Migratory *O. mykiss* Colonizing a Natal Stream After Barrier Removal in the Methow River basin, WA

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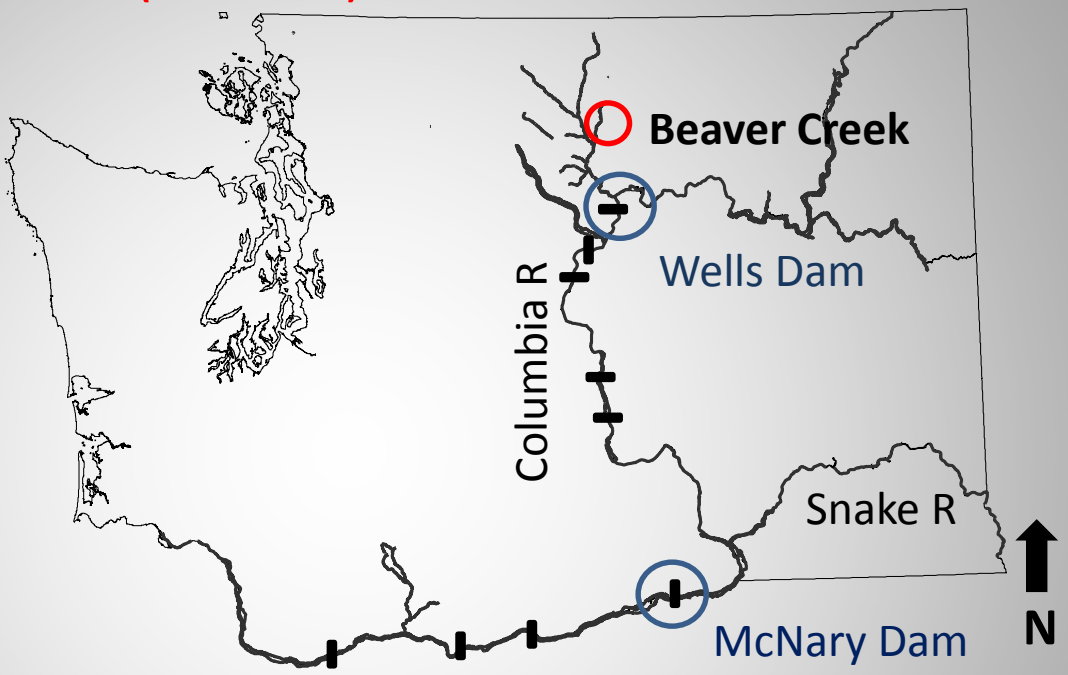
Willamette Science Review
February 2017

Study Area – tributary Methow River, upper Columbia Basin

Long mainstem migration (843 km)

9 mainstem dams



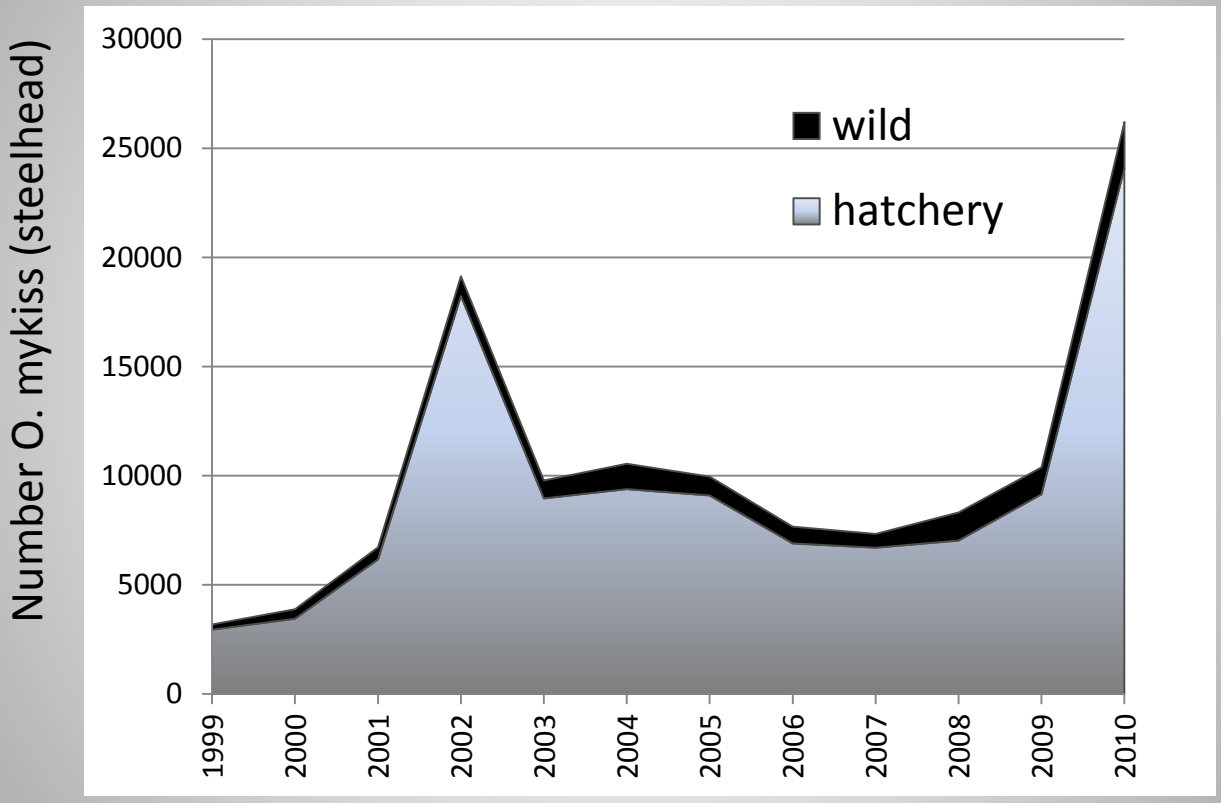
Upper Columbia Steelhead listed endangered 1997 -> threatened

Abundance	<5% extinction risk 100 yrs
Productivity	3,000 spawners
Spatial Structure	Previously occupied habitats
Diversity	Natural patterns genetic, phenotypic diversity

2010 Status Review
Not viable

Study Area - Steelhead returns to Wells Dam 1999-2010

80-90% returning adults hatchery-origin



From WDFW 2010

Study Area - 7 Diversion dams redesigned in Beaver Creek 2002-2004

Objectives

- Do migratory steelhead establish a population in the re-opened habitat?
- Which source -> establishes a population?
  - Individual reproductive success
  - mate selection, successful phenotypes to next generation
  - Founder effect? Or low diversity
- What spatial extent of colonization 1 generation after re-open habitat?
  - Migration strategy (tag tracking)
  - Genetic

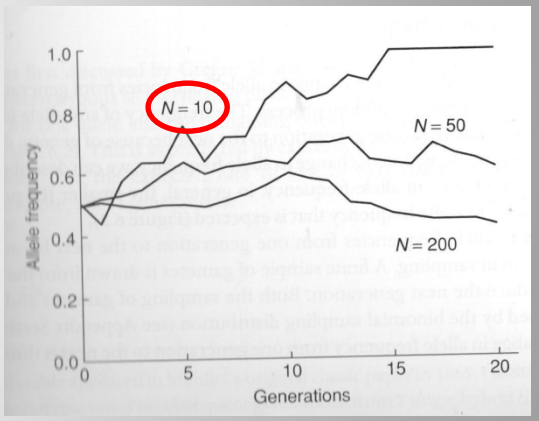
Three major processes shaping genetic structure ~

Gene Flow ~

Migration
Decreases genetic
Differences thru
mixing

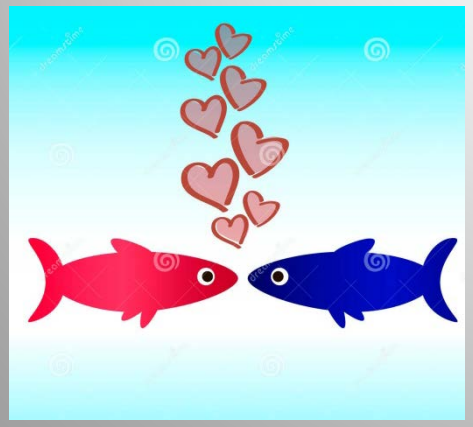
Drift ~

Increases genetic
Differences
Random fixation alleles
Due to finite popn size



System of Mating ~

selection for trait – genetic link



Mutation

Selection

spawn

egg

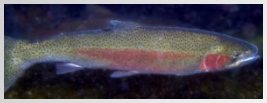
fry

parr

Rear in stream 1-4 yr

Migrate back to natal stream

Adult



Rear in ocean
1-4 years

smolt

estuary

Life history diversity

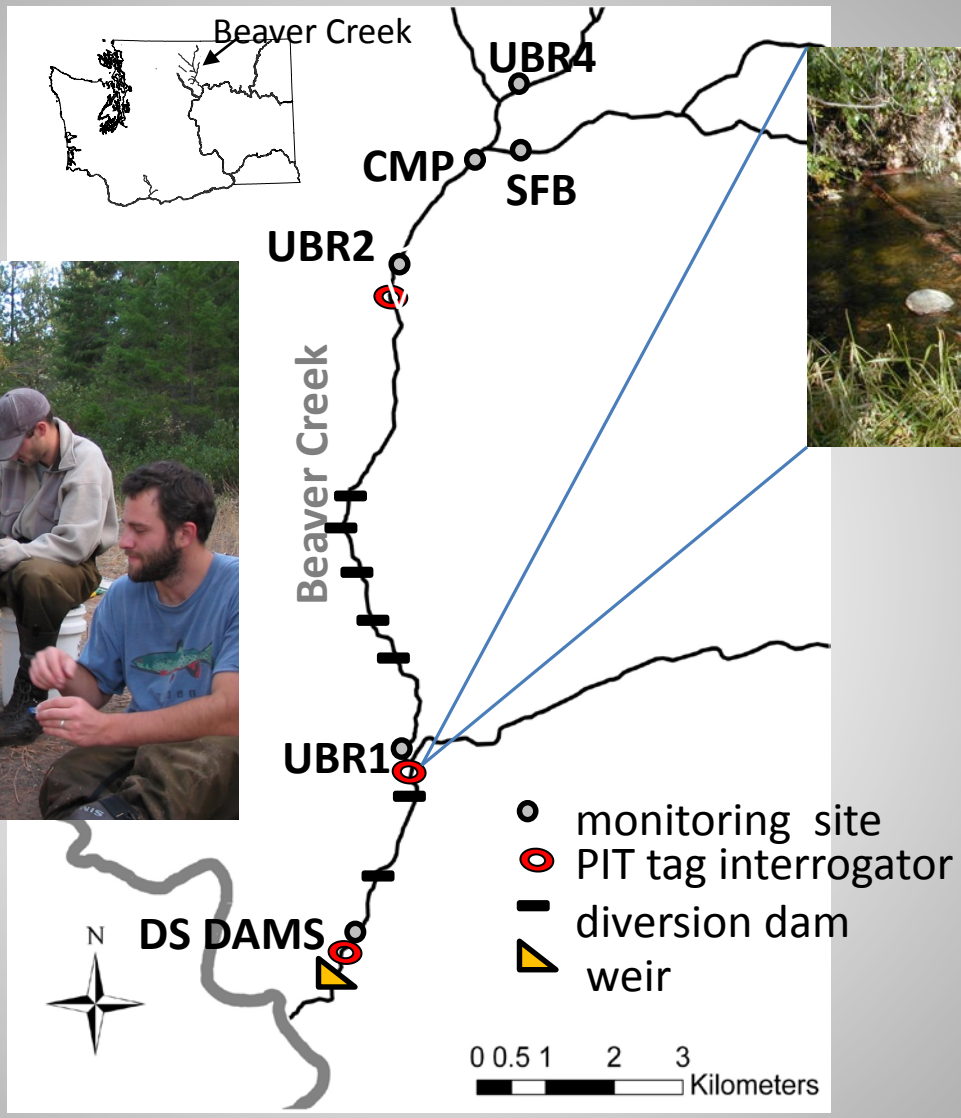
Migration

Iteoparous
Overlapping generations

Anadromous Estuary	Steelhead
Fluvial (River) Resident (Stream) Adfluvial (Lake)	Rainbow Trout

Fresh:salt

1:1	2:1	3:1
1:2	2:2	3:2
1:3	2:3	3:3
1:4	2:4	3:4



Downstream tag readers

Near mouth Methow
Dams on Columbia R

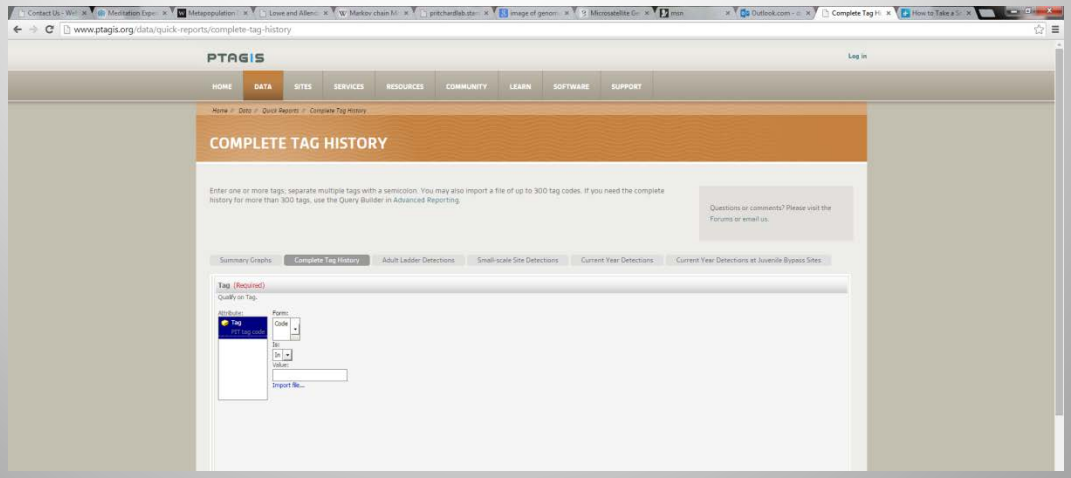
Methods – Capture

- Upstream/downstream picket weir
  - Feb to Dec 2005, 2006, 2007, 2008
  - Adults on spawning migration
  - Parr outmigrating

- Electrofishing at monitoring sites
  - Juvenile rearing in tributary

Methods - Tagging

- Migration behavior was identified using PIT tag
- 16 digit alpha-numeric code
  - 3D9.1BF1FDC829
- Followed tags of juveniles reared in Beaver Creek to return as adults
  - PTAGIS



Methods - Sample Selection

- Used Spawners from BY 2005 and 2006
- Queried tissue samples for analysis by length to match these brood years collected 2005-2008

Collection/BY age	2005	2006	2007	2008
2005	0			
2006	1	0		
2007	2	1	0	
2008	3	2	1	0

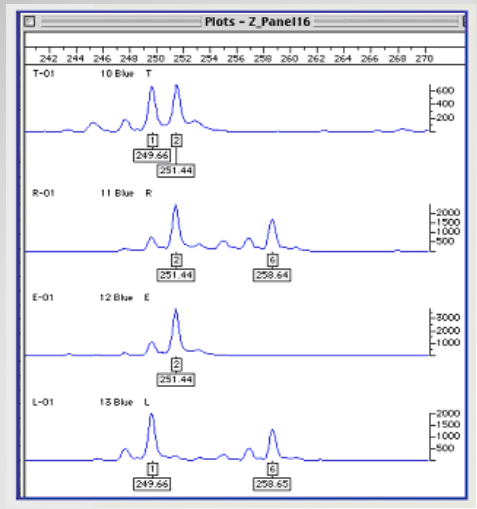
Collected Wells Hatchery tissue from WDFW for reference

Methods - Tissue collection and Genotyping

- Fin clip preserved in 95% EtOH
- DNA extracted
- PCR amplification optimized for each locus
- 16 usat loci – analysis conducted at UI Aquaculture Research Station, Hagerman ID
    - 13 usat loci standardized (Stevensen et al. 2009)
    - *One102* (Olsen et al 2000), *Omm1036* and *Omm1046* (Rexroad et al 2002)

Parent – Offspring Matching

Exclusion tests with 1 mismatch using Cervus > match 15 of 16 loci



Father	249	251
Mother	251	258
Child	251	251
Child	249	258

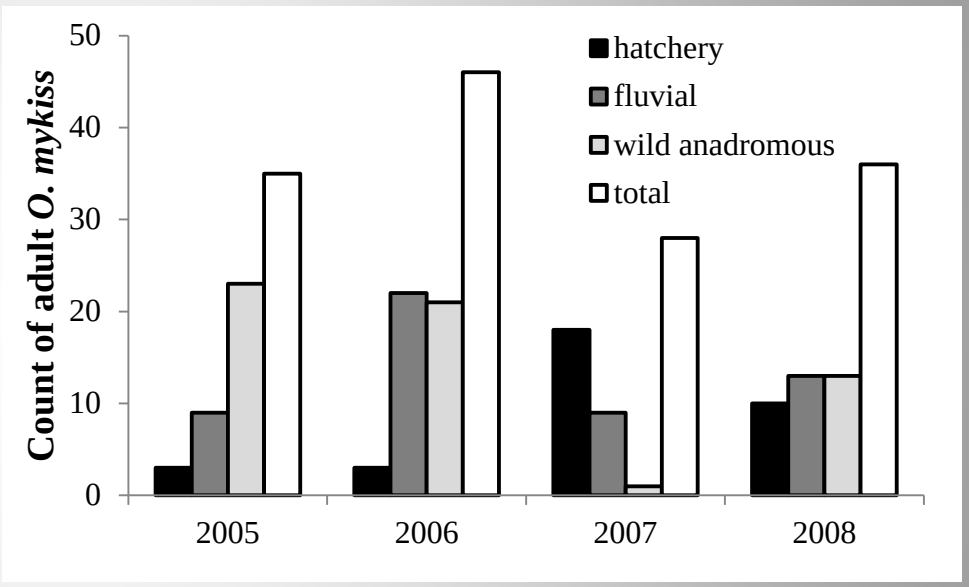
Relate Successful Reproduction to Mate Selection

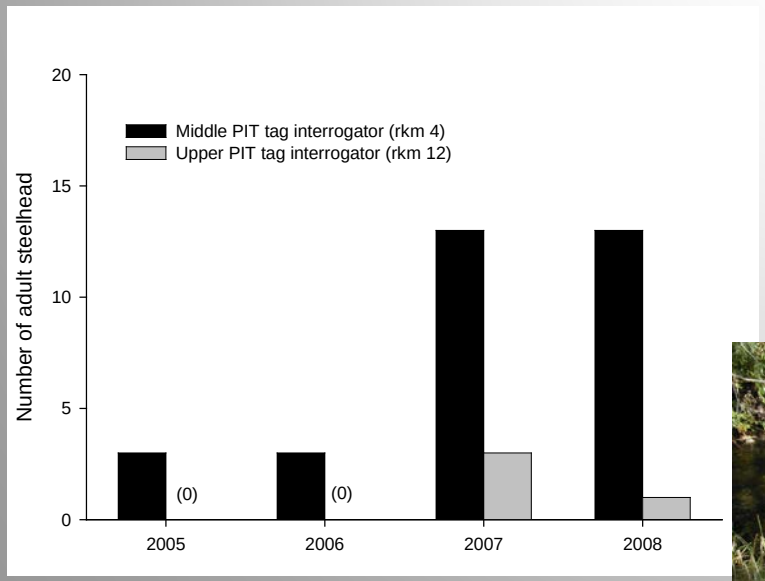
- Use Spearman Rank correlation to look at association between mating pairs

Change in Popn Genetics over Generation

- F_{ST} and Fisher exact tests

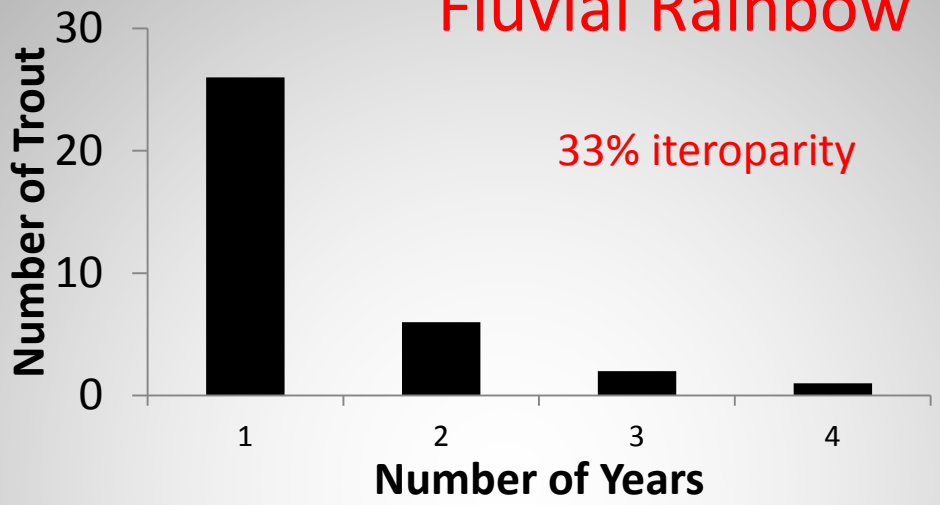
Results – Do steelhead enter the re-opened Habitat? Source?



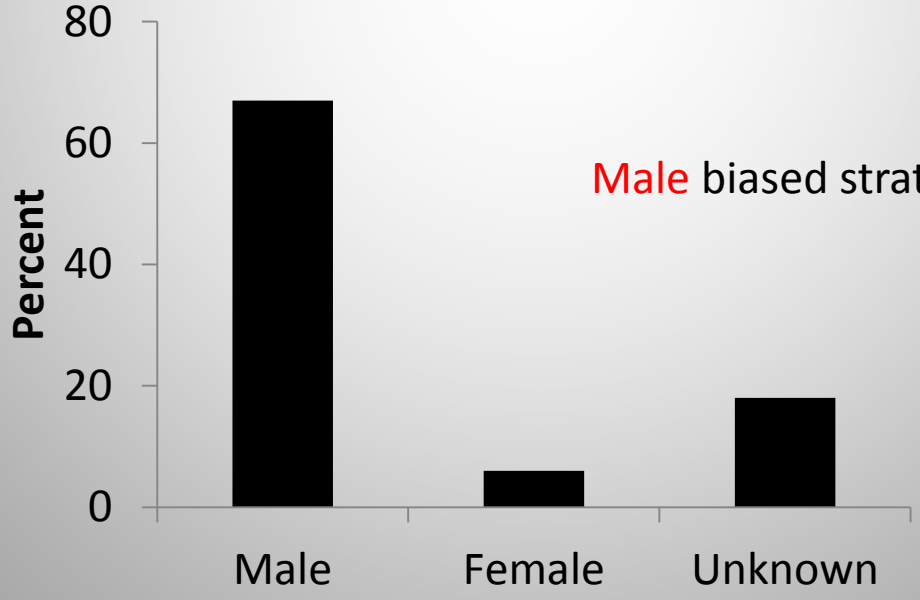


Results – Do steelhead colonize the re-opened Habitat? Source?

Fluvial Rainbow Trout

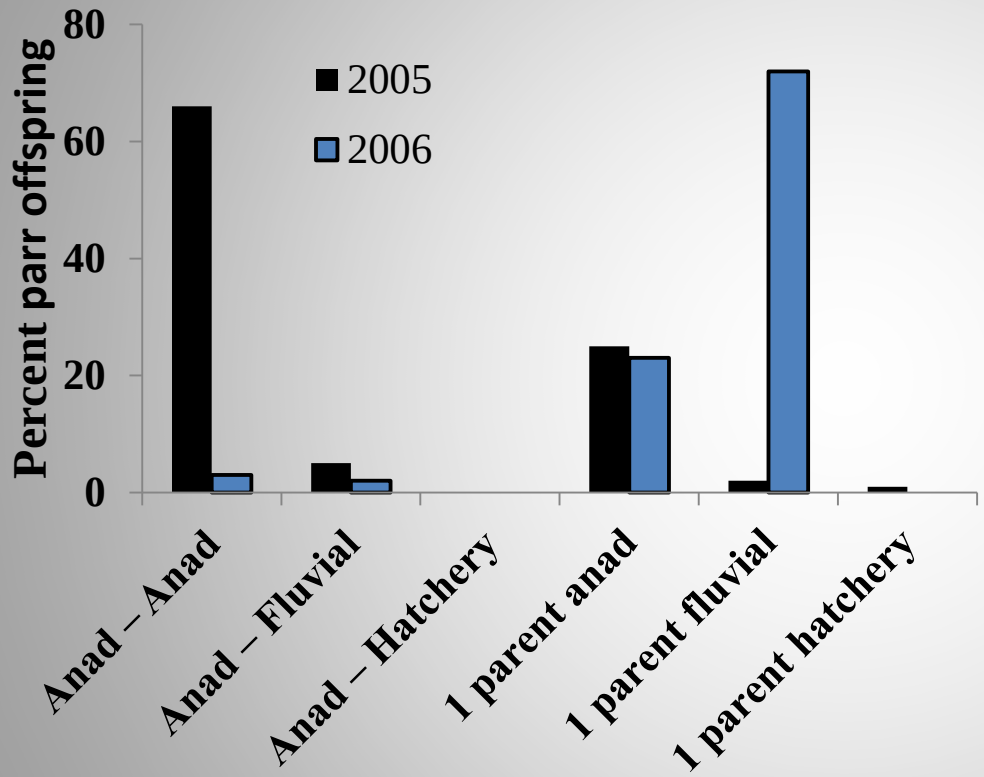


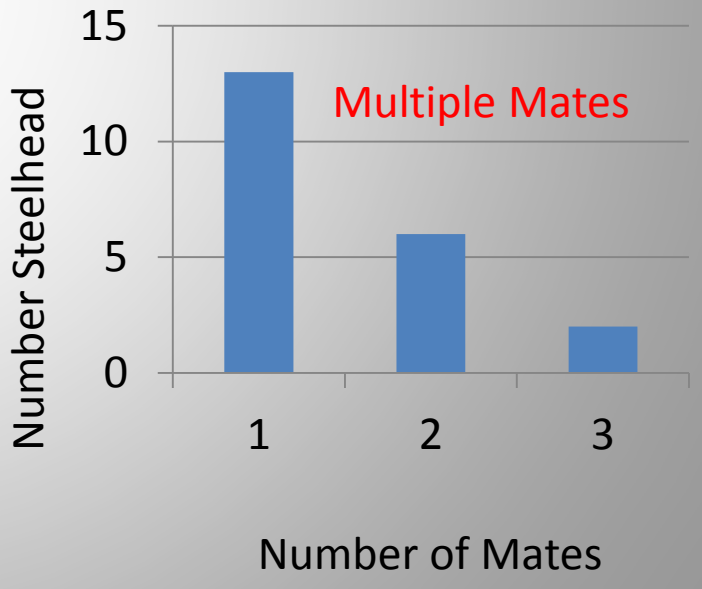
33% iteroparity



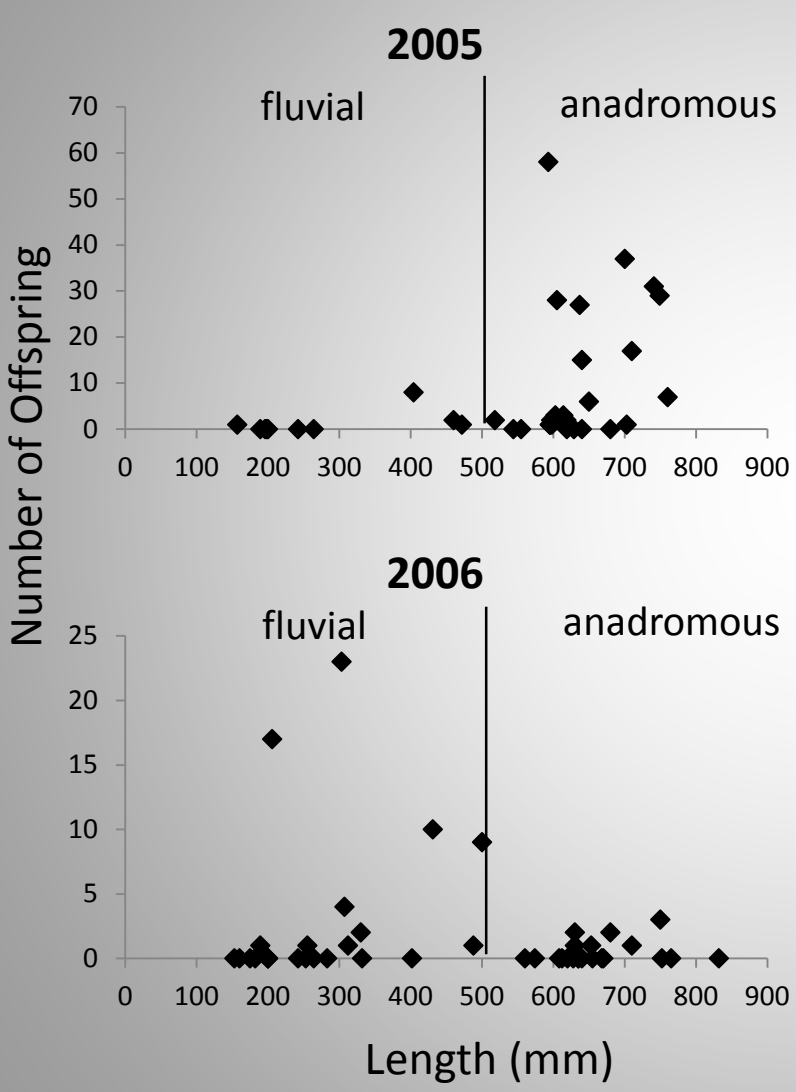
Male biased strategy

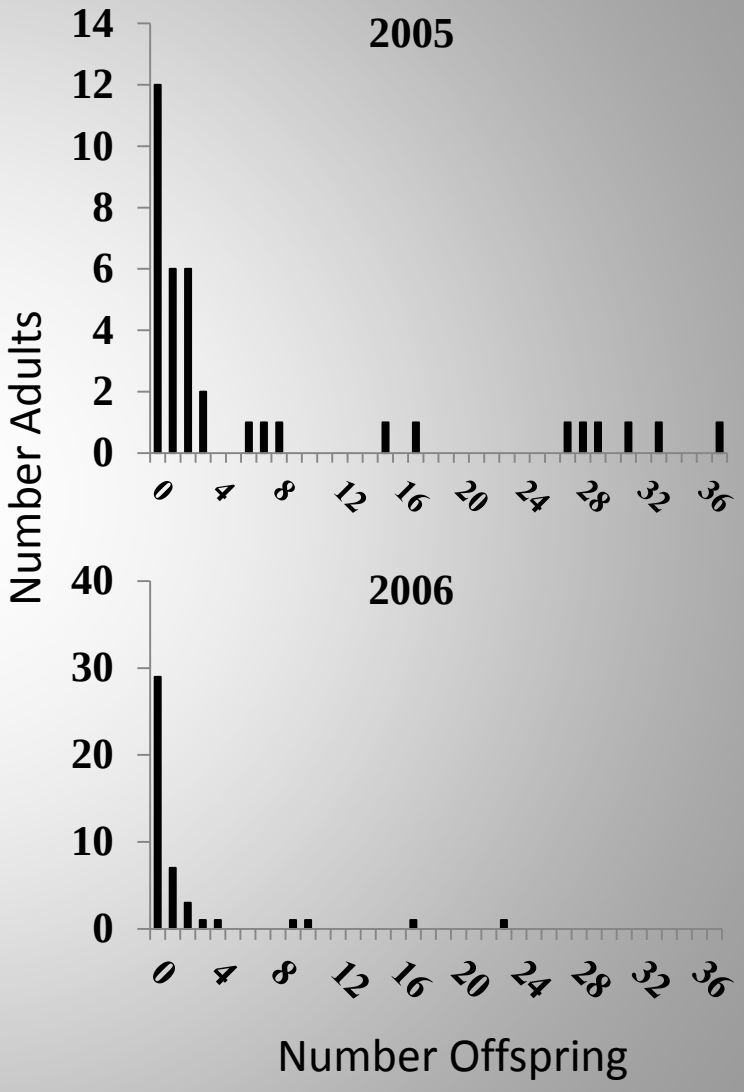
Results – Successful mate selection by source?



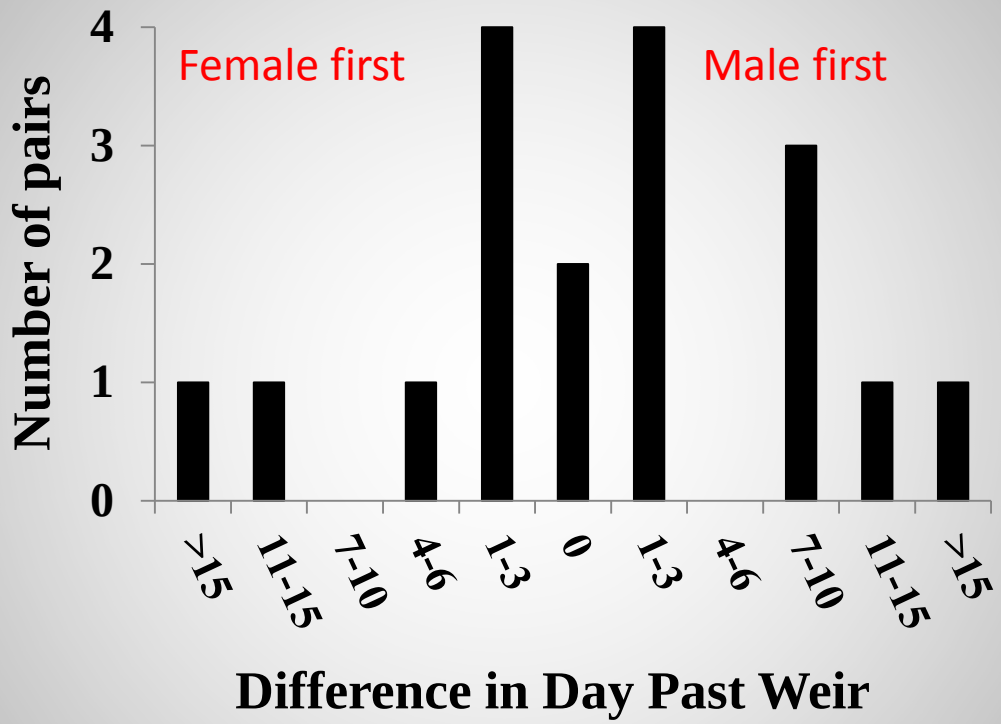


Results –Successful spawners by size/life history



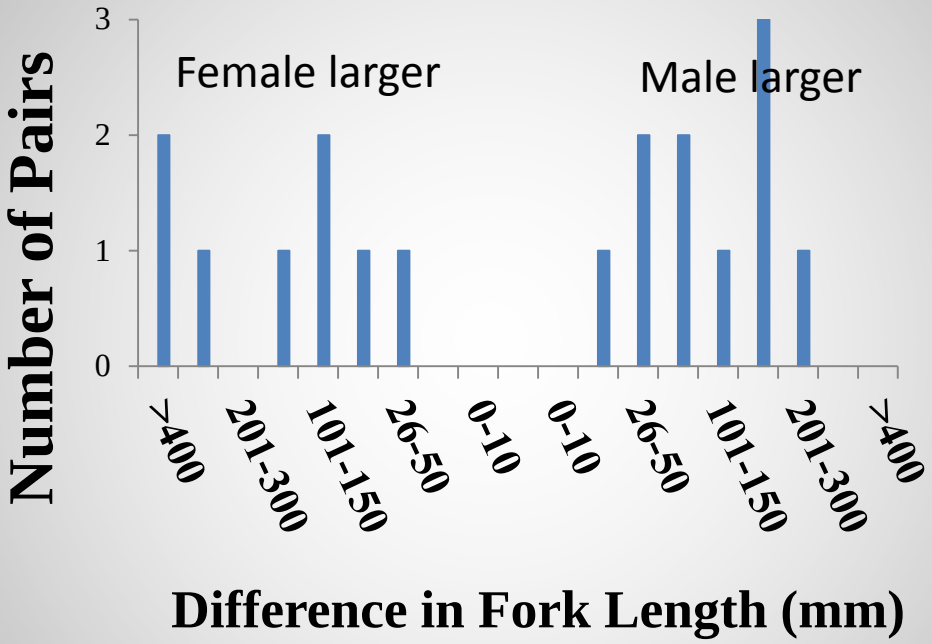


Results - What phenotypes were associated with successful mating?



- Sig. paired by day past weir (early-early, later-later) ($p<0.001$, $\rho=0.84$)

Results – What phenotypes were associated with successful mating?

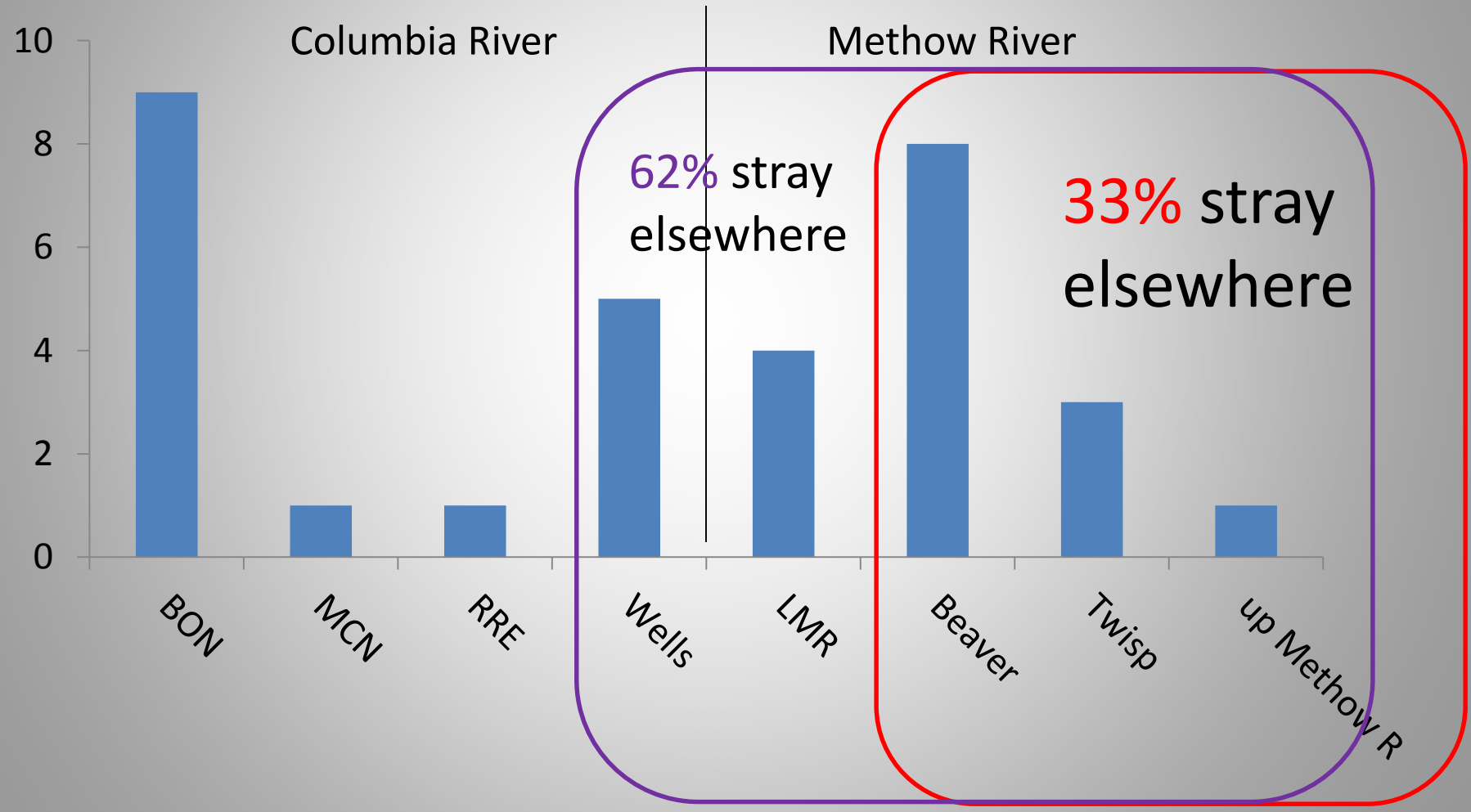


Sig. disassociation in size (larger-smaller) ($p=0.005$, $\rho=-0.72$)

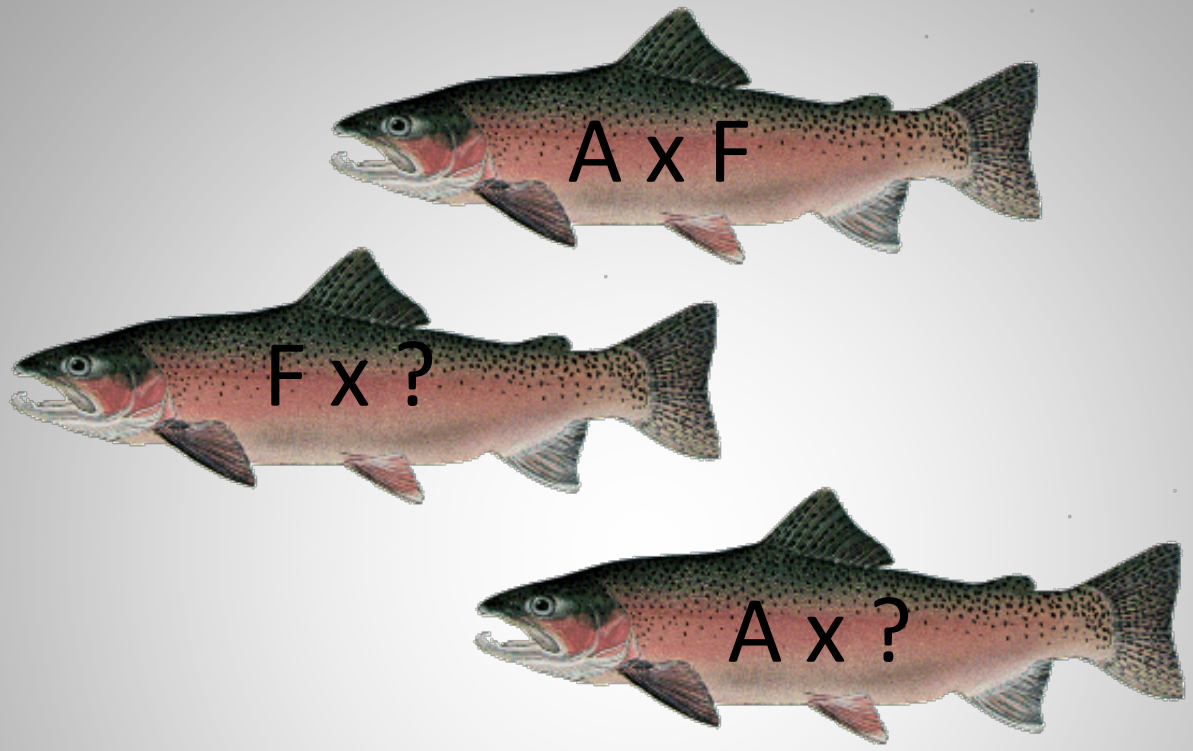
High genetic exchange among life history and generations

Random mating => no founder effect

Results - Do steelhead colonize the reopened habitat?



Results - Returning Offspring as Adults

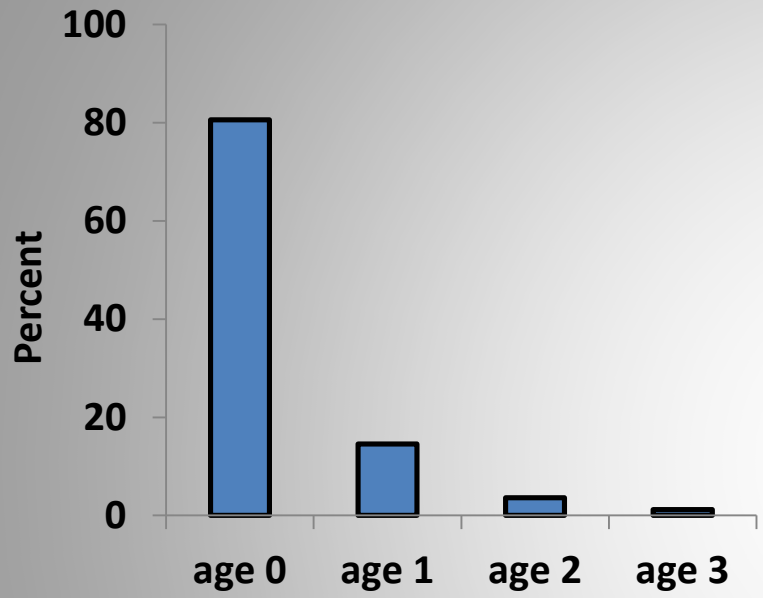


BUT, 50% parr progeny were AxA cross

Survival 1.3%

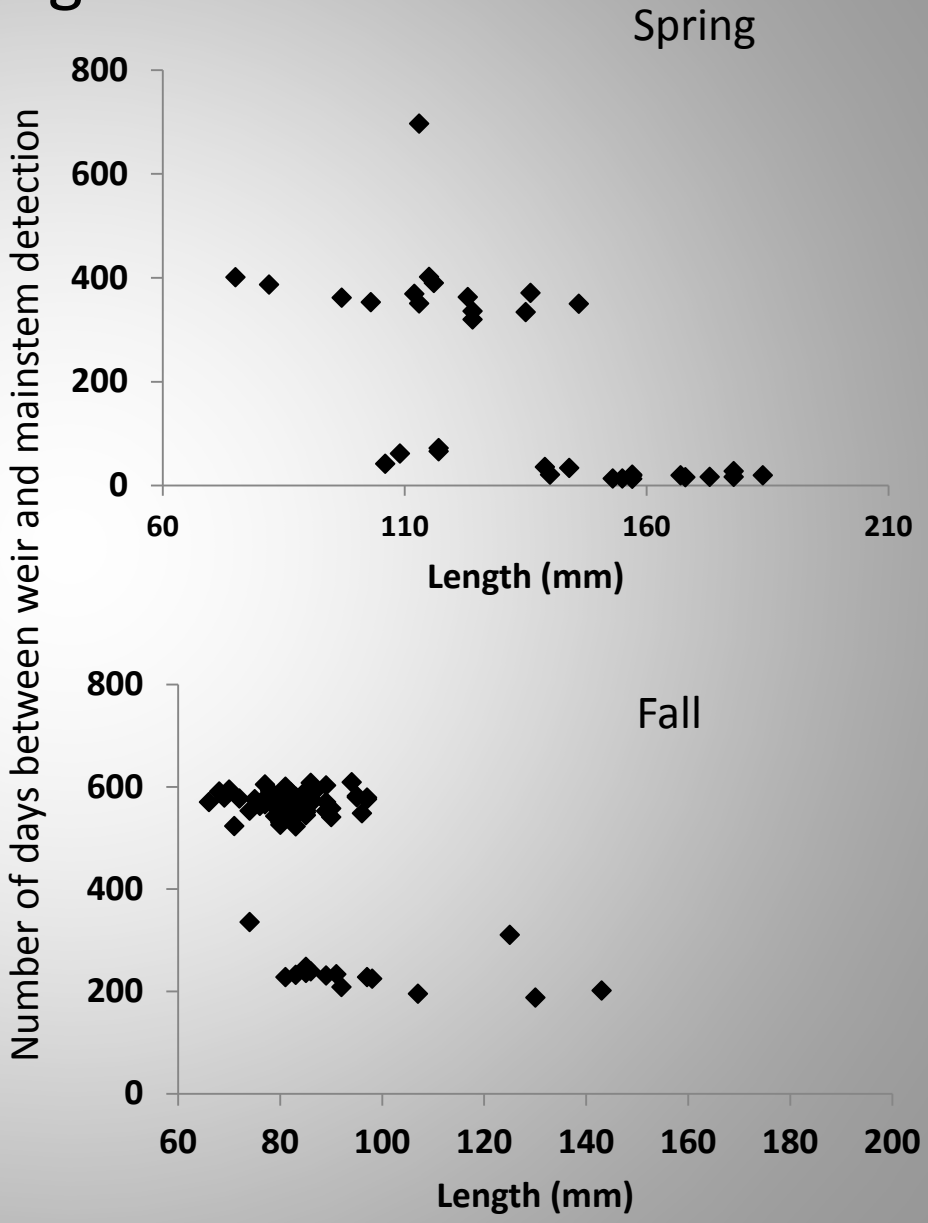
Results – Successful phenotypes?

Juvenile migration



80% offspring captured
Age 0

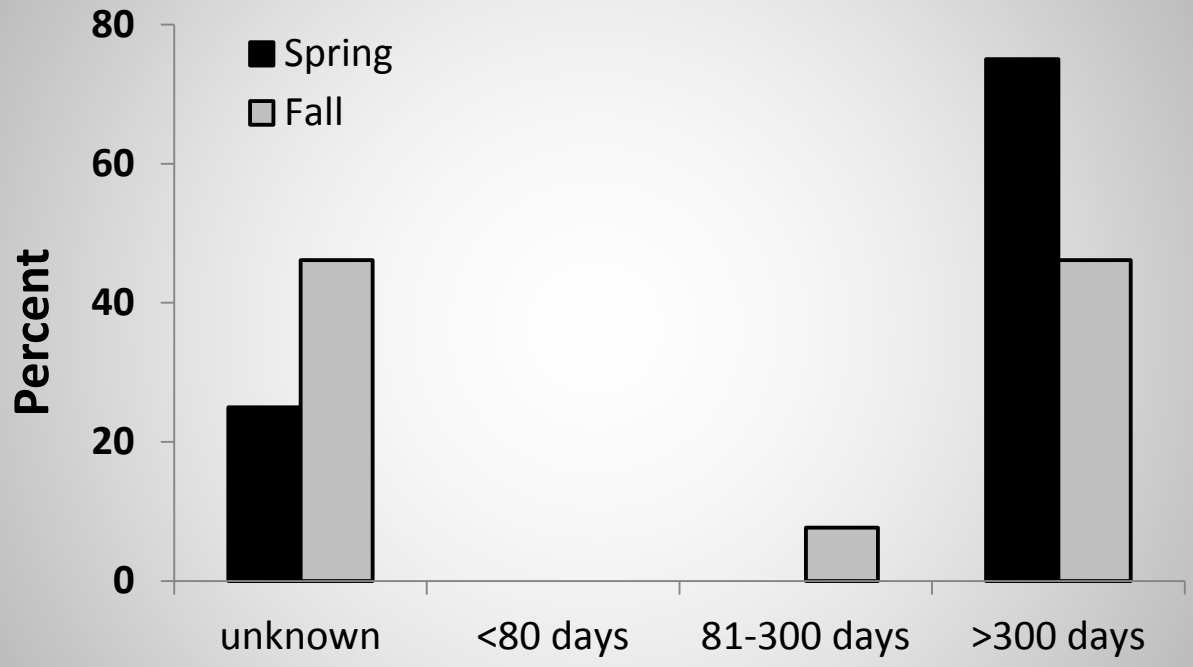
Most parr reared >200 days downstream from the natal tributary before smolt outmigration



Results – Successful phenotypes?

Juvenile Migration/Survival

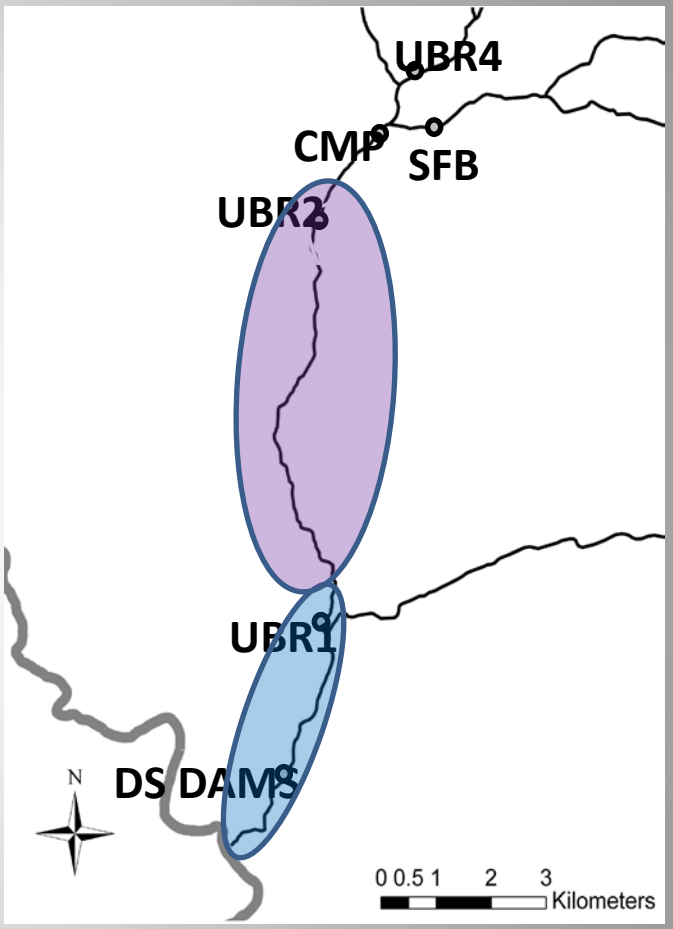
Most successful adult returns rear in –basin > 300 days



Results – Spatial extent of measurable changes?

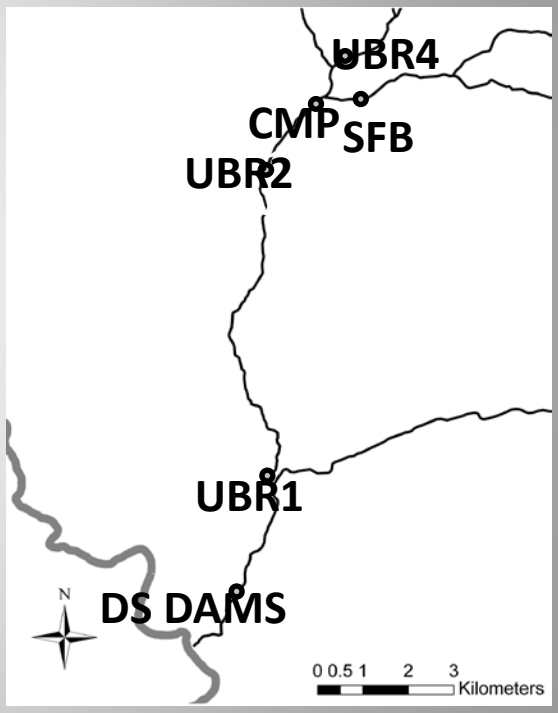
Site	Before Year	After Year	F_{ST}	Pval
DS Dam	2005	2009	0.014*	0.001*
UBR1	2004	2008	0.021*	<0.001*
UBR1	2004	2009	0.027*	<0.001*
CMP	2005	2009	0.002	0.047
UBR4	2004	2008	0.011*	0.009*
UBR4	2004	2009	-0.002	0.558
SFB	2005	2008	0.004	0.121
SFB	2005	2009	0.002	0.276

* Indicates statistical significance

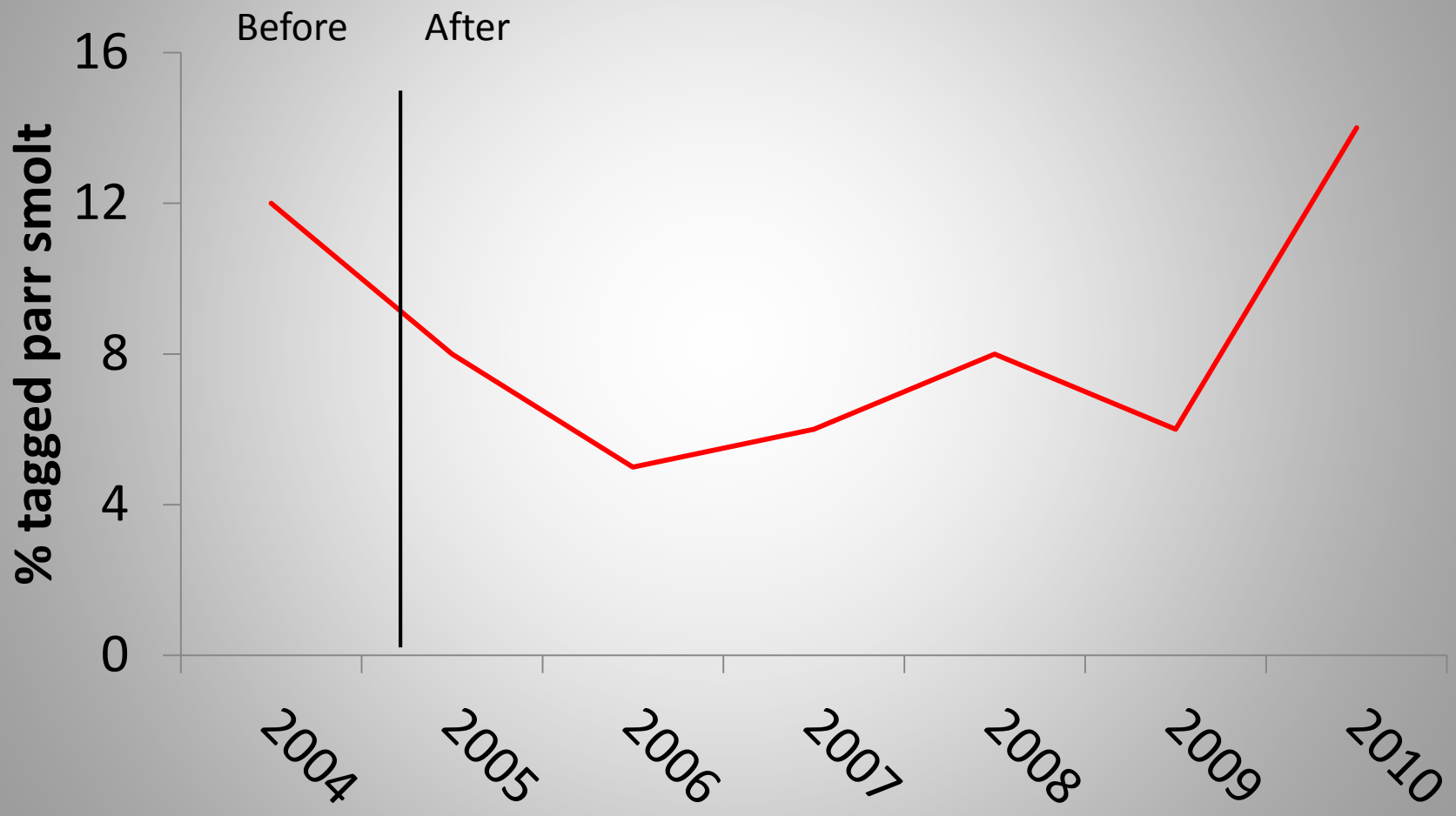


Results – Temporal Tests (sampling effect)

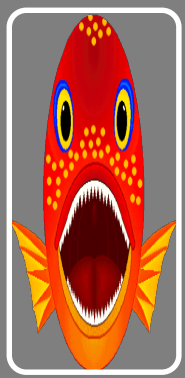
site	year	year	F_{ST}	Pval
UBR1	2008	2009	-0.003	0.253
UBR2	2008	2009	-0.004	0.880
UBR4	2008	2009	<-0.001	0.147
SFB	2008	2009	0.005	0.568



% smolt UBR1


Before
After
16
12
8
4
0
% tagged parr smolt
2004
2005
2006
2007
2008
2009
2010

Conclusions - Colonization

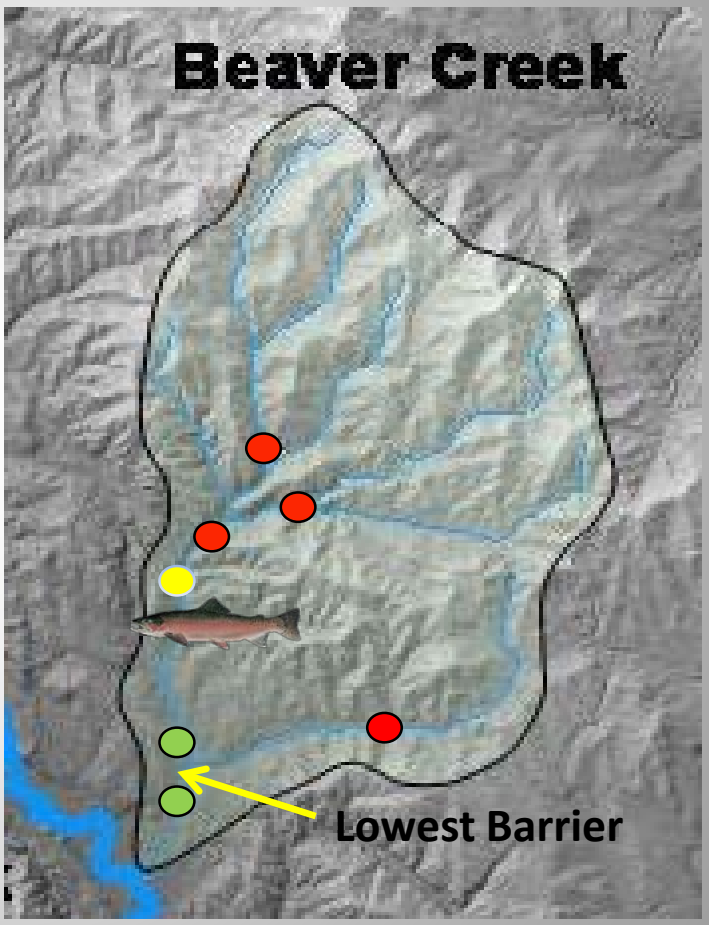


Before barrier removal

- Fragmented
- Smolts out, but no adult returns

After barrier removal

- Genetic shifts lowest site km 5
- Tag movement to middle site km 12
- Smolts out and adult returns



Conclusions – Indiv Success

- Fluvial RBT were key to re-colonization, gene flow and reserve of wild genotype
- Hatchery unsuccessful in early years of colonization
- Phenotypes of successful spawners shifted dramatically between 2005 and 2006
- Successful juvenile SH reared in the Methow R (or Wells Res) for 1 to 2 years prior to smolt outmigration
- No clear relationship between number of offspring and returning adults

≠

What is the weakest link in steelhead conservation?

- Phenotypes/genotypes under selection for adult survival and how these interact in time, space, density -> selection gradients
  - Interactions between rearing habitats and selection gradients influences fitness
- Aggressive work to understand, control or eliminate hatchery steelhead effects

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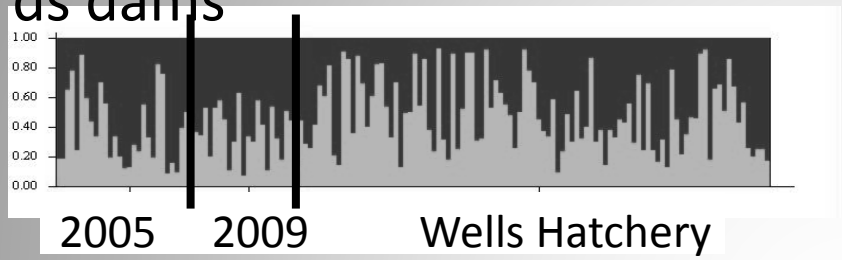
Kyle Martens, Wes Tibits, Brian Fisher

Lab analysis assistance Joyce Faler (Univ. of Idaho)

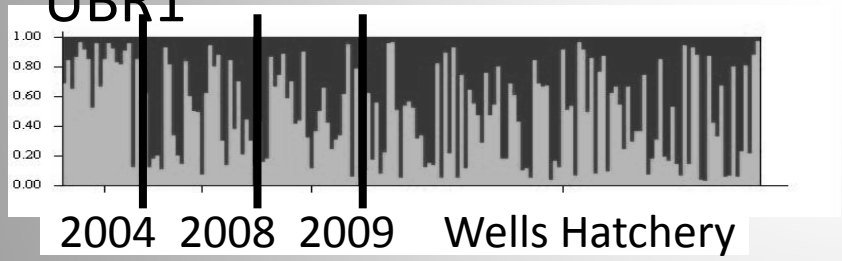
Coordination Greg Knott, Michael Newsom

Results - % Hatchery

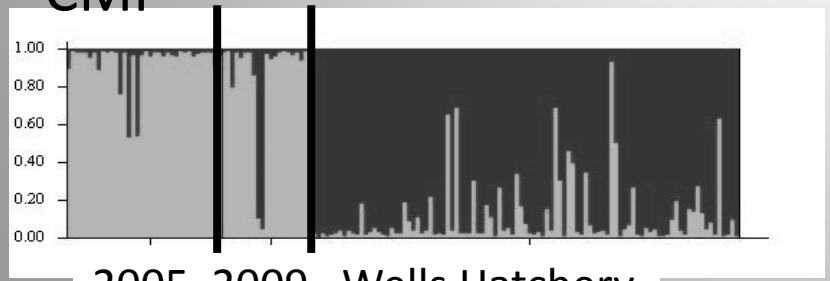
ds dams



UBR1



CMP



Site	Before %	After %
DS Dams	40	35
UBR1	27	47
CMP	6	12

Gene Flow

Genetic Differentiation (Fst)

	Fluvial	Wild Anad
Wild Anad	0.002 - ns	
Hatchery	0.006	0.004