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

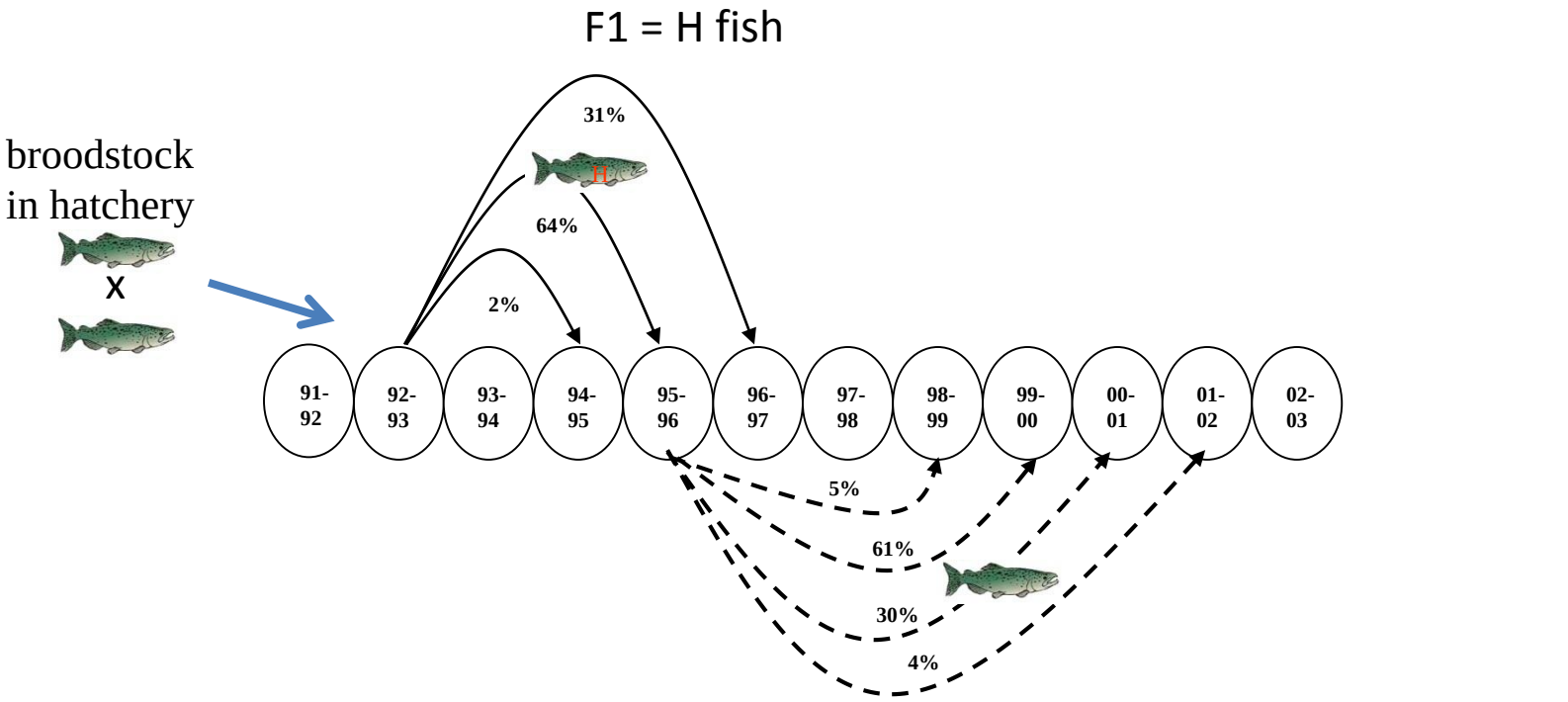
See also Christie et al., 2014. *Evolutionary Applications*

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

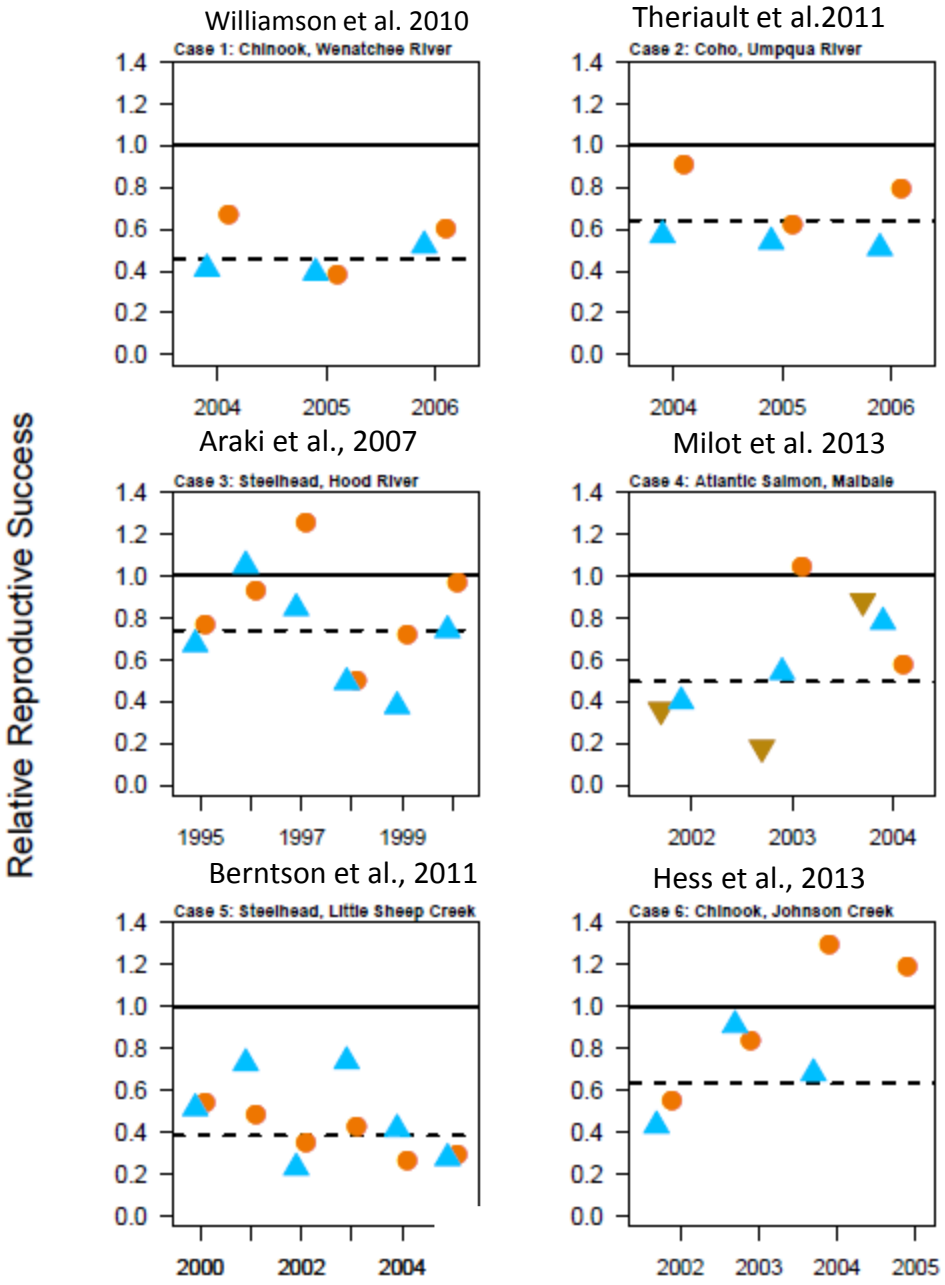
Case studies: criteria for inclusion:

- 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



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).

2: Is the difference genetic or environmental?

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1. **Effects of an extra generation of hatchery rearing**

   (common garden experiment)

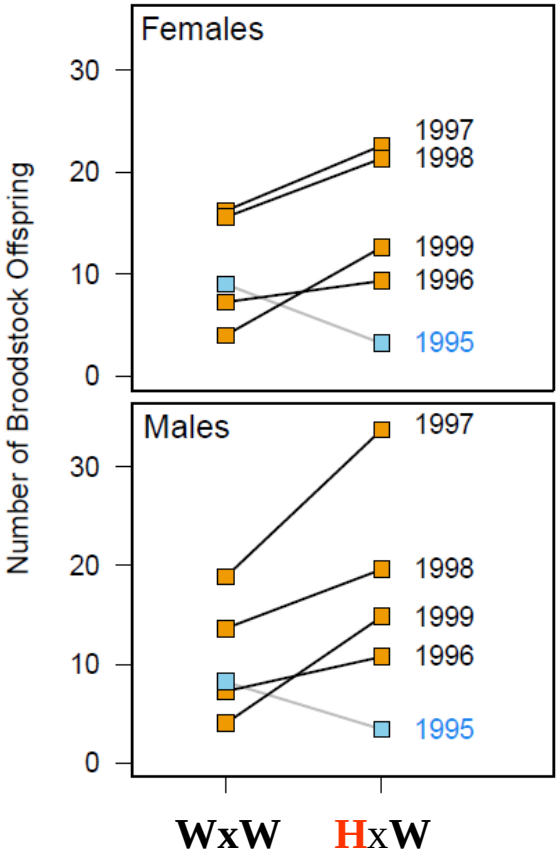
2: Is the difference genetic or environmental?

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



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

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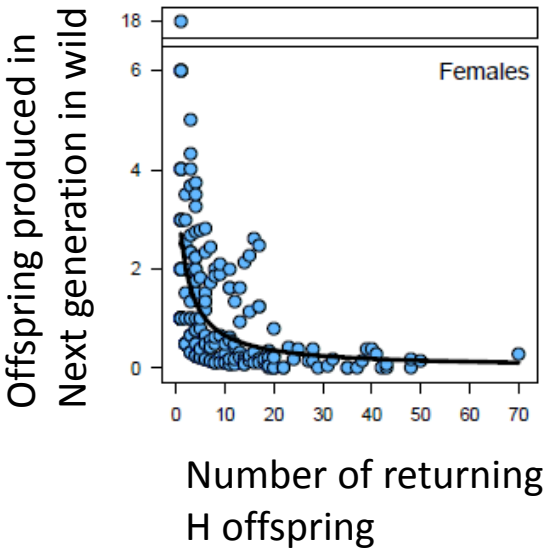
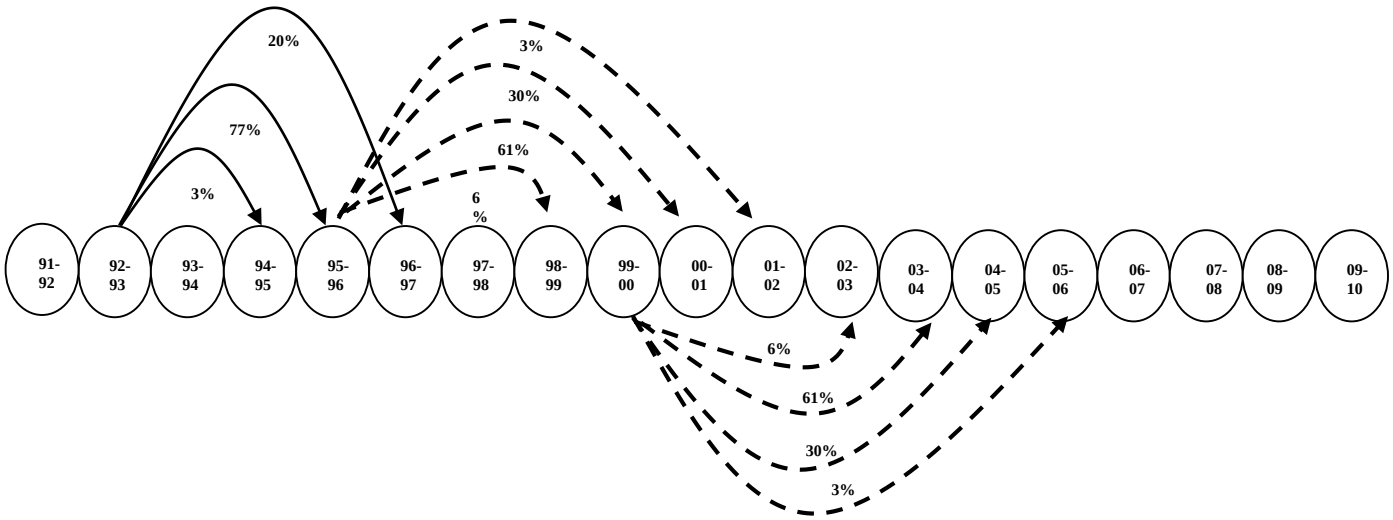


3. *Wild-born* adults of different parents differ in fitness

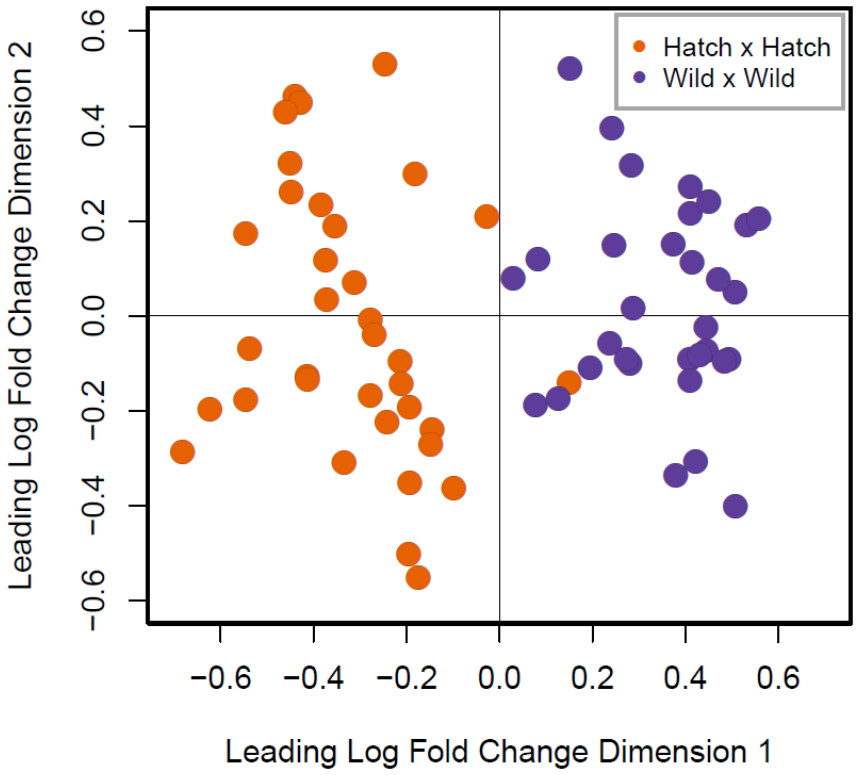


Hood River Steelhead: W_{HxH} fitness 30-40% that of W_{WxW}

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)

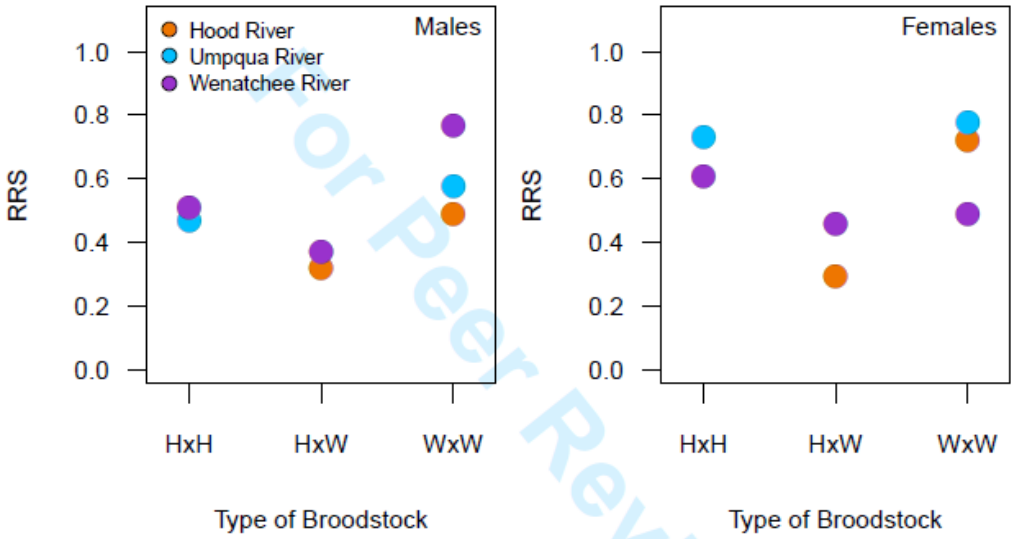
Next: what physiological pathways do those genes control?

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 1st and 2nd 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??

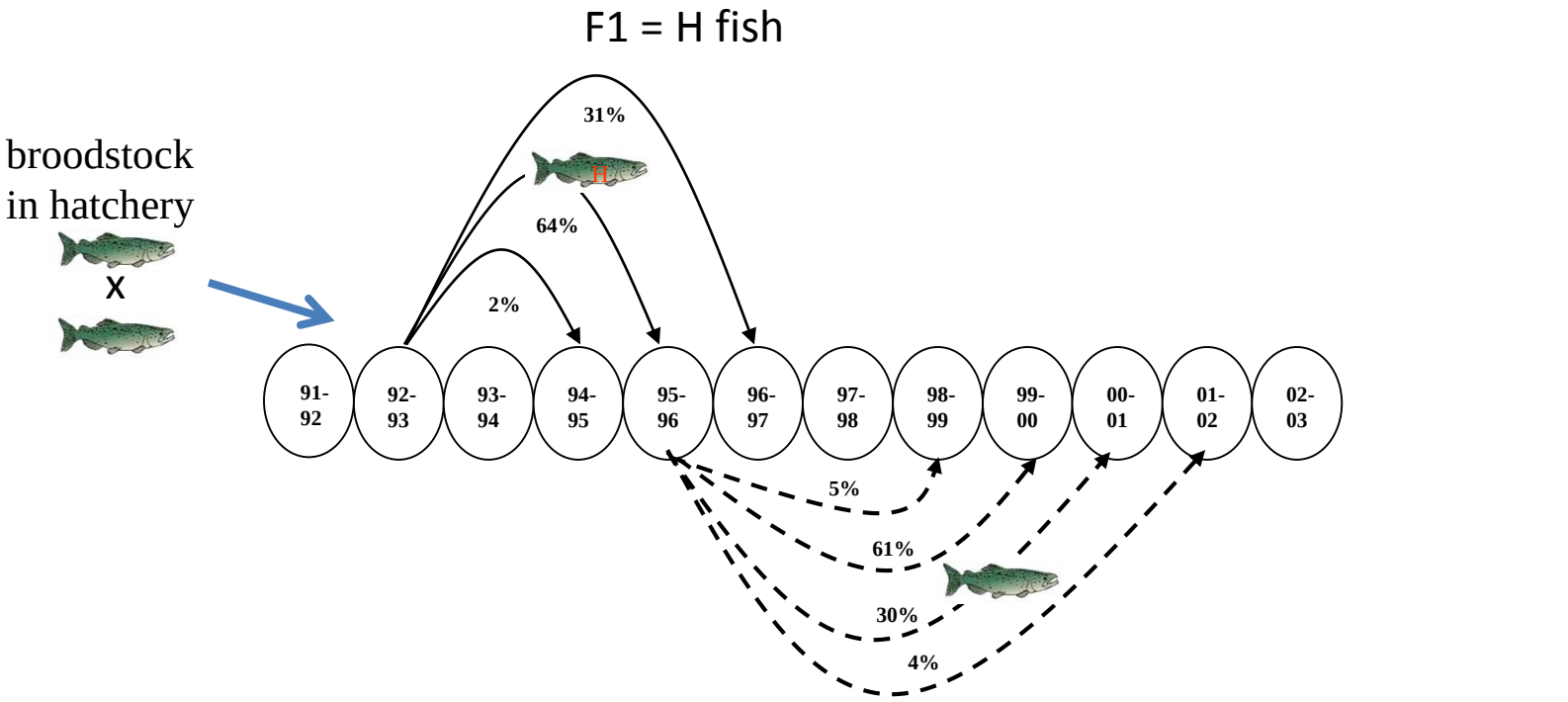
3. Insights into mechanisms

Selection against H fish occurs early in life cycle

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

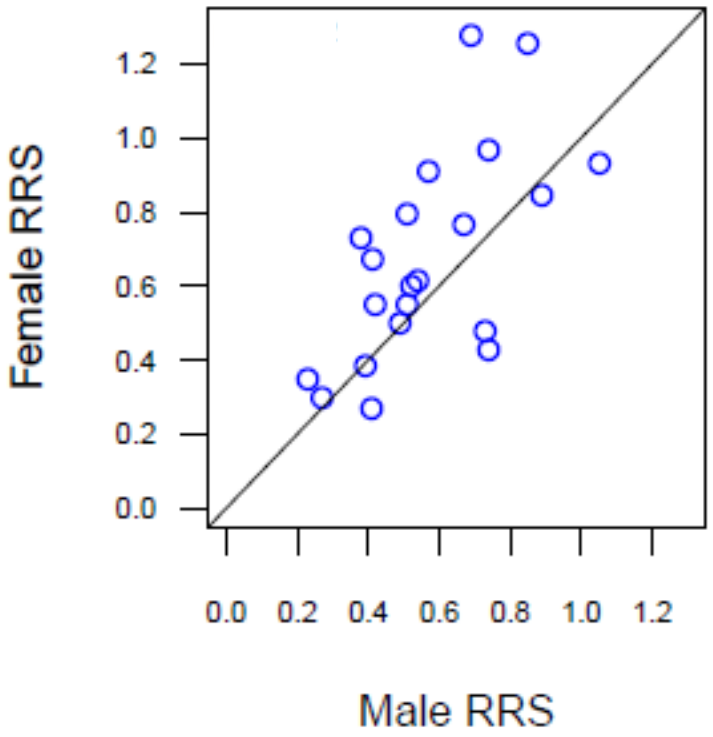
Ford et al., 2013 *Cons letters* Chinook, Wenatchee

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



F2 = wild born, of various ancestry

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



Sexual selection?

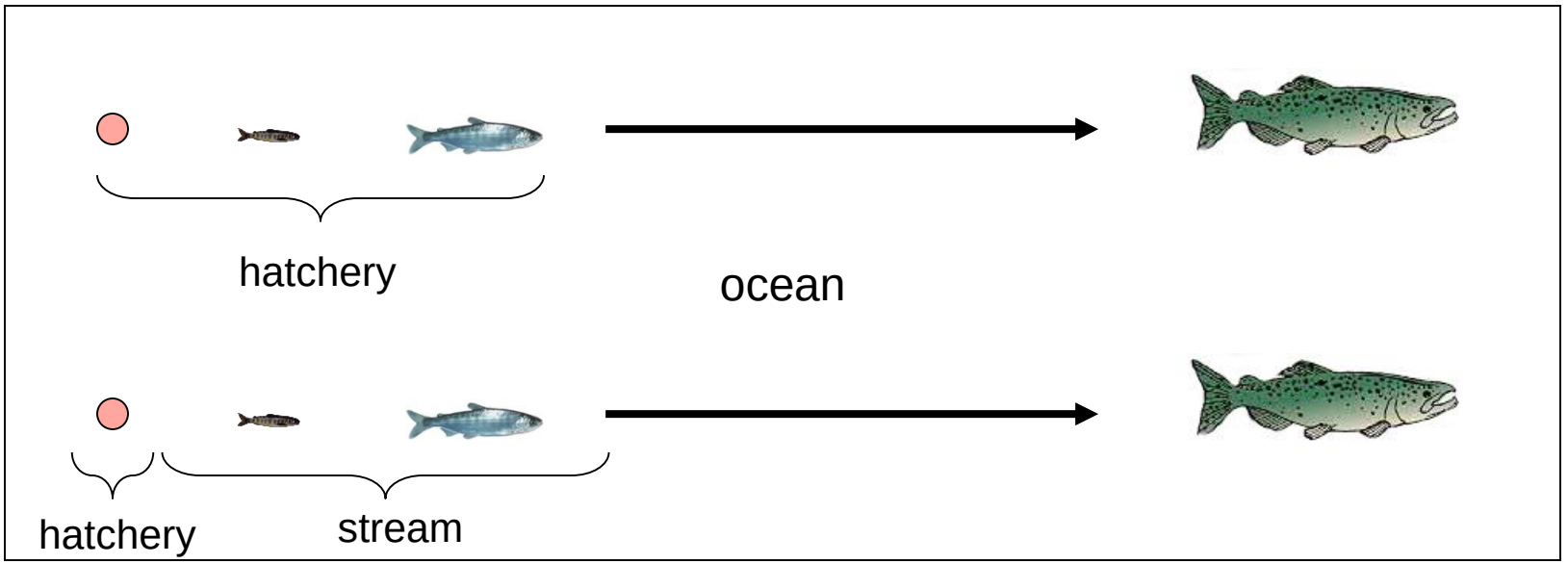
Early male maturity? (e.g. Ford et al., 2012 *Cons Letters*)

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

RRS: as smolts < as fry < wild

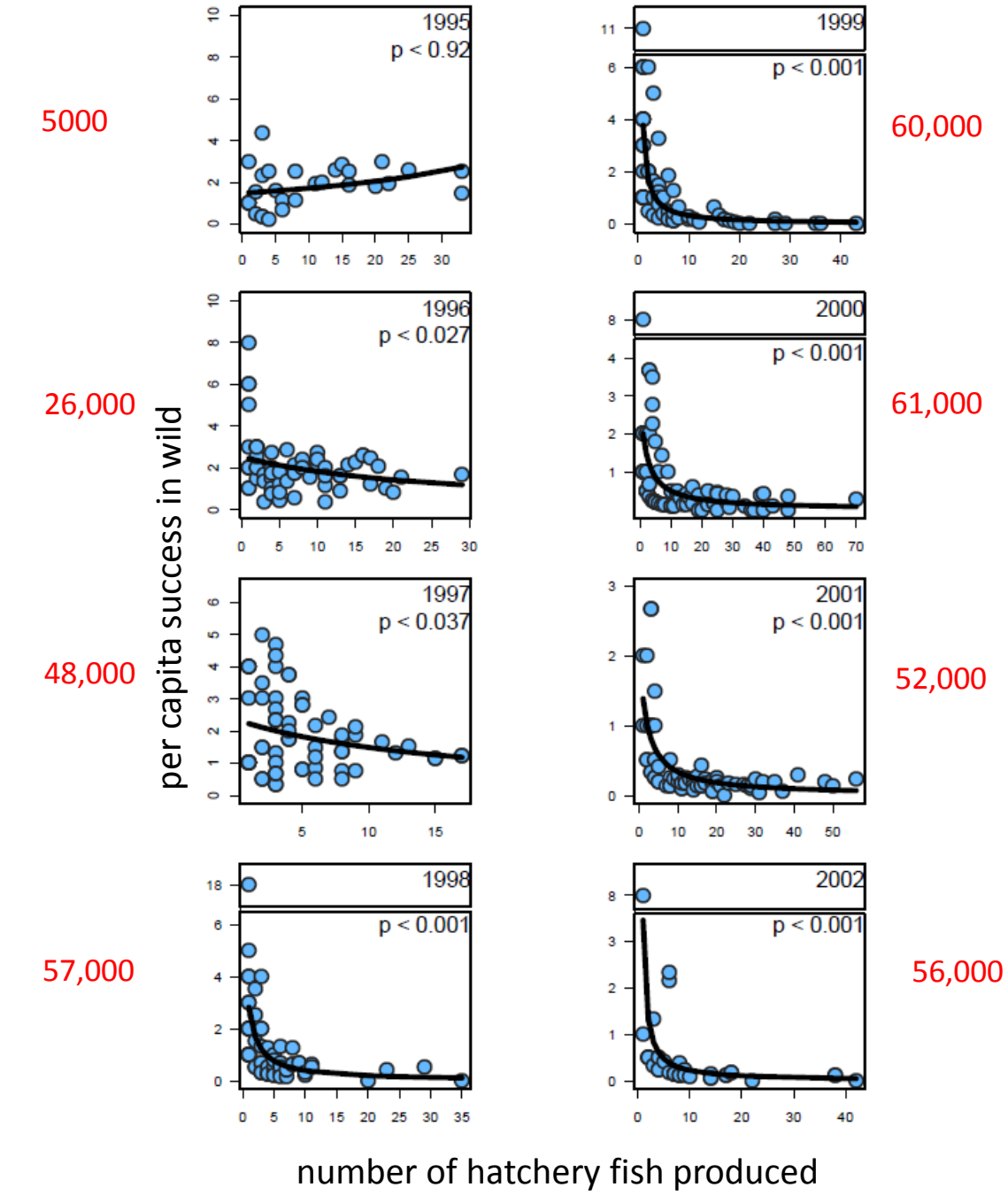
Theriault et al. 2011 *Mol Ecol*, coho, Umpqua
Milot et al. *Evol Appl* Atlantic salmon, Malbaie

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



4: A possible source of selection in the hatchery

Rearing density

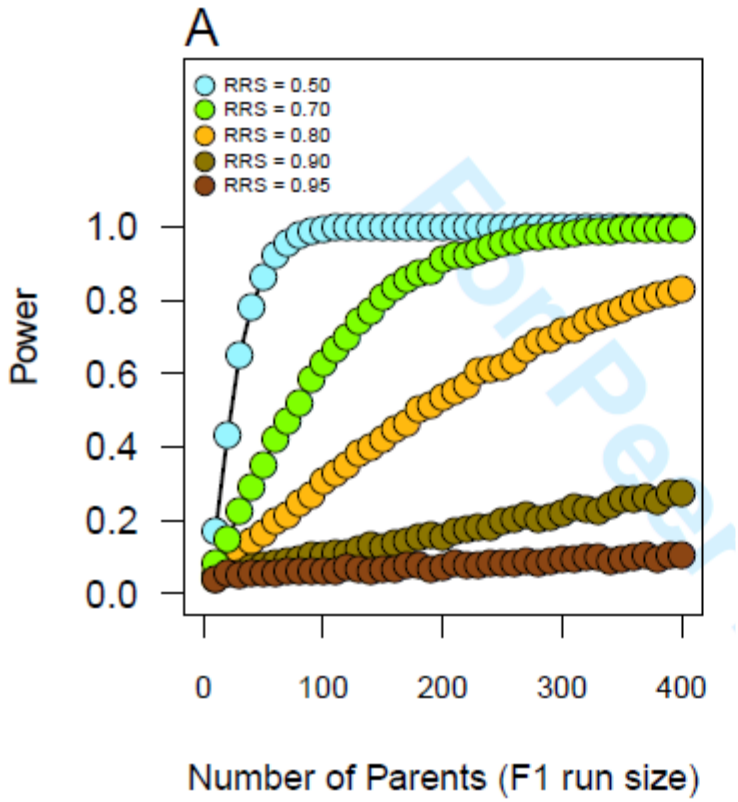


One final comment on RRS studies:

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.

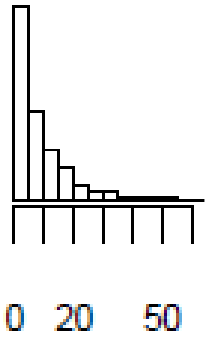
Power to detect differences is very low.

Thanks!

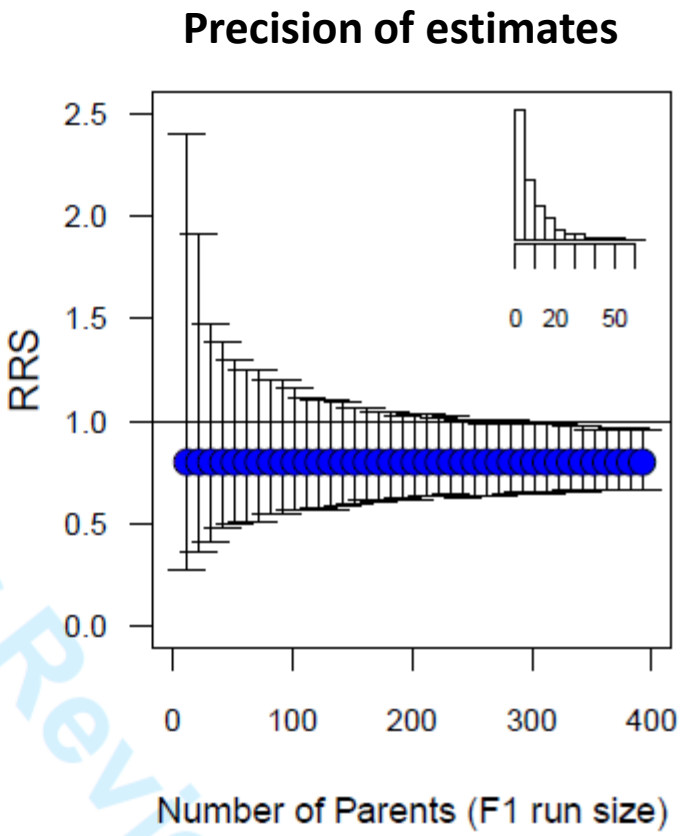
One final comment on RRS studies:

5. Statistical power and precision of estimates

Salmon have highly skewed distributions of number of returning offspring



Estimates of RRS are *very* imprecise



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