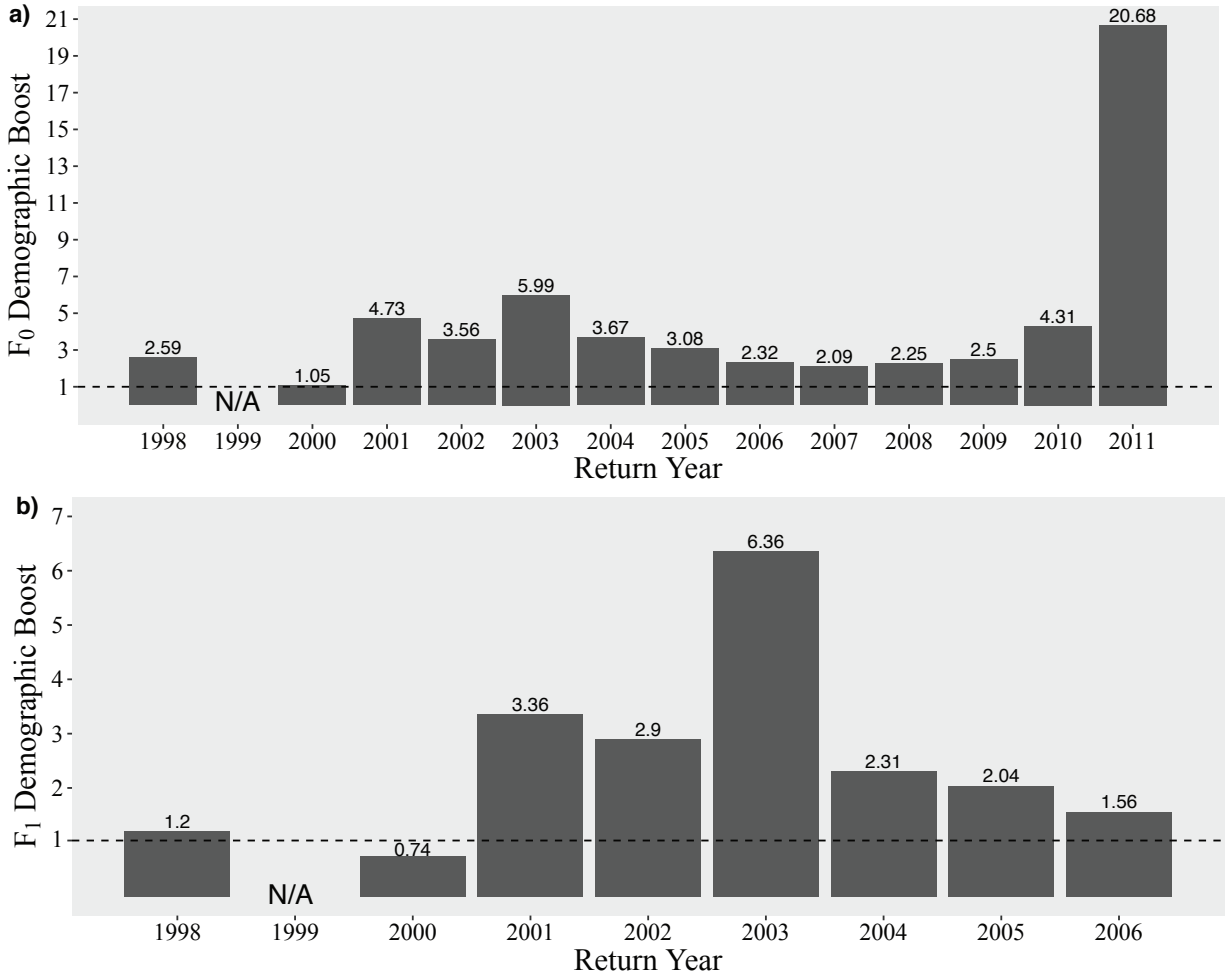
Questions

Evaluate the long-term effects of supplementation over two full generations in Johnson Creek:

1. Does the hatchery boost population abundance?
2. Do hatchery-origin fish demonstrate lower (or higher) reproductive success than natural-origin fish?
3. What are some of the key factors affecting variation in reproductive success?

Result 1: Demographic Boost

- **First generation:** Broodstock produced ~5 times the number of returning adult offspring compared to natural spawners (average = 4.52).
- **Second generation:** Broodstock produced ~3 times the number of returning adult grand-offspring compared to natural spawners (average = 2.56).

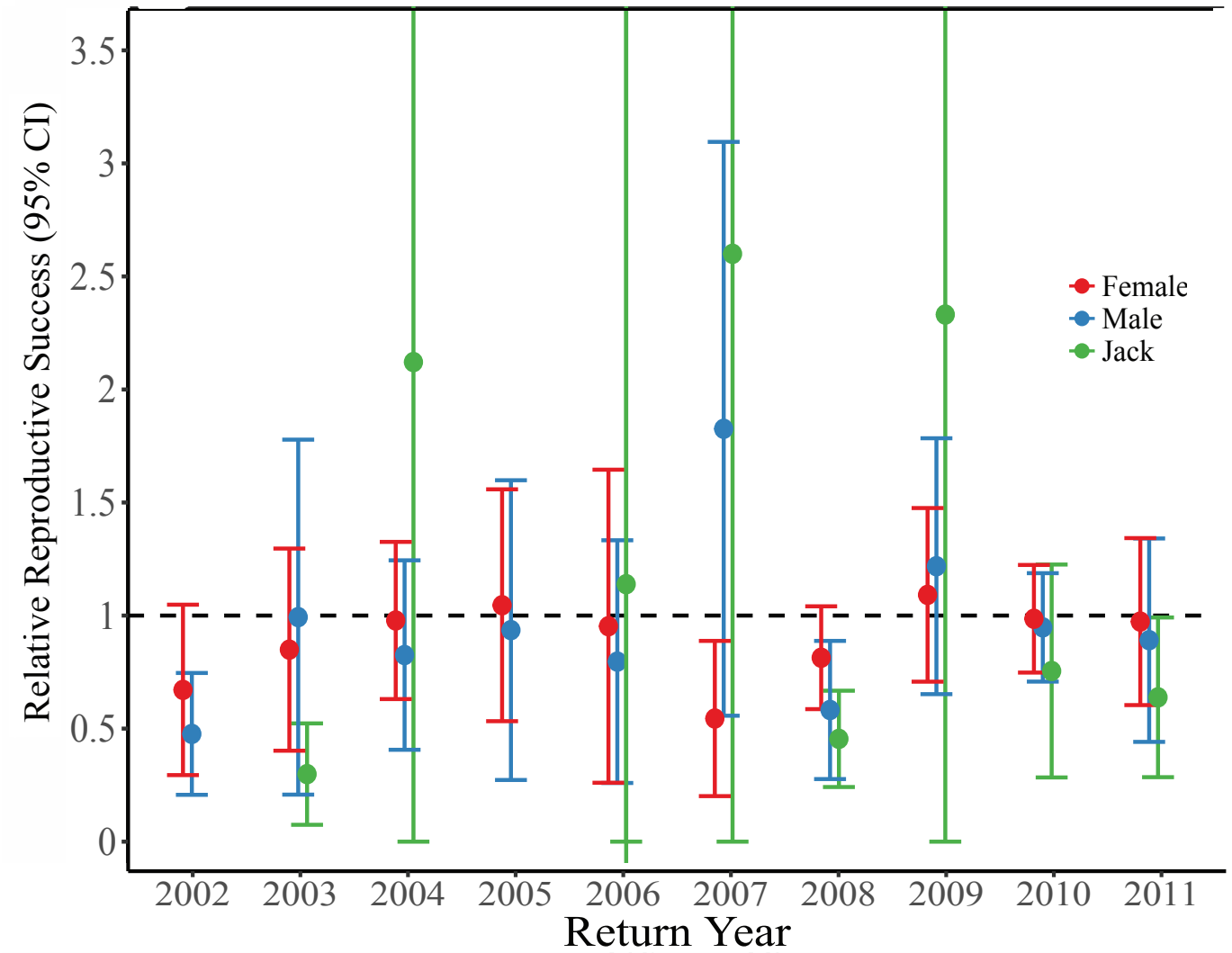


Does the hatchery boost population abundance? **YES**

Janowitz-Koch, I, *et al*. 2018. *Evol App*.

Result 2a: Relative Reproductive Success- All Sampled Adults

- Trend toward lower reproductive success for hatchery-origin fish, especially for:
- **Females:** 2007
- **Males:** 2002 & 2008
- **Jacks:** 2003 & 2008



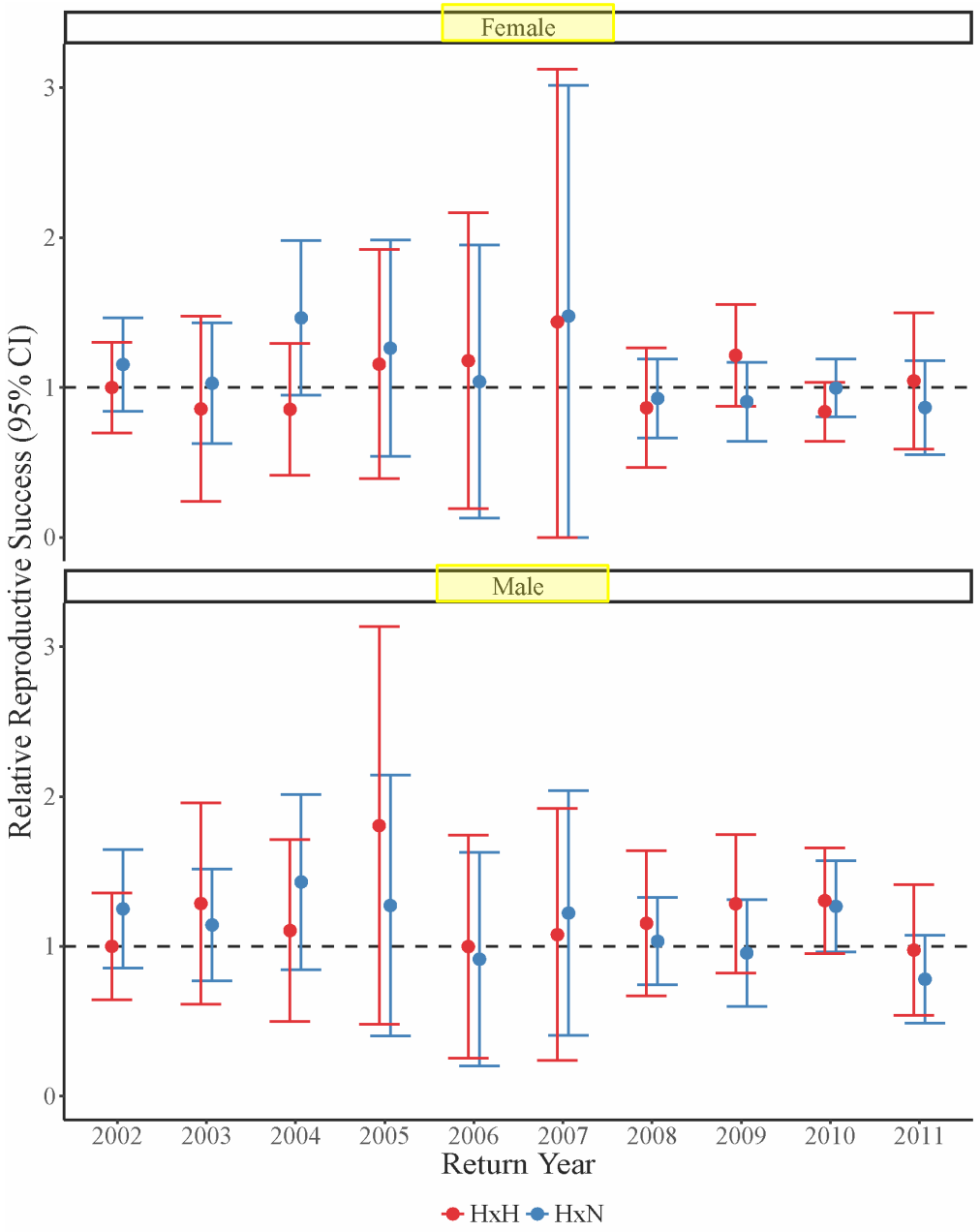
Do hatchery-origin fish exhibit lower reproductive success than natural-origin fish?
In certain years YES, but OVERALL, NO.

Janowitz-Koch, I, *et al*. 2018. *Evol App*.

Result 2b: Relative Reproductive Success- Single Generation Crosses

- No difference in reproductive success of Hatchery-origin x Natural-origin crosses compared to Natural-origin x Natural-origin crosses.
- No difference in reproductive success of Hatchery-origin x Hatchery-origin crosses compared to Natural-origin x Natural-origin crosses.

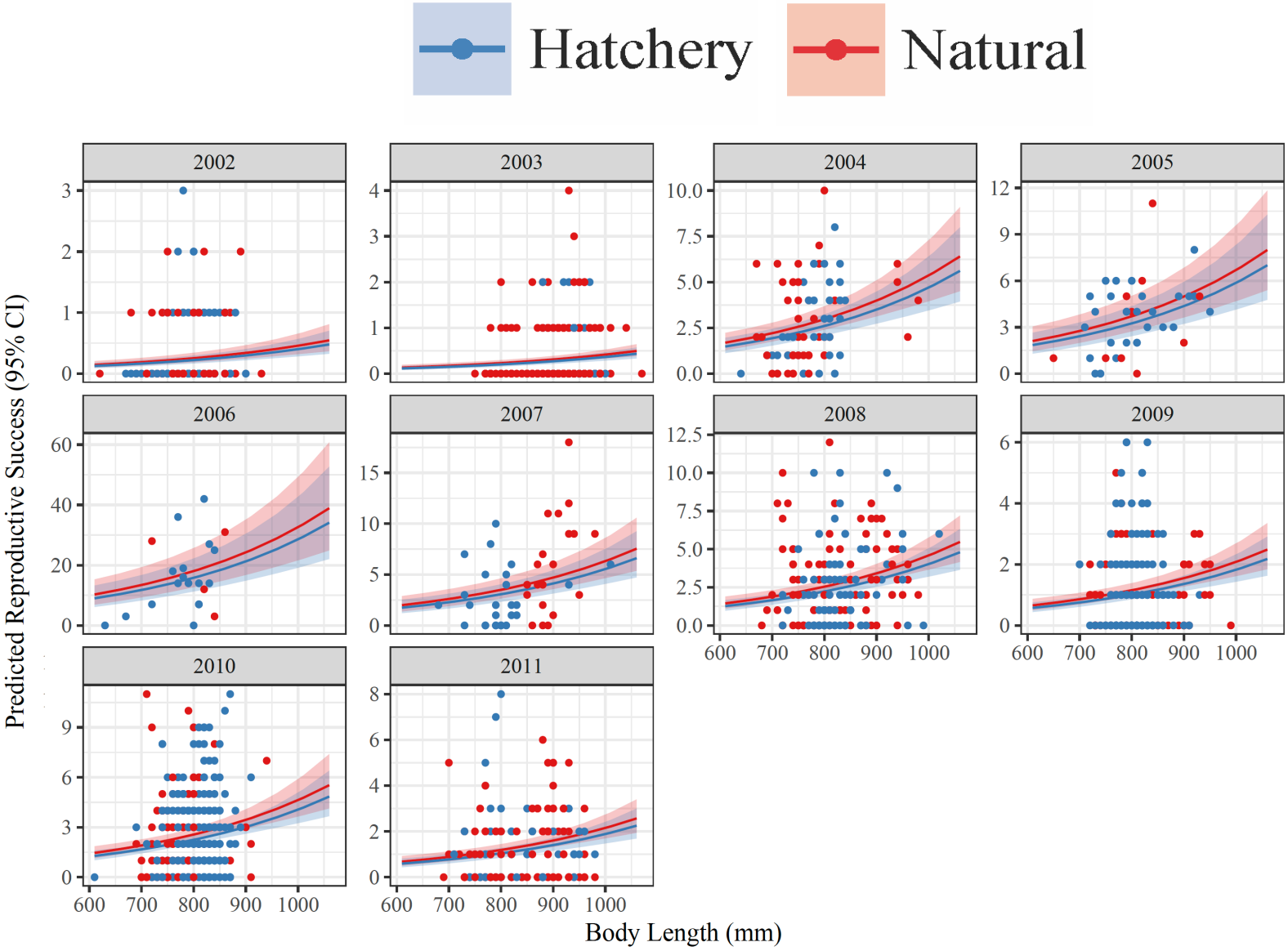
Do hatchery-origin fish impact the reproductive success of natural-origin fish? **NO**



Janowitz-Koch, I, *et al.* 2018. *Evol App.*

Result 3: The Impact of Size on Reproduction

- As body length increases, reproductive success also increases.
- In some years, hatchery-origin fish are smaller and have lower reproductive success.



Janowitz-Koch, I, *et al*. 2018. *Evol App*.

General Conclusions from Case Studies in Chinook

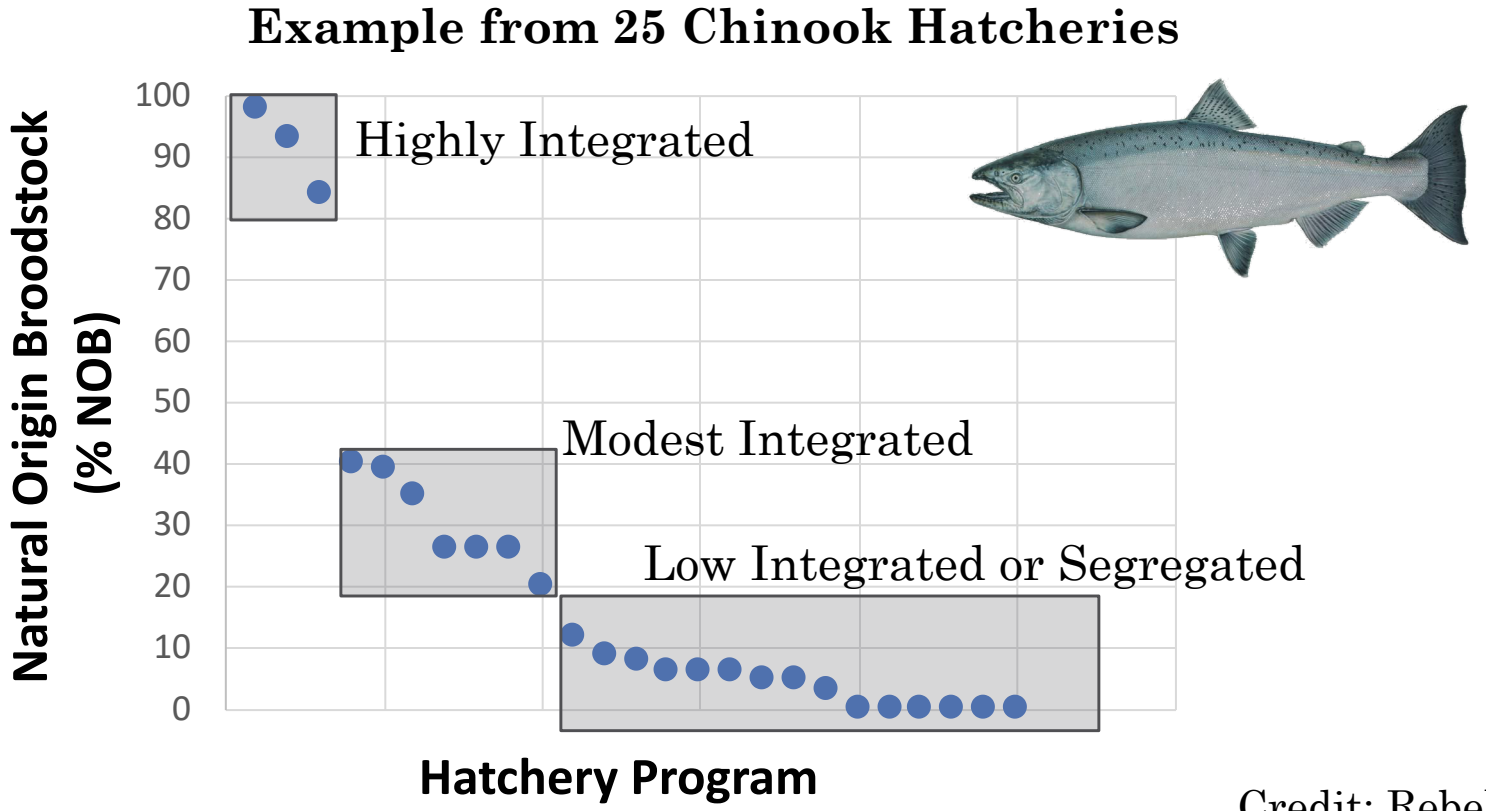
- Supplementation programs provide a boost in population abundance (survival advantage in hatchery)
- Hatchery adults have lower reproduction when spawning in nature in some cases, but decrease is slight overall
- Smaller, younger males (jacks) have lower reproductive success
- No effect detected when natural-origin fish mate with hatchery-origin fish

Overall: Limited effects for integrated hatchery programs that use ~100% natural origin fish in broodstock

Results in Steelhead: Natural-origin broodstock produce offspring that reproduce better in nature (Ford et al. 2016, *PLOS One*)

Integrated vs. Segregated Programs

- Results support that integrated programs have lower risks to natural populations than segregated programs
- However, very few integrated hatchery programs with high percent of natural origin broodstock



Credit: Rebekah Horn

Future Directions

- Additional studies needed that contrast integrated vs. segregated programs
- Evaluate differences after hatchery reform measures implemented
- Ensure genetic & life history diversity is maintained in natural populations
- Important that the breadth of RRS studies continue to expand across a wide range of salmonid species
- Evaluate the effect of annual environmental factors on reproductive success

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