

Why is there a difference in sex ratio between hatchery and wild steelhead?



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Hood River steelhead



Hood River Sex Ratio

- Winter run
- Integrated broodstock program



Brood Year	Hatchery Sex Ratio	Wild Sex Ratio
1992	54.2	59.7
1993	43.8	59.9
1994	50.2	63.7
1995	53.0	67.9
1996	55.3	64.7
1997	53.0	60.6
1998	44.8	62.8
1999	47.3	60.0
2000	53.1	62.6
2001	51.9	58.9
2002	52.6	69.3
2003	48.4	63.0
2004	54.8	64.3
Mean SR	50.9	62.9

Sex ratio measured as % female

Hood River Sex Ratio

- Wild population: ALL 13 years female biased
Range: 58.9 – 69.3
- Hatchery population: 9 years female biased
Range: 43.8 – 55.3

Difference in proportions Z-test, $P \lll 0.001$

Question: Why is there a difference in sex ratio between wild and hatchery populations?

Potential explanations

1. Sex reversal of chromosomally XX females into phenotypic males
2. Selection against hatchery females
3. Selection against wild males
4. Lower rates of residency in male hatchery fish



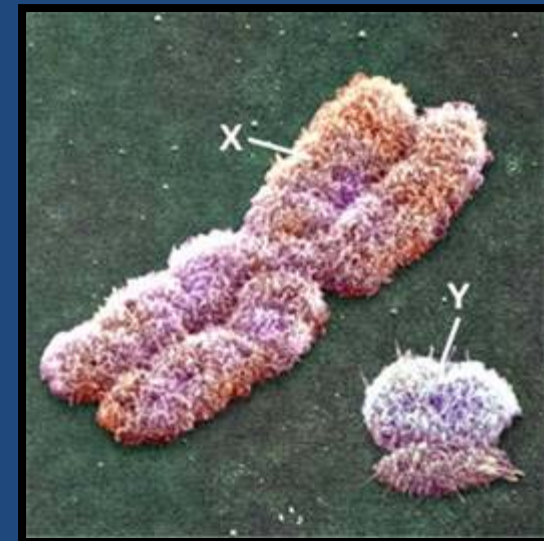
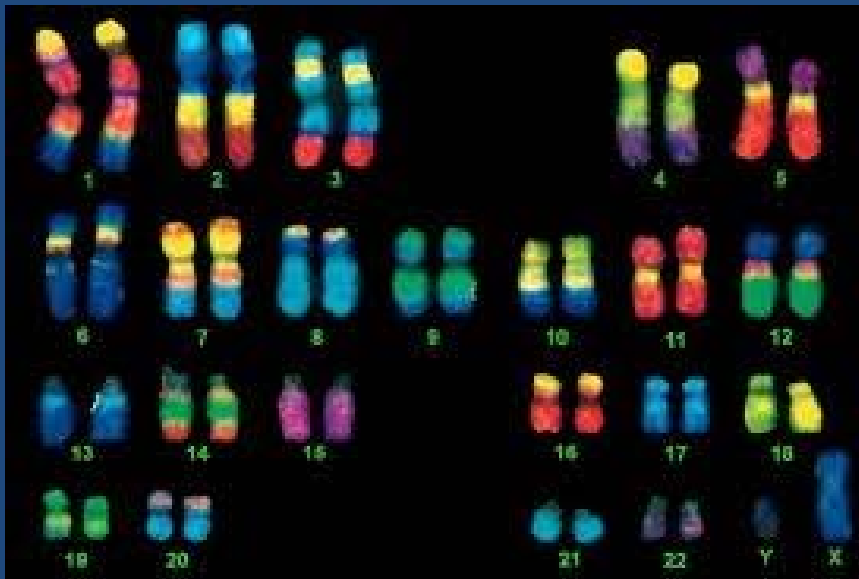
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Sex determination in *O. mykiss*

- Y chromosome = male
- No Y chromosome = female



Mechanism of Sex Reversal

- Aromatase enzyme
 - Converts testosterone to estrogen
- High temperature inhibits aromatase



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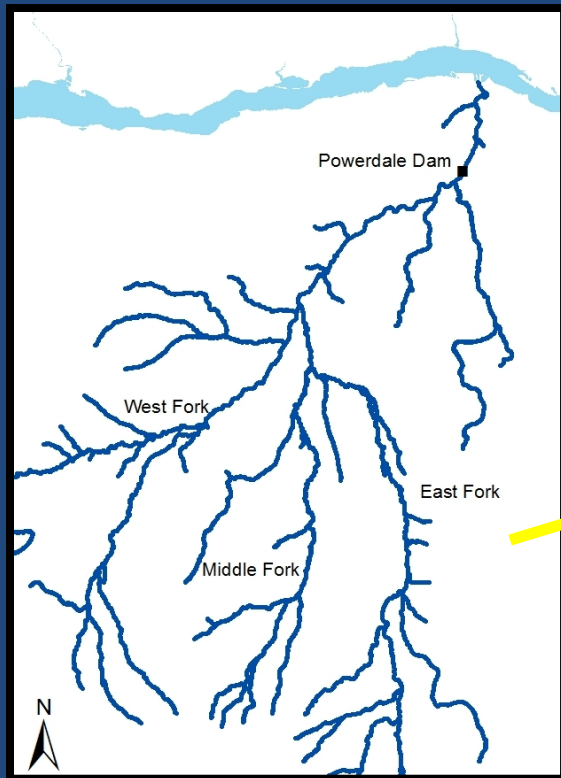


XX females
develop testes



Why Aromatase?

- Spawned Hood River Basin
- Reared at Oak Springs on Deschutes R.
- Deschutes warmer than Hood River



Research question

(1) Does the chromosomal sex match the phenotypic sex in Hood River steelhead?

- % non-matching?
- direction?



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(2) Does the sex ratio in the hatchery population change from juvenile release to adult return?

(3) Is the sex ratio of out-migrating wild smolts 50:50?

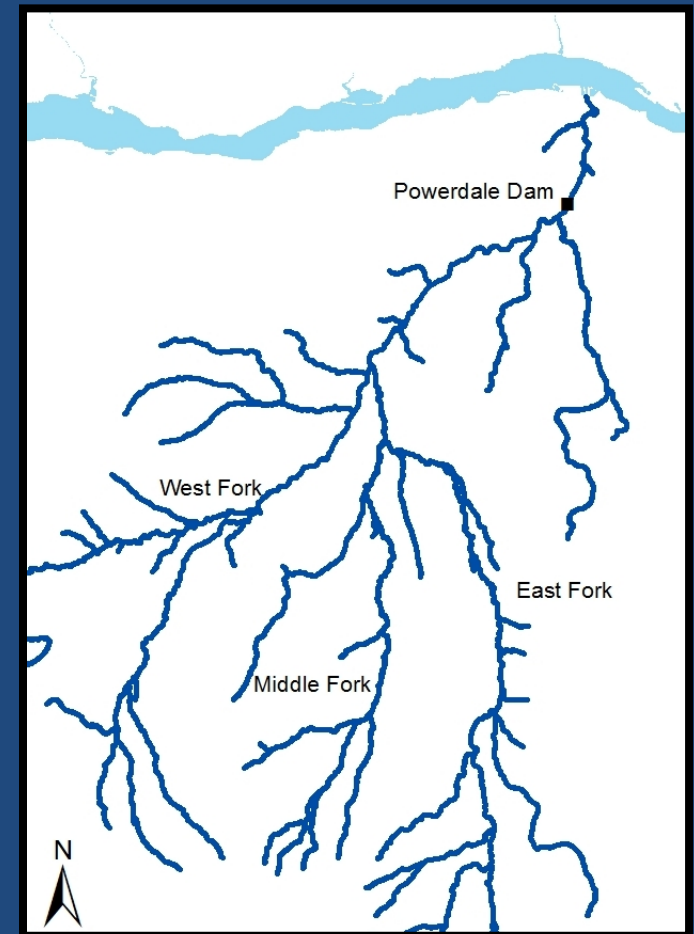
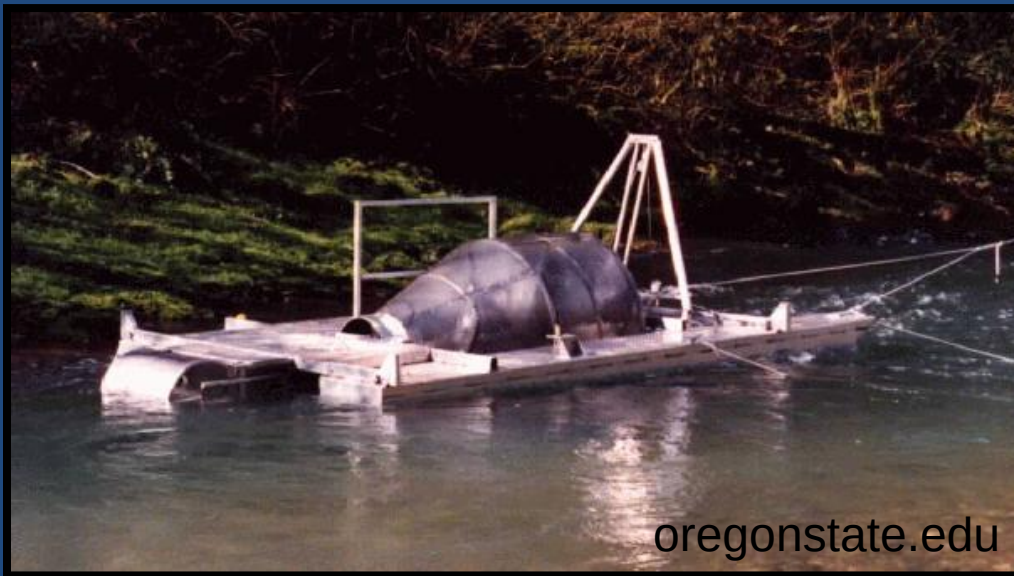
Methods – hatchery juveniles

- Hood River Production Program
- Sampled at 1 year of age
- Fin clip & floy tagged
- Bodies preserved in formalin
- Gonad inspected by stereomicroscopy
- Fish type, family, spawn date



Methods – wild juveniles

- Run year 2006
- 150 juveniles
- ≥ 140 millimeters fork length
- PIT tag
- Winter run offspring



Methods - Adults

- Adults sampled at Powerdale dam (1991-2009)
- Gender, origin, fin clip taken by ODFW
- Random 96 individuals per sex
- Total 196 adult samples
- Wild and Hatchery origin



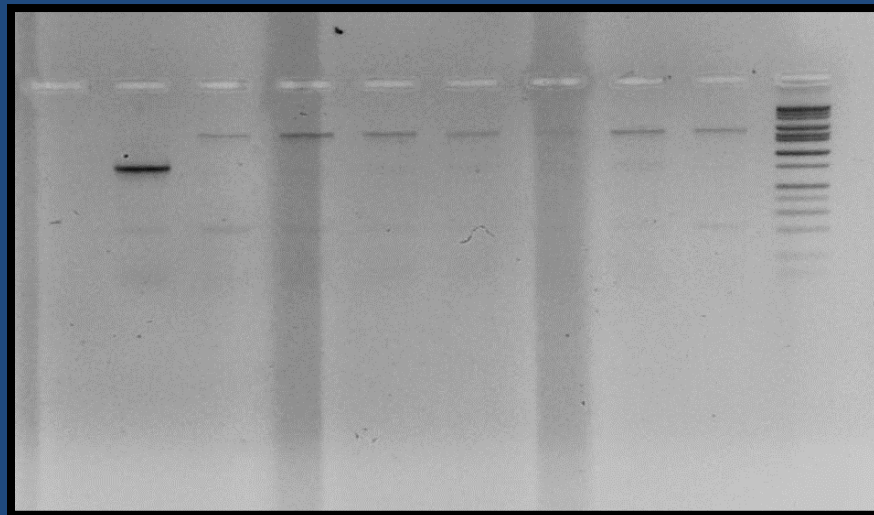
Phenotypic sex

- Adults:
 - ODFW staff visually sexed fish @ Powerdale



Chromosomal sex

- OmyY1 marker - sex marker (Brunelli *et al.* 2008)
- 4% non-concordance rate
- Male band or female band
- Positive reaction band



Research question

(1) Does the chromosomal sex match the phenotypic sex?

– % non-matching?

- Mismatch = putative sex reversal
- Test for non 50:50 sex ratio
 - Chi-square test

Results – hatchery juveniles

- 173 successful reactions
- 6 fish mismatched (3.5 % non-concordance)
- Male-to-female and female-to-male mismatch

Juvenile ID	Spawn Date	Family ID	Fish Type
2	4/20/2010	2821x2796	HH
3	5/24/2010	382x477	WW
29	5/10/2010	2764x2783	HH
44	5/10/2010	2812x2761	HH
62	5/17/2010	458x2804	WH
223	5/24/2010	2774x383	HW

Results - Adults

- 175 successful reactions
- 3 fish mismatched (1.7 % non-concordance)
- Male-to-female and female-to-male mismatch

Run	Chromosomal Gender	% Non-concordance
Winter	Male	2.27
	Female	1.15

Sex Reversal?

- Juveniles
 - No evidence for sex reversal
 - Mismatches in both directions
 - Non-concordance rate below published rate
 - Mismatches from 6 different families, 4 spawn dates and 4 fish types



J. McMillan, NOAA

Sex Reversal?

- Adults
 - No evidence for sex reversal
 - Mismatches in both directions
 - Rate not above published non-concordance rate



Potential explanations

1. Sex reversal of chromosomally XX females into phenotypic males → NOT happening
2. Selection against hatchery females, in captivity or at sea

Juvenile sex ratio at release

	<u># Male</u>	<u># Female</u>
Chromosomal	85	88
Phenotypic	87	86

Not different from 50:50 ratio

Chi-square p-values of 0.82 & 0.94

50:50 at release and at return to the dam

Potential explanations

1. Sex reversal of chromosomally XX females into phenotypic males → NOT happening
2. Selection against hatchery females, in captivity or at sea → NOT happening
3. Selection against wild males at sea

Wild smolt sex ratio

- 127 successful reactions
 - 64% female
 - 82 females, 45 males
- Ages 1-4
- 2 and 3 year olds – similar sex ratios



Potential explanations

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2. Selection against hatchery females, in captivity or at sea → NOT happening
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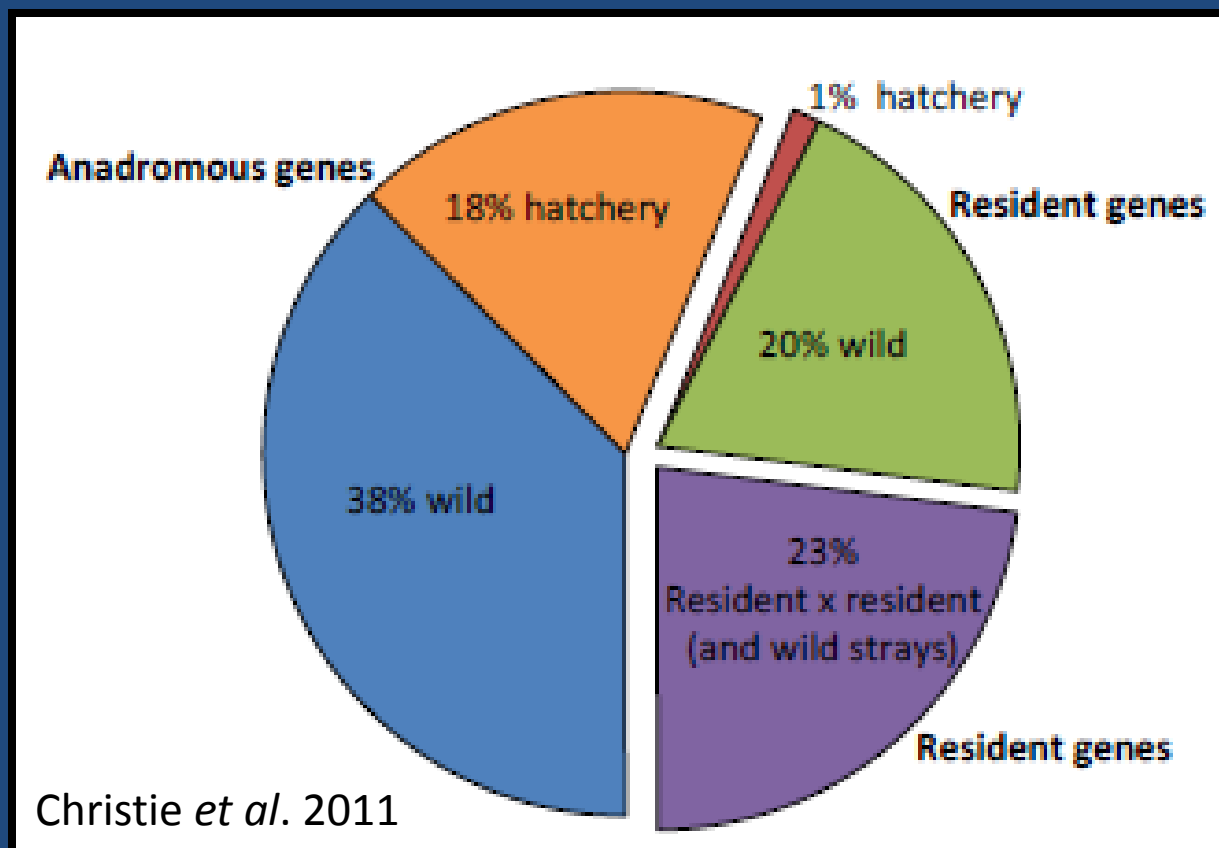
Potential explanations

1. Sex reversal of chromosomally XX females into phenotypic males → NOT happening
2. Selection against hatchery females, in captivity or at sea → NOT happening
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Selection in freshwater? Rundio *et al.* 2012
→ NOT likely

Potential explanations

4. Lower rates of residency in male hatchery fish

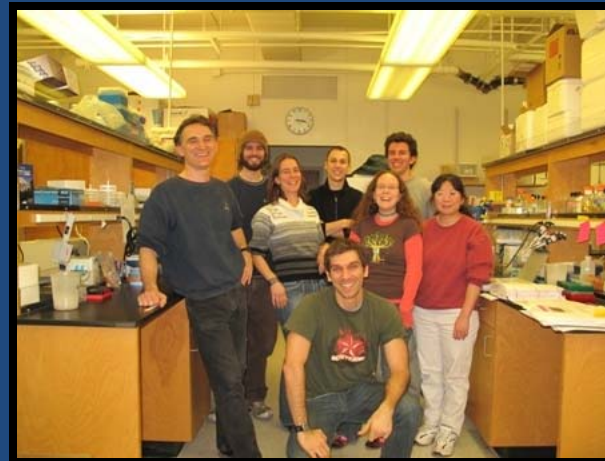


Potential explanations

1. Sex reversal of chromosomally XX females into phenotypic males → NOT happening
2. Selection against hatchery females, in captivity or at sea → NOT happening
3. Selection against wild males at sea → NOT happening
4. Higher residency in wild males than hatchery males
→ Most plausible explanation

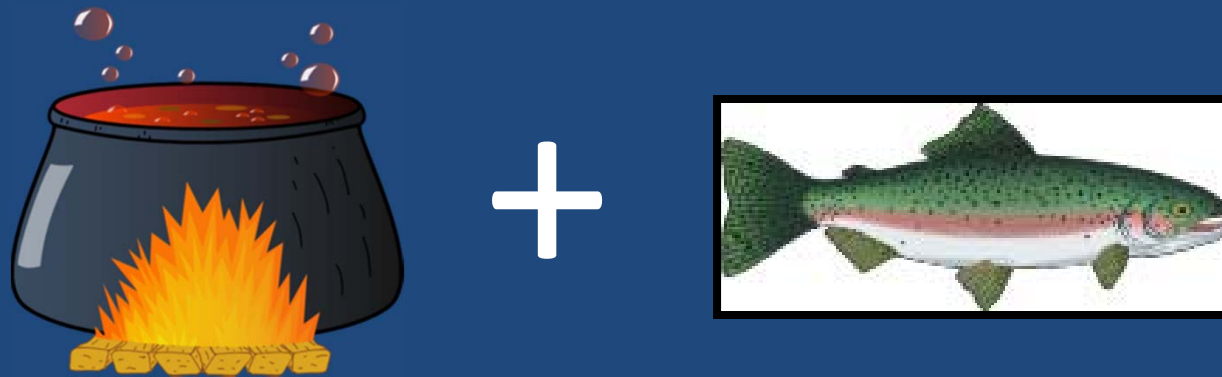
Thank You!

- Jim Gidley & Albert Santos
 - Parkdale fish facility
- Lyle Curtis & staff
 - Oak Springs hatchery
- Blouin lab



Other research projects

- Noakes *et al.* Temperature and Steelhead Sex: a threat from climate change?



- Thompson *et al.* Sex biased survival in wild Alsea and Nehalem River smolts?