

# An analysis of studies of relative reproductive success of early-generation hatchery salmon

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## Topics:

- 1: Do F1 or integrated stock hatchery fish have lower fitness than wild fish?
- 2: Is the difference genetic or environmental?
- 3: Insights into mechanisms?
- 4: A possible source of selection in the hatchery
5. Statistical power and precision in RRS studies

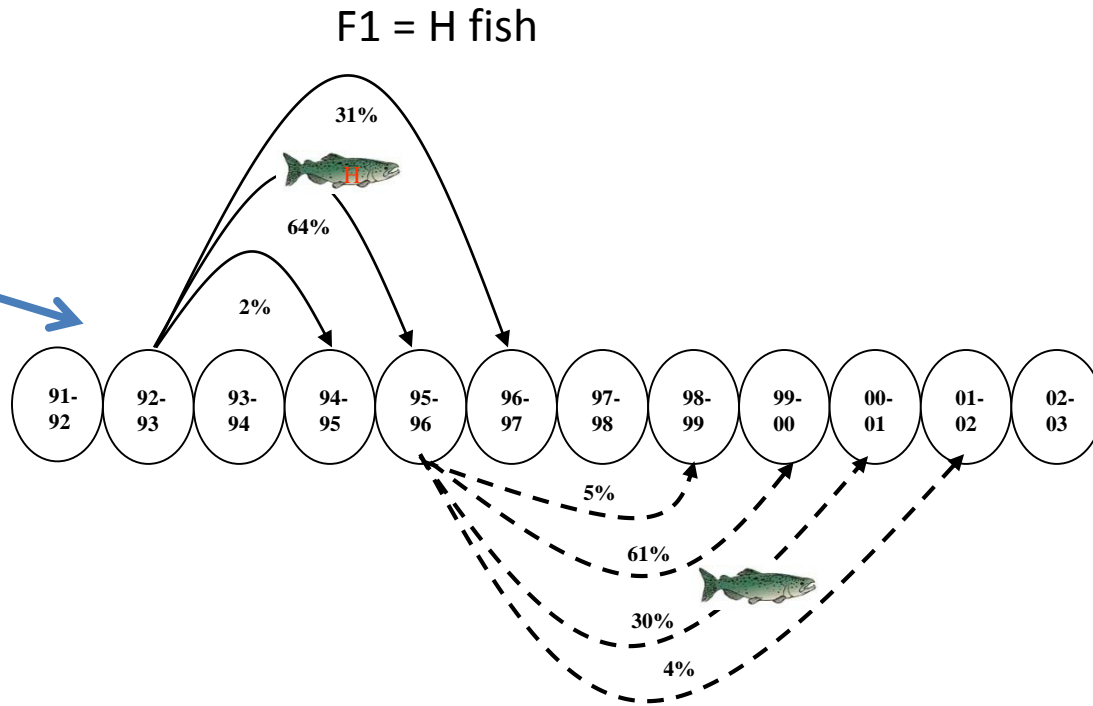
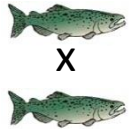
# 1: Do F1 or integrated stock hatchery fish have lower fitness than wild fish?

## Case studies: criteria for inclusion:

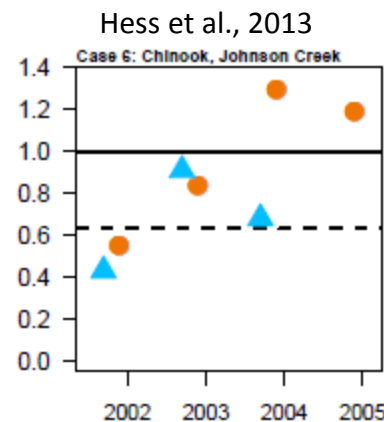
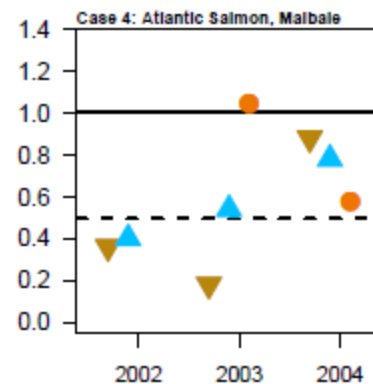
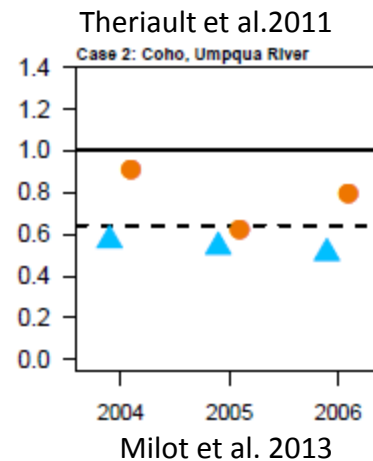
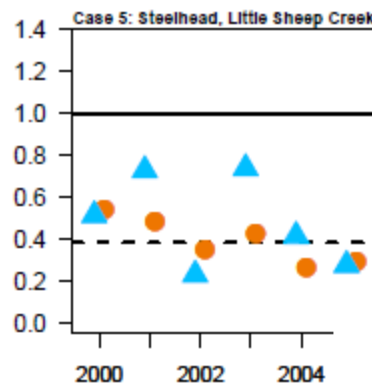
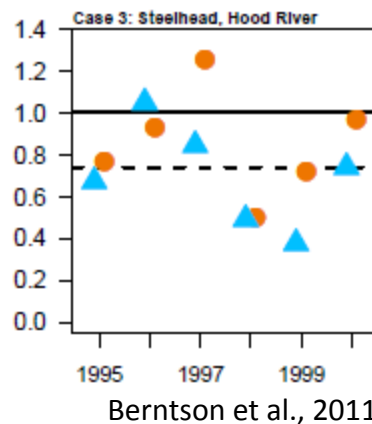
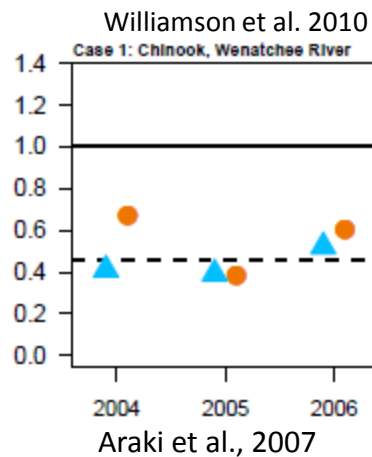
- local origin broodstock, offspring evaluated in river of origin
- relatively “wild” population

Case	Species	Citation	river	# run yrs examined
1	Chinook	Williamson et al. 2010 CJFAS	Wenatchee, WA	2
2	Coho	Theriault et al. 2011 Molec Ecology	Calapooya Ck, OR	3
3	Steelhead	Araki et al. 2007a,b Cons. Biol; Science	Hood River, OR	6
4	Atlantic salmon	Milot et al. 2013 Evol Applications	Malbaie, Quebec	3
5	Steelhead	Berntson et al. 2011 Trans Am Fish Soc	Little Sheep Ck. OR	6
6	Chinook	Hess et al. 2012 Molec Ecology	Johnson Ck, ID	4

broodstock  
in hatchery



F2 = wild born, of various ancestry



48 point estimates from 6 studies

Weighted geometric mean **RRS = 0.48** across all studies (0.45 if exclude steelhead).

▲ Male  
● Female  
▼ Unknown

**2:** Is the difference genetic or environmental?

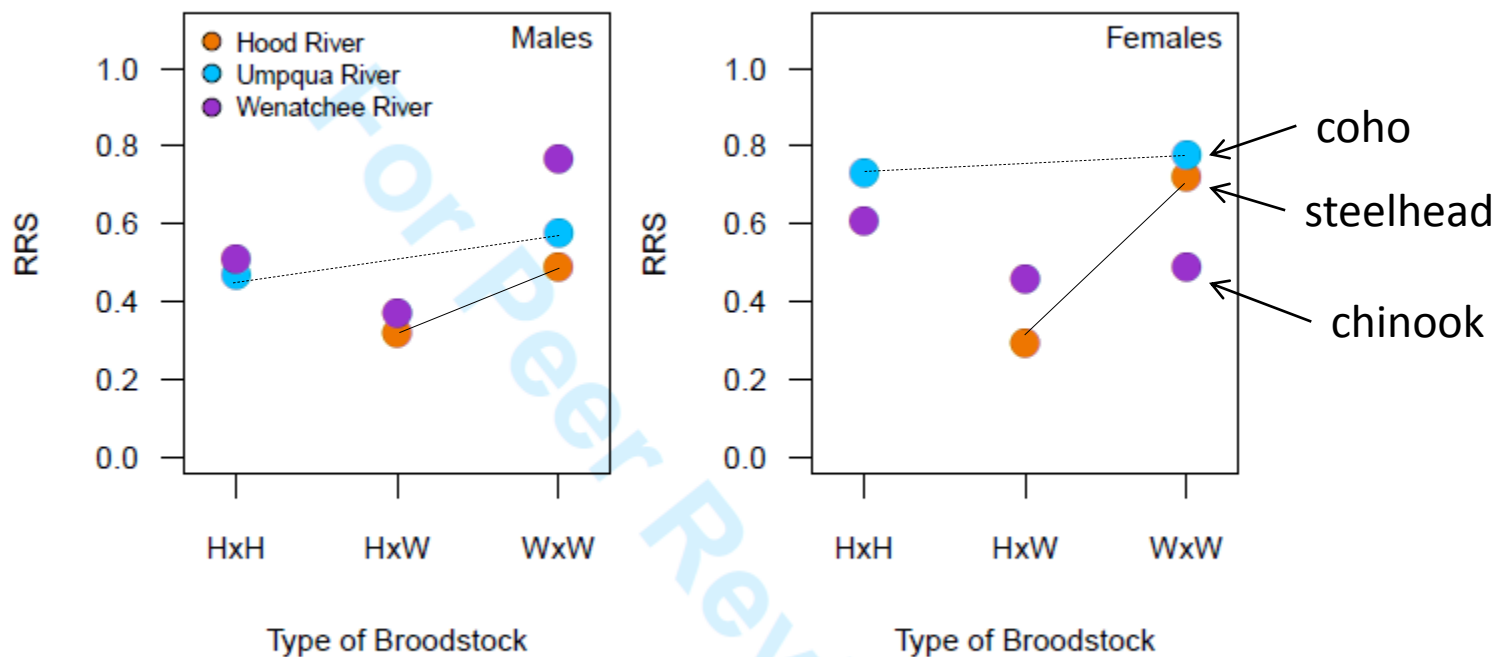
**2:** Is the difference genetic or environmental?

- 1. Effects of an extra generation of hatchery rearing  
(common garden experiment)**

## 2: Is the difference genetic or environmental?

Strong effect in Hood River steelhead

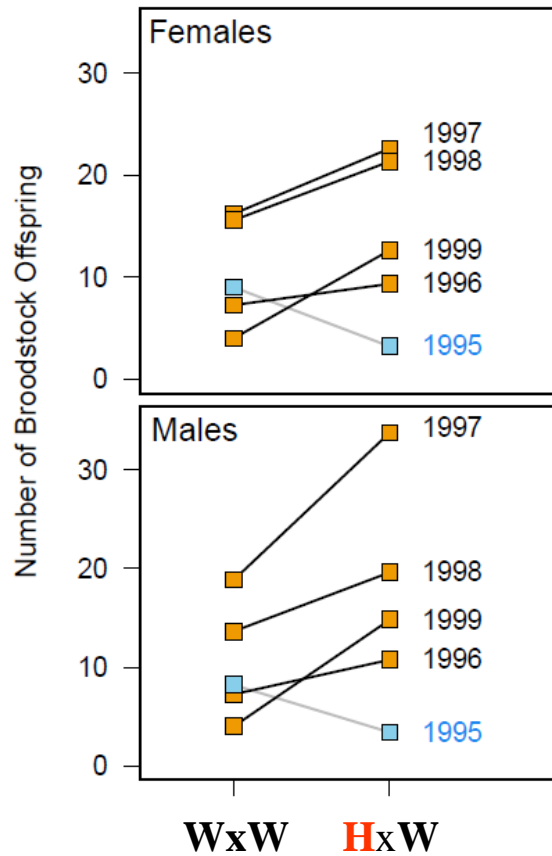
Not so in Coho or Wenatchee Chinook





## 2. Evidence for adaptation to captivity

### a. F1 fish make better broodstock than wild fish, but do worse in wild



Type of broodstock

Christie et al., 2012. *PNAS*  
steelhead, Hood River

## Evidence for adaptation to captivity, cont'd

### **b. There is a trade-off between performance in hatchery and in wild**

WxW families that do best in hatchery do worst  
in wild and *vice versa*

Christie et al. 2012 *PNAS* steelhead, Hood River

Ford et al. 2012 *Cons Letters* chinook, Wenatchee *males only*

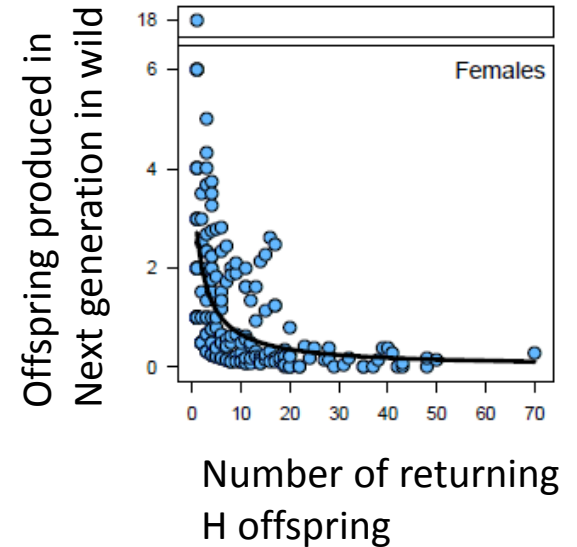
## Evidence for adaptation to captivity, cont'd

### b. There is a trade-off between performance in hatchery and in wild

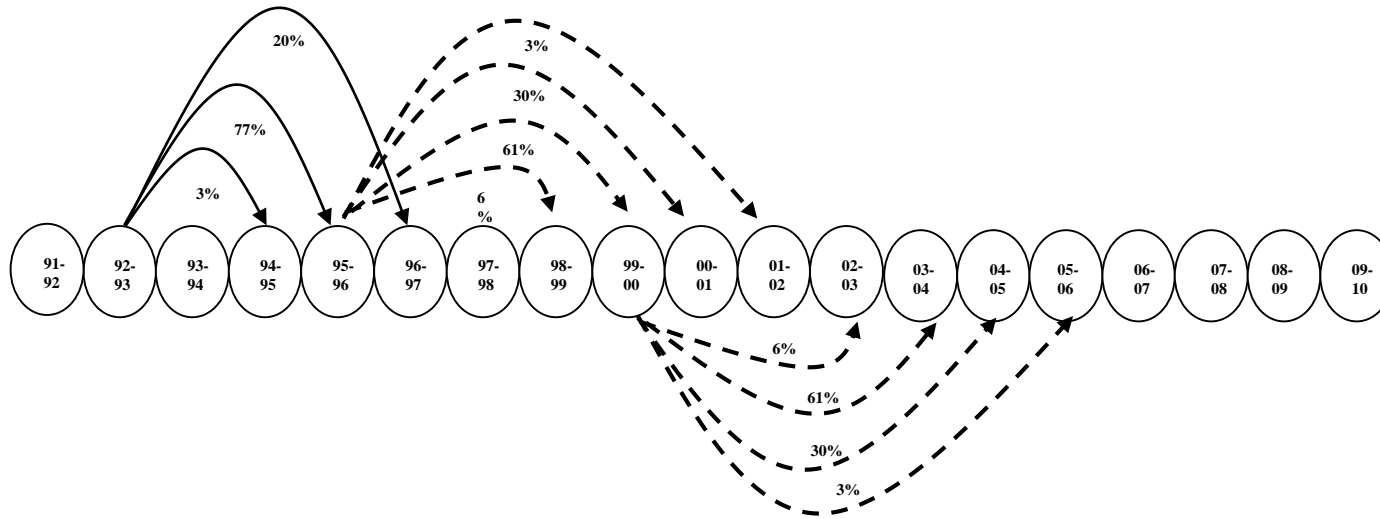
WxW families that do best in hatchery do worst  
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Christie et al. 2012 *PNAS* steelhead, Hood River

Ford et al. 2012 *Cons Letters* chinook, Wenatchee males only



### 3. *Wild-born* adults of different parents differ in fitness

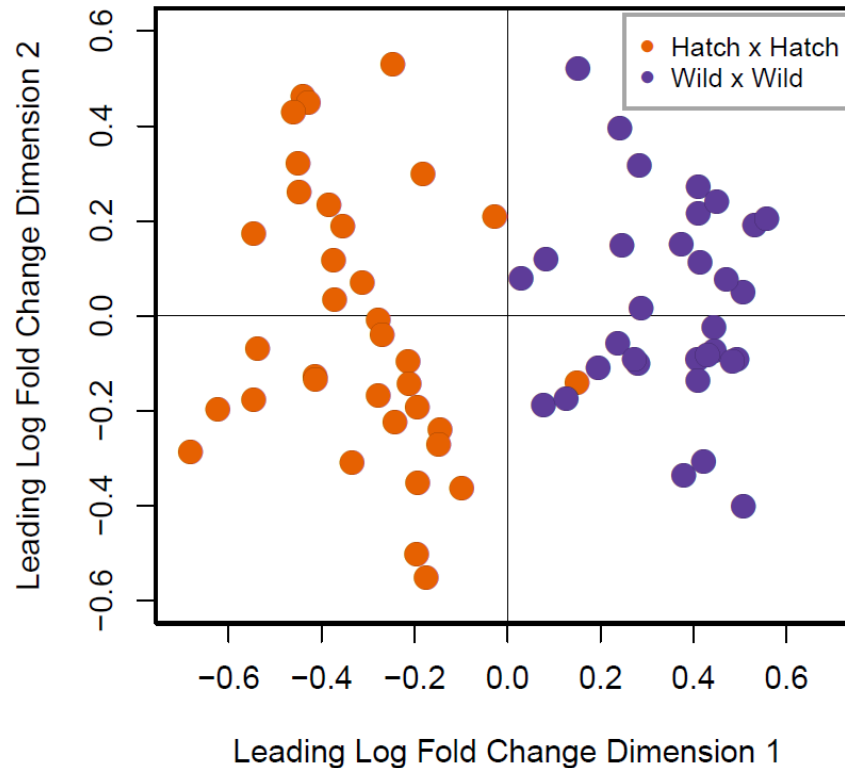


Hood River Steelhead:  $W_{HxH}$  fitness 30-40% that of  $W_{wxw}$

Araki et al., 2009 *Biology Letters*

#### 4. Changes at genomic level visible after 1 generation in hatchery

>700 differentially expressed genes between offspring of HxH and WxW



**Hood River steelhead (unpub. Data)**

**Next:** what physiological pathways do those genes control?

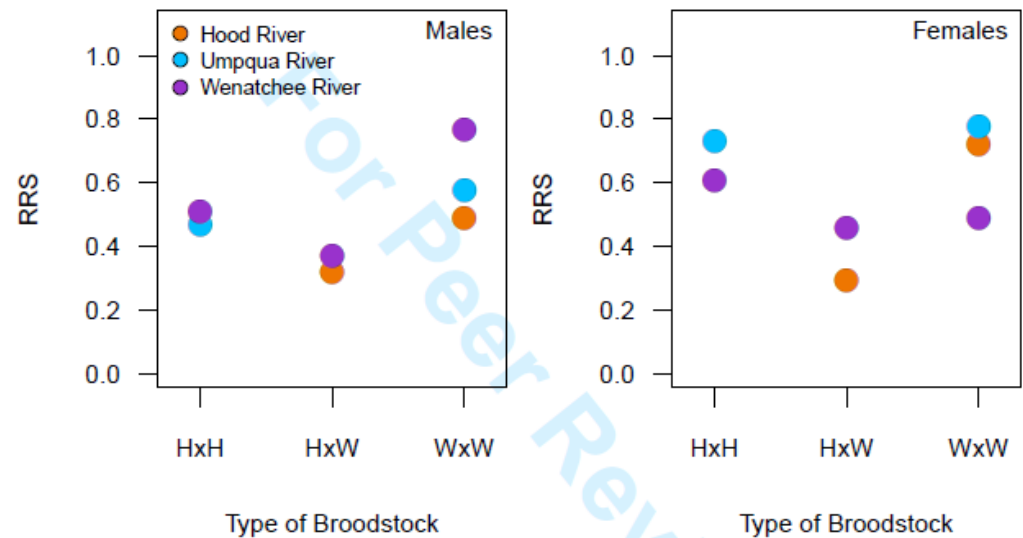
e.g. appear enriched for genes that control stress & wounding response

## Evidence for environmental effects

1. Williamson et al., 2010 chinook, Wenatchee  
Spawning location correlates with RS



2. Only 1 of 3 studies showed a difference between 1<sup>st</sup> and 2<sup>nd</sup> generation fish raised in a common environment



## Conclusions:

**1:** Do F1 or integrated stock hatchery fish have lower fitness than wild fish?

Yes. RRS ~ 50%

**2:** Is the difference genetic or environmental?

Evidence for both effects. Strong evidence for genetic effects in steelhead.

Mechanisms??

### **3. Insights into mechanisms**

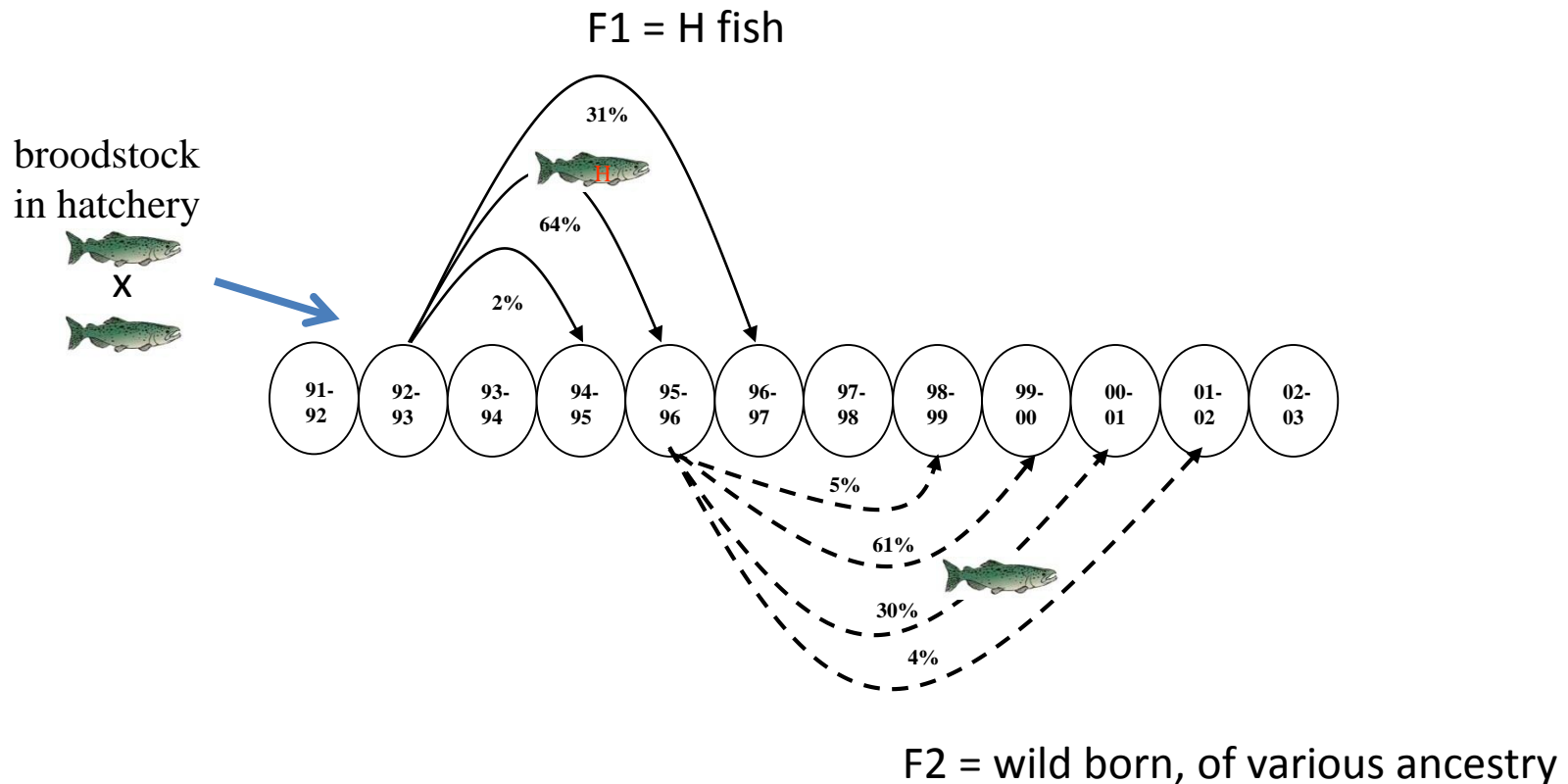
Selection against H fish occurs early in life cycle



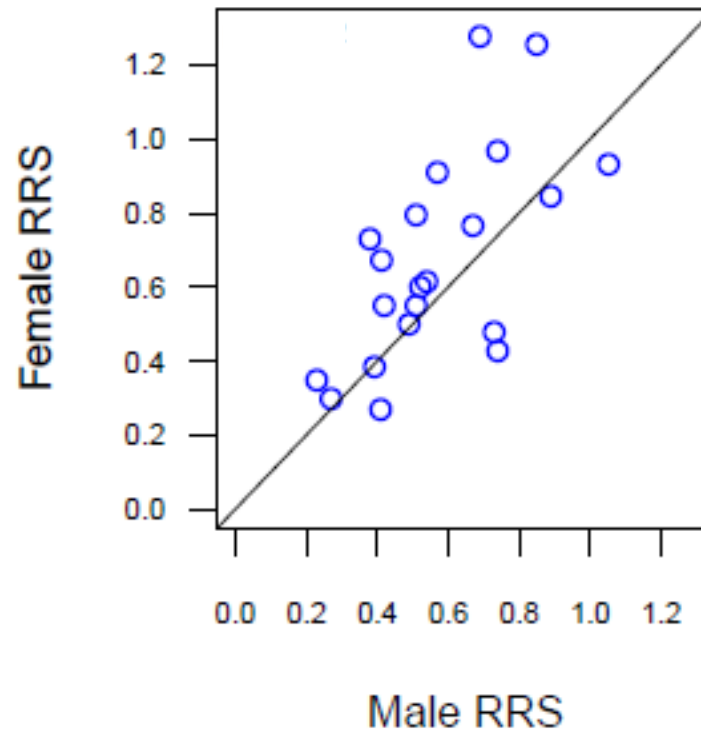
**a. RRS: based on returning *adults* = RRS based on *juvenile* samples**

Ford et al., 2013 *Cons letters* Chinook, Wenatchee

Berntson et al., 2011 *TAFS* steelhead Little sheep creek



**b. Effect of hatchery ancestry on RRS appears stronger in males than females**



Sexual selection?

Early male maturity? (e.g. Ford et al., 2012 *Cons Letters*)

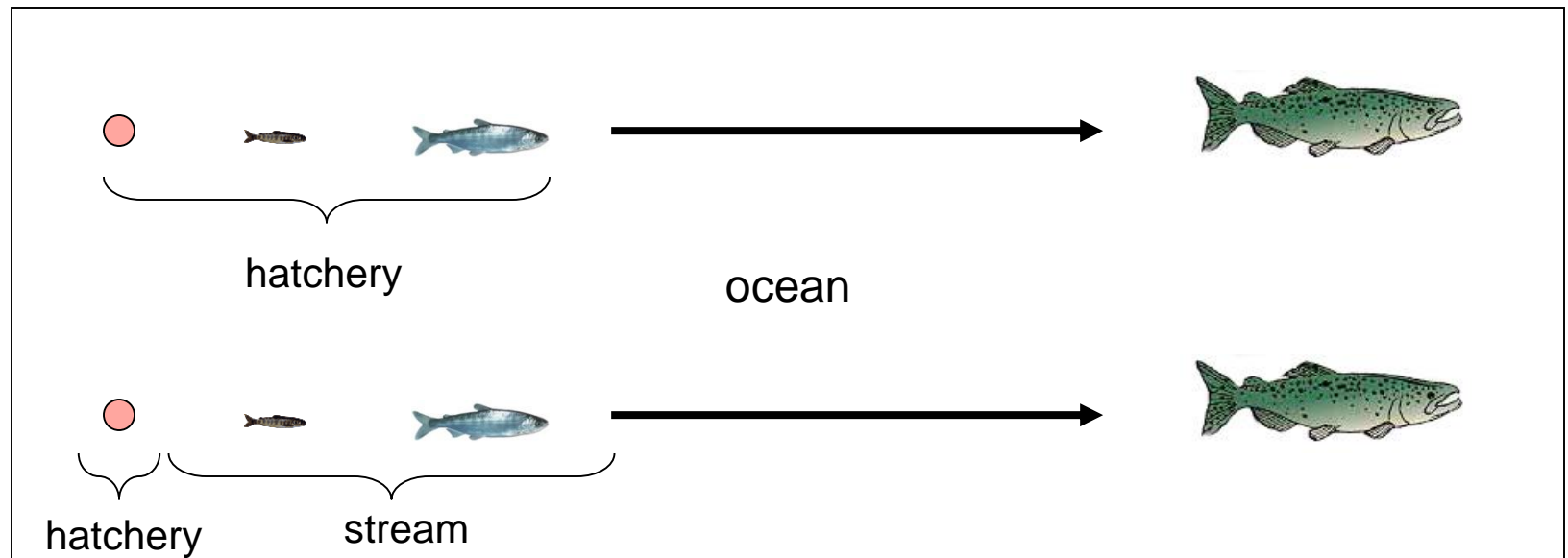
### c. RRS of Hatchery fish released as fry *versus* as smolts

RRS: as smolts < as fry < wild

Theriault et al. 2011 *Mol Ecol*, coho, Umpqua

Milot et al. *Evol Appl* Atlantic salmon, Malbaie

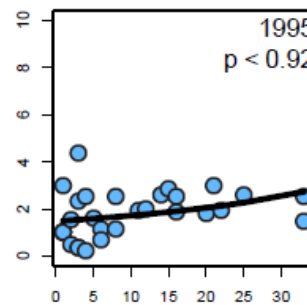
Therefore, some effects of hatchery occur very *early* in life cycle



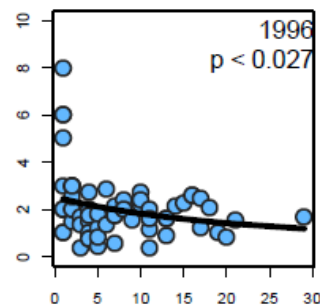
**4:** A possible source of selection in the hatchery

# Rearing density

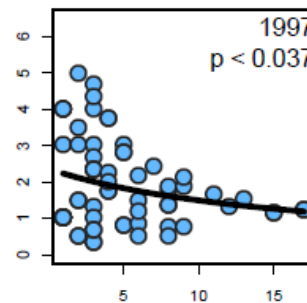
5000



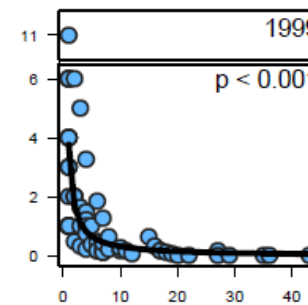
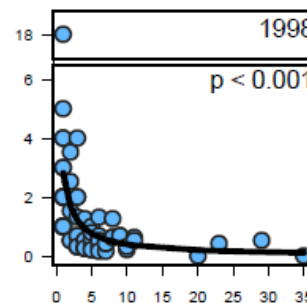
26,000



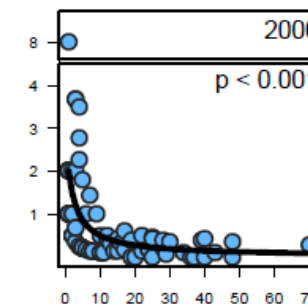
48,000



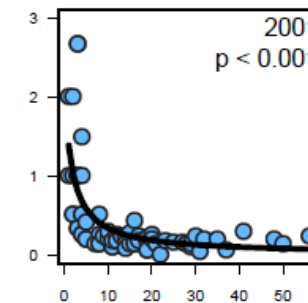
57,000



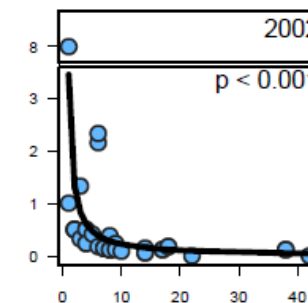
60,000



61,000



52,000



56,000

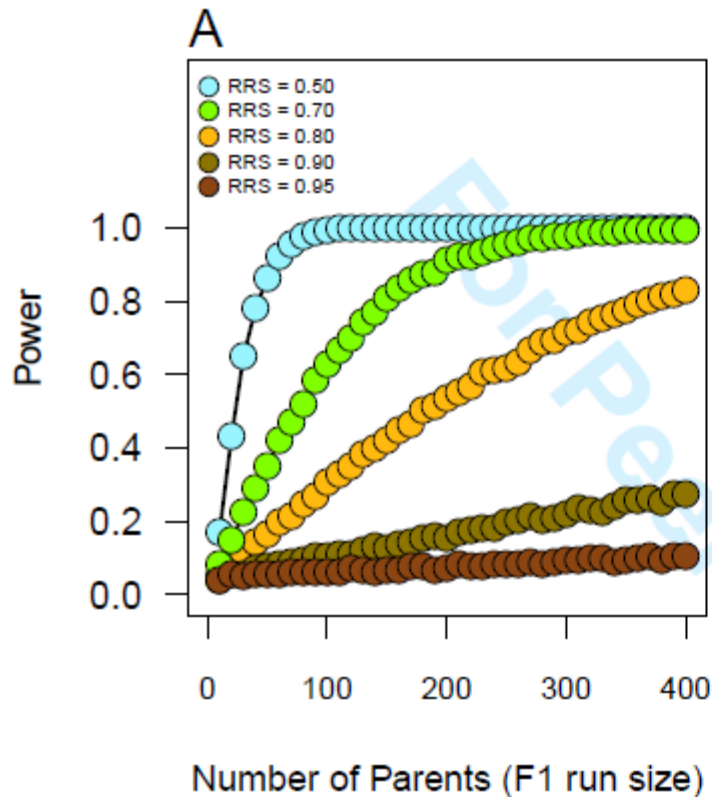
number of hatchery fish produced

One final comment on RRS studies:

## 5. Statistical power and precision of estimates

Estimates of RRS are extremely imprecise

Statistical power to detect a difference is low



Therefore,

Collect data from multiple run years before make conclusions

Consider statistical power when make conclusions from negative results

## Conclusions:

**1:** Do F1 or integrated stock hatchery fish have lower fitness than wild fish?

Yes. RRS ~ 50%

**2:** Is the difference genetic or environmental?

Evidence for both effects.

**3:** Insights into mechanisms?

Selection may occur early in the life cycle, both in hatchery and in wild

**4:** A possible source of selection in the hatchery

Rearing density?

**5.** Statistical power and precision in RRS studies

Typical estimates of RRS are very imprecise.

Power to detect differences is very low.



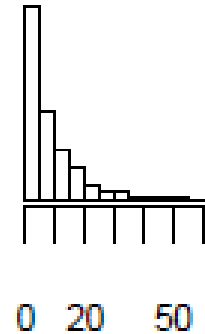
Thanks!



One final comment on RRS studies:

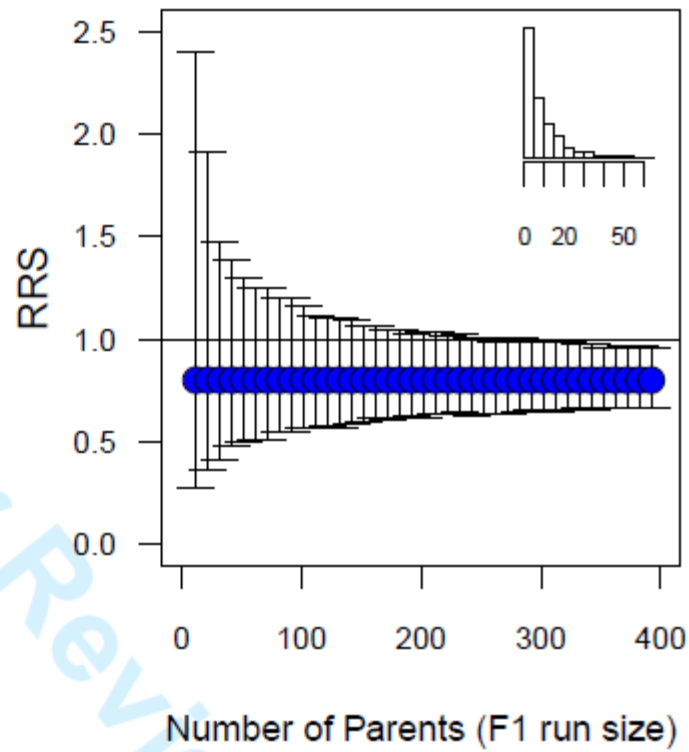
## 5. Statistical power and precision of estimates

Salmon have highly skewed distributions of number of returning offspring



Estimates of RRS are *very* imprecise

### Precision of estimates



Statistical power to detect a difference between H and W fish is very low

### Power to detect a difference

