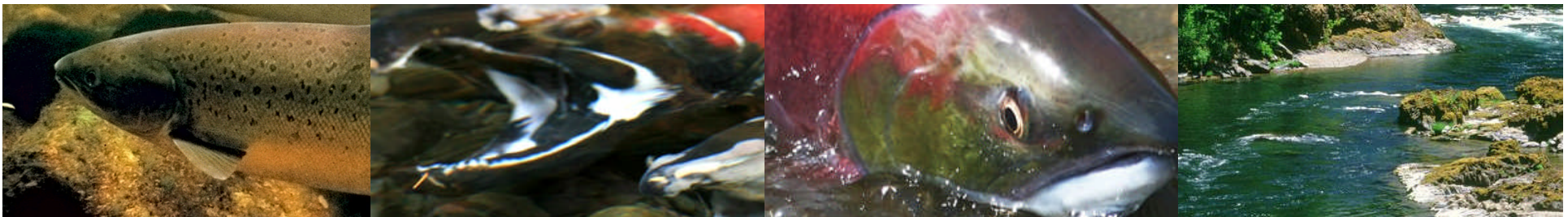


# Mate choice of wild spawning coho salmon (*Oncorhynchus kisutch*) in the Umpqua River, Oregon

Amelia Whitcomb, Michael Banks, Kathleen O'Malley

Coastal Oregon Marine Experiment Station  
Hatfield Marine Science Center  
Department of Fish and Wildlife  
Oregon State University



# Mate choice = hatchery and wild RS differences

- RS compatibility via sensory cues
- Diversity at genes that influence survival
- Major Histocompatibility Complex (MHC) – pathogen recognition<sup>1,2,3</sup>
  - Humans prefer mates dissimilar at MHC (sweaty t-shirt)<sup>4</sup>
  - MHC dissimilar preference in Atlantic salmon<sup>5</sup>

1. Evans et al. (2012) 2. Consuegra and Leaniz (2008) 3. Pitcher and Neff (2008)  
4. Wedekind and Ruri (1997) 5. Landry et al. (2001) 6. Aeschlimann et al. (2003)



# Immune-relevant gene-linked markers as metric

| EST-linked           |             | MHC-linked                  |             |
|----------------------|-------------|-----------------------------|-------------|
| Locus                | No. Alleles | Locus                       | No. Alleles |
| <i>SsaIR010TKU</i> * | 15          | <i>OMM3026</i> <sup>F</sup> | 7           |
| <i>SsaIR013TKU</i> * | 24          | <i>BHMS429</i> <sup>F</sup> | 49          |
| <i>SsaIR015TKU</i> * | 9           | <i>OMM3085</i> <sup>°</sup> | 53          |
| <i>SsaIR016TKU</i> * | 17          | <i>OMM3115</i> <sup>°</sup> | 56          |

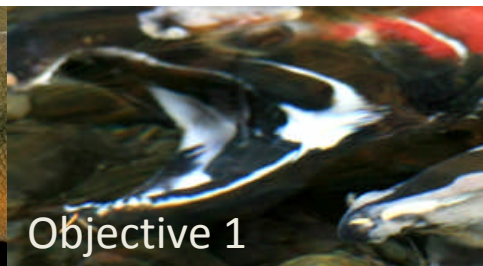
\*Tonteriet *al.* (2008),<sup>F</sup>Johnsonet *al.* (2008), <sup>°</sup>per. comm. C. Rexroad III



# Objectives

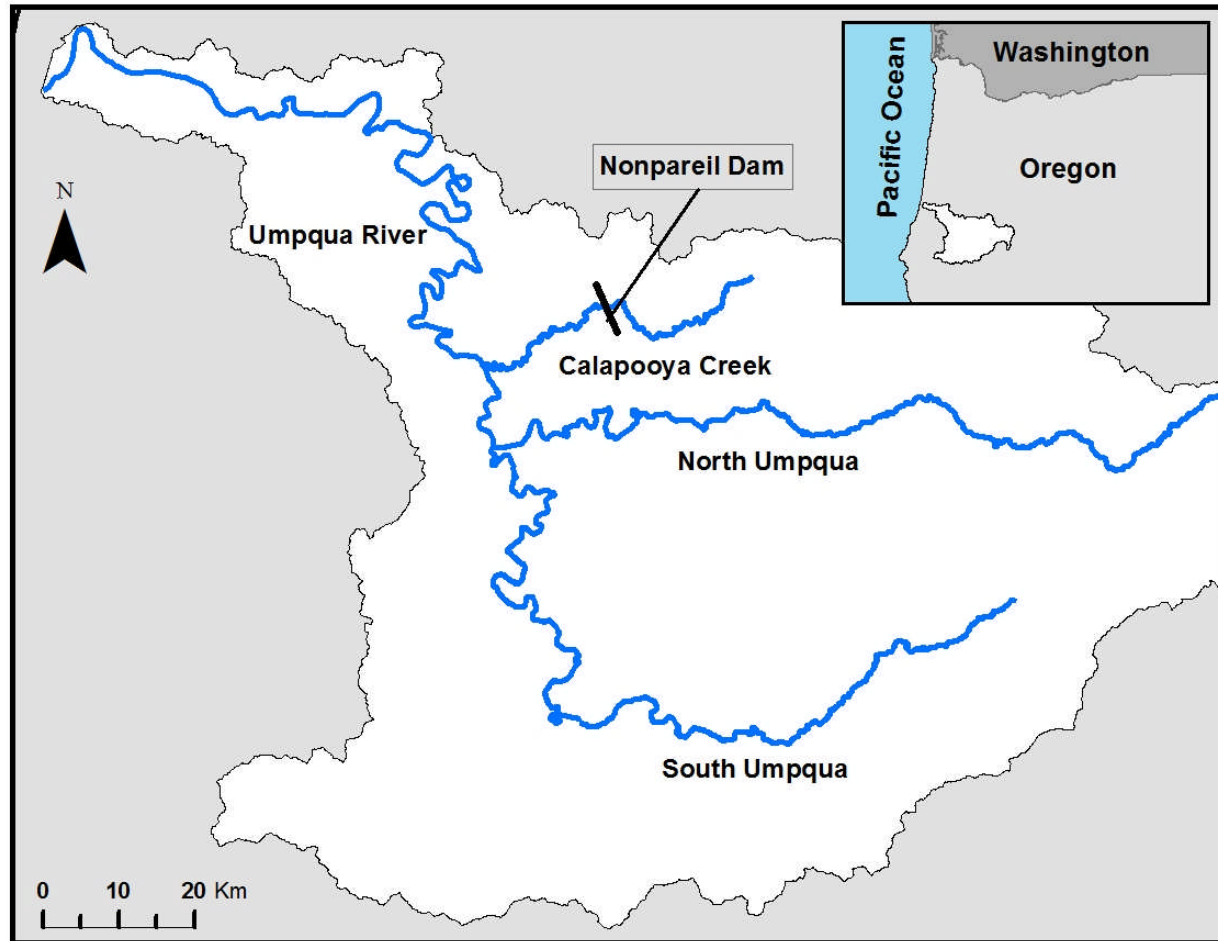
1. Test for evidence of mate choice (i.e. non-random mating) based on immune gene diversity
2. Test for a correlation between immune gene diversity and RS

Is there a genetic difference between W x W, H x H, and W x H successful mate pairs spawning in the wild?



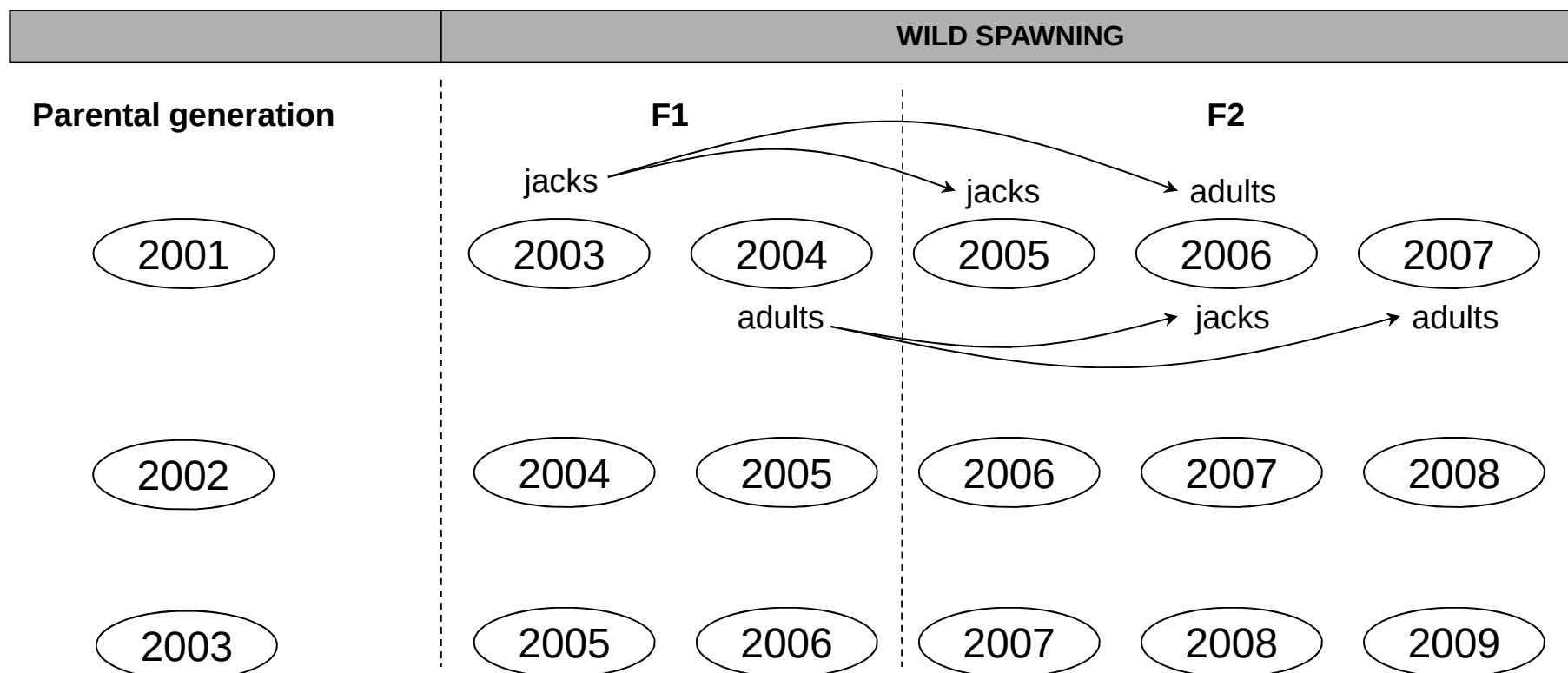
# Umpqua River Parentage Study

Thériault et al. (2011)

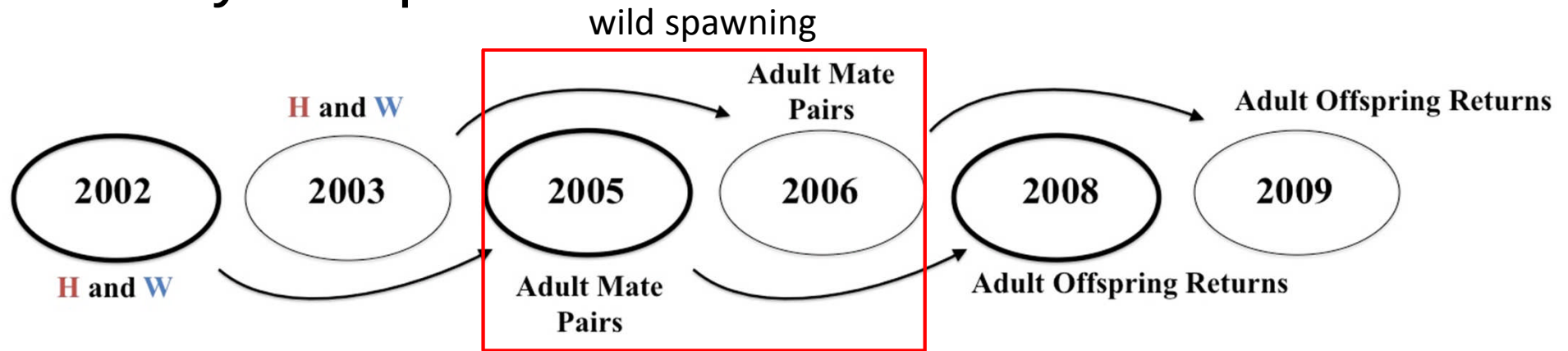


# Umpqua River Parentage Study

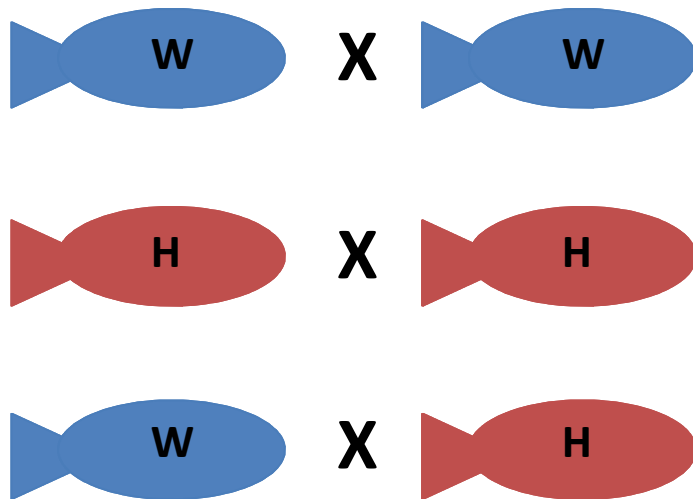
Thériault et al. (2011)



# Study Samples



Lifetime reproductive success = # offspring returned as adults



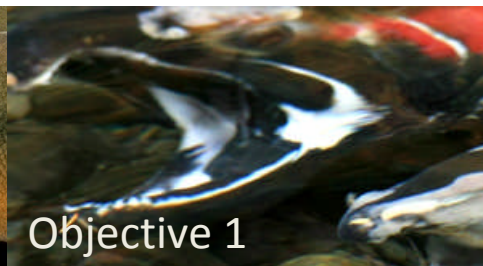
| Class | Number of Pairs |      |
|-------|-----------------|------|
|       | 2005            | 2006 |
| W x W | 180             | 138  |
| H x H | 146             | 417  |
| W x H | 221             | 289  |



# Objectives

1. Test for evidence of mate choice (i.e. non-random mating) based on immune gene diversity
2. Test for a correlation between immune gene diversity and RS

Is there a genetic difference between W x W, H x H, and W x H successful mate pairs spawning in the wild?



# Objective 1: Results

| Year | Mate Class | <i>SsalR</i> 010TKU | <i>SsalR</i> 013TKU | <i>SsalR</i> 015TKU | <i>SsalR</i> 016TKU             | OMM 3026 | <i>BHMS</i> 429 | OMM 3085 | OMM 3115 |
|------|------------|---------------------|---------------------|---------------------|---------------------------------|----------|-----------------|----------|----------|
| 2006 | W x W      |                     |                     |                     |                                 |          |                 |          |          |
|      | H x H      |                     |                     |                     | dissimilar                      |          | similar         |          |          |
|      | W x H      |                     |                     |                     | <b>p = 0.01*</b>                |          | <b>p=0.001*</b> |          |          |
|      |            |                     |                     |                     | intermediate<br><b>p=0.002*</b> |          |                 |          |          |

Role in Immune Response:

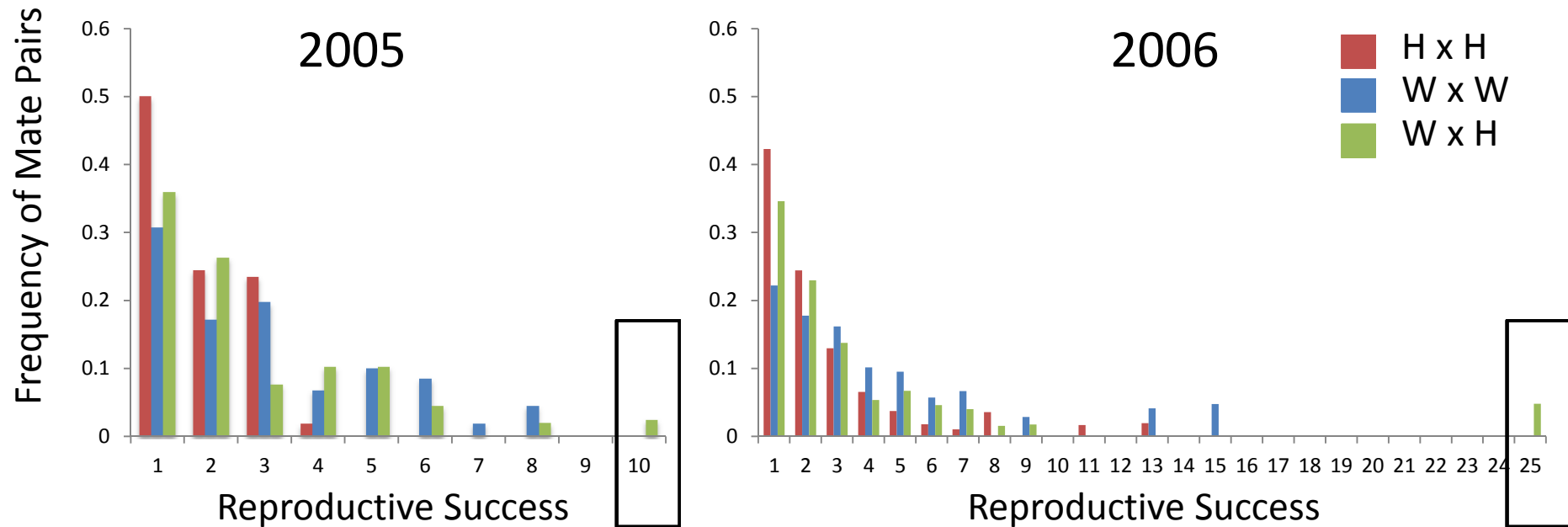
- *SsalR016TKU* = vasodilator-stimulated phosphoprotein (regulate platelet aggregation<sup>7</sup>)
- *BHMS429* = MHC class IB<sup>8</sup> (pathogen recognition)

7. Li Calzi et al. (2008) 8. Rexroad et al. (2005 )



# Objective 1: Discussion

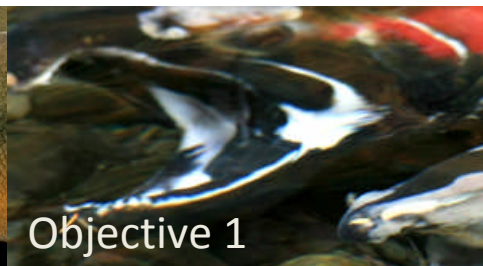
- What is special about W x H 2006 mate pairs?
  - W x H pairs = largest incidence of high RS pairs out of all pair classes
- 2005 mate choice signal inhibited?
  - # of jacks
  - overall density



# Objectives

1. Test for evidence of mate choice (i.e. non-random mating) based on immune gene diversity
2. Test for a correlation between immune gene diversity and RS

Is there a genetic difference between W x W, H x H, and W x H successful mate pairs spawning in the wild?



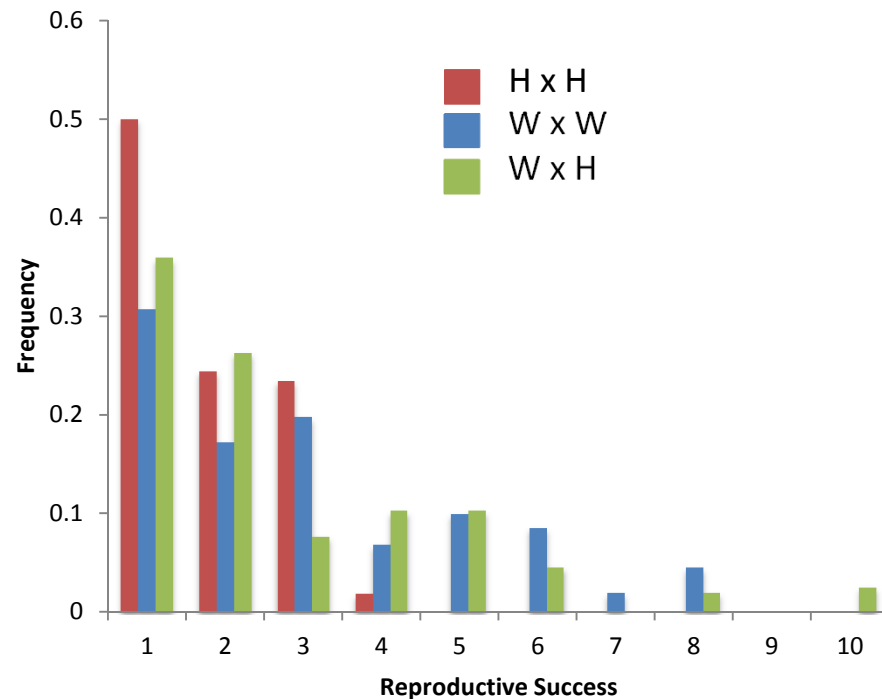
# Objective 2: Immune Gene Diversity and RS Approach

| Class | Number of Pairs |      |
|-------|-----------------|------|
|       | 2005            | 2006 |
| W x W | 180             | 138  |
| H x H | 146             | 417  |
| W x H | 221             | 289  |

- Constructed Poisson-distributed generalized linear models (GLM)
- Mate Pair RS = # shared alleles (8 markers) + fork length + run date + origin + run date difference
- Built 6 models:  
mate class and year separate



# Objective 2: Immune Gene Diversity and RS Model Selection



- Mate Pair RS = # shared alleles (8 markers) + fork length + run date + origin + run date difference
- Collinearity
- Akaike's information criterion (AIC)
- Robust standard errors for parameter estimates



# Objective 2: Results

| 2005<br>HH |         |        |  | WW         |           |          |        | WH             |           |          |        |
|------------|---------|--------|--|------------|-----------|----------|--------|----------------|-----------|----------|--------|
| estimate   | std.err | pvalue |  | estimate   | std.err   | pvalue   |        | estimate       | std.err   | pvalue   |        |
|            |         |        |  | BHMS429    | -2.65E-01 | 1.05E-01 | 0.011* | F fork length  | 2.27E-03  | 1.12E-03 | 0.042* |
|            |         |        |  | F run date | 7.80E-03  | 3.87E-03 | 0.044* | M run date     | 1.09E-02  | 3.87E-03 | 0.004* |
|            |         |        |  |            |           |          |        | run date diff. | -9.73E-03 | 4.89E-03 | 0.046* |
| 2006<br>HH |         |        |  | WW         |           |          |        | WH             |           |          |        |
| estimate   | std.err | pvalue |  | estimate   | std.err   | pvalue   |        | estimate       | std.err   | pvalue   |        |
|            |         |        |  | BHMS429    | -2.40E-01 | 1.23E-01 | 0.048* | F fork length  | 0.002     | 0.001    | 0.011* |
|            |         |        |  | M run date | 1.33E-02  | 6.48E-03 | 0.039* | OMM3085        | 0.383     | 0.137    | 0.005* |

Only significant\* predictors of mate pair RS listed



# Objective 2: Results

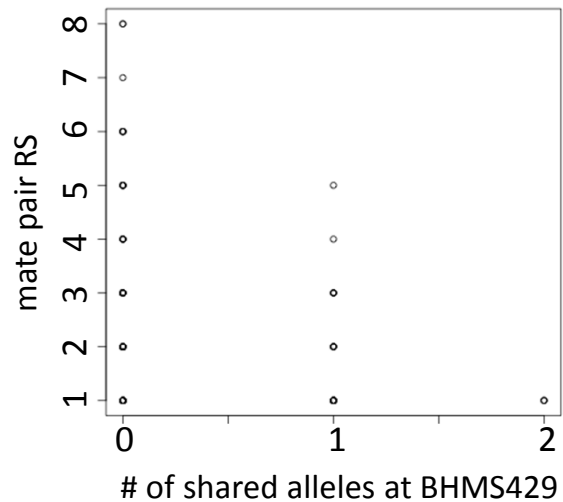
| 2005<br>HH |         |        |  | WW         |           |          |        | WH             |           |          |        |
|------------|---------|--------|--|------------|-----------|----------|--------|----------------|-----------|----------|--------|
| estimate   | std.err | pvalue |  | estimate   | std.err   | pvalue   |        | estimate       | std.err   | pvalue   |        |
|            |         |        |  | BHMS429    | -2.65E-01 | 1.05E-01 | 0.011* | F fork length  | 2.27E-03  | 1.12E-03 | 0.042* |
|            |         |        |  | F run date | 7.80E-03  | 3.87E-03 | 0.044* | M run date     | 1.09E-02  | 3.87E-03 | 0.004* |
|            |         |        |  |            |           |          |        | run date diff. | -9.73E-03 | 4.89E-03 | 0.046* |
| 2006<br>HH |         |        |  | WW         |           |          |        | WH             |           |          |        |
| estimate   | std.err | pvalue |  | estimate   | std.err   | pvalue   |        | estimate       | std.err   | pvalue   |        |
|            |         |        |  | BHMS429    | -2.40E-01 | 1.23E-01 | 0.048* | F fork length  | 0.002     | 0.001    | 0.011* |
|            |         |        |  | M run date | 1.33E-02  | 6.48E-03 | 0.039* | OMM3085        | 0.383     | 0.137    | 0.005* |



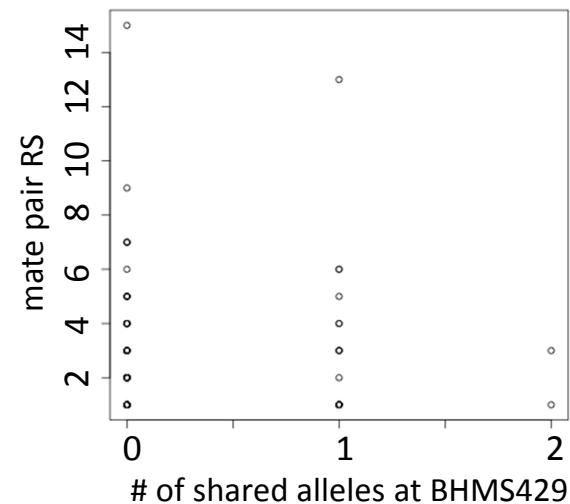
# Objective 2: Results

| 2005     |         |        |  |            |          |          |        | 2006           |           |          |        |
|----------|---------|--------|--|------------|----------|----------|--------|----------------|-----------|----------|--------|
| HH       |         |        |  | WW         |          |          |        | WH             |           |          |        |
| estimate | std.err | pvalue |  | estimate   | std.err  | pvalue   |        | estimate       | std.err   | pvalue   |        |
|          |         |        |  |            |          |          |        |                |           |          |        |
|          |         |        |  |            |          |          |        | F fork length  | 2.27E-03  | 1.12E-03 | 0.042* |
|          |         |        |  | F run date | 7.80E-03 | 3.87E-03 | 0.044* | M run date     | 1.09E-02  | 3.87E-03 | 0.004* |
|          |         |        |  |            |          |          |        | run date diff. | -9.73E-03 | 4.89E-03 | 0.046* |
| estimate | std.err | pvalue |  | estimate   | std.err  | pvalue   |        | estimate       | std.err   | pvalue   |        |
|          |         |        |  |            |          |          |        |                |           |          |        |
|          |         |        |  |            |          |          |        | F fork length  | 0.002     | 0.001    | 0.011* |
|          |         |        |  | M run date | 1.33E-02 | 6.48E-03 | 0.039* | OMM3085        | 0.383     | 0.137    | 0.005* |

2005



2006

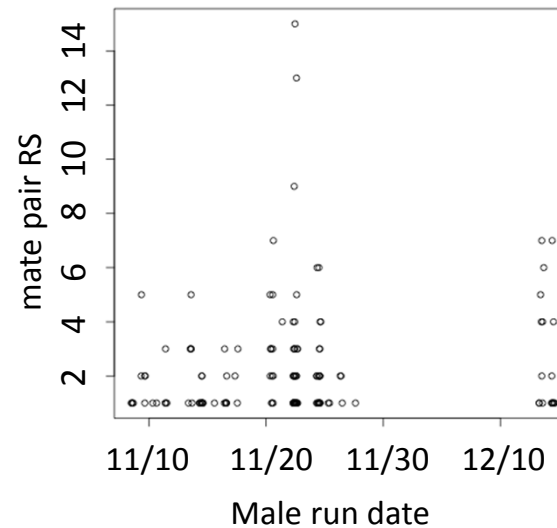
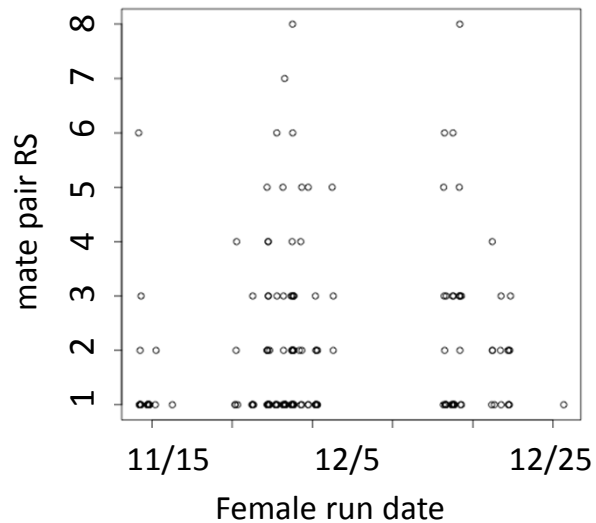


# Objective 2: Results

| 2005     |         |        |  |          |           |          |        | 2006           |           |          |        |
|----------|---------|--------|--|----------|-----------|----------|--------|----------------|-----------|----------|--------|
| HH       |         |        |  | WW       |           |          |        | WH             |           |          |        |
| estimate | std.err | pvalue |  | estimate | std.err   | pvalue   |        | estimate       | std.err   | pvalue   |        |
|          |         |        |  | BHMS429  | -2.65E-01 | 1.05E-01 | 0.011* | F fork length  | 2.27E-03  | 1.12E-03 | 0.042* |
|          |         |        |  |          |           |          |        | M run date     | 1.09E-02  | 3.87E-03 | 0.004* |
|          |         |        |  |          |           |          |        | run date diff. | -9.73E-03 | 4.89E-03 | 0.046* |
| 2006     |         |        |  |          |           |          |        | 2006           |           |          |        |
| HH       |         |        |  | WW       |           |          |        | WH             |           |          |        |
| estimate | std.err | pvalue |  | estimate | std.err   | pvalue   |        | estimate       | std.err   | pvalue   |        |
|          |         |        |  | BHMS429  | -2.40E-01 | 1.23E-01 | 0.048* | F fork length  | 0.002     | 0.001    | 0.011* |
|          |         |        |  |          |           |          |        | OMM3085        | 0.383     | 0.137    | 0.005* |

2005

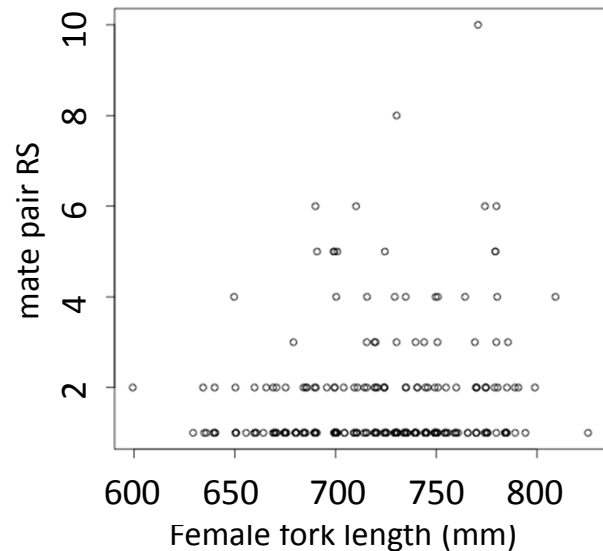
2006



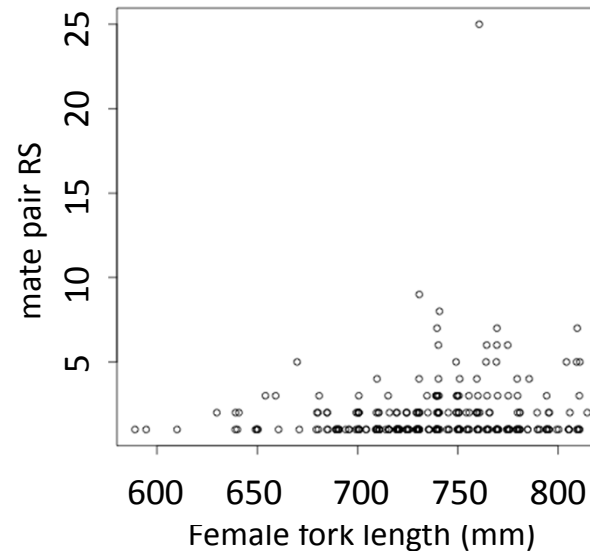
# Objective 2: Results

| 2005     |         |        |                | 2006      |          |        |  |
|----------|---------|--------|----------------|-----------|----------|--------|--|
| HH       |         |        |                | HH        |          |        |  |
| WW       |         |        |                | WW        |          |        |  |
| estimate | std.err | pvalue |                | estimate  | std.err  | pvalue |  |
|          |         |        | BHMS429        | -2.65E-01 | 1.05E-01 | 0.011* |  |
|          |         |        | F run date     | 7.80E-03  | 3.87E-03 | 0.044* |  |
| WH       |         |        |                | WH        |          |        |  |
| estimate | std.err | pvalue |                | estimate  | std.err  | pvalue |  |
|          |         |        |                |           |          |        |  |
|          |         |        | M run date     | 1.09E-02  | 3.87E-03 | 0.004* |  |
|          |         |        | run date diff. | -9.73E-03 | 4.89E-03 | 0.046* |  |
| WW       |         |        |                | WW        |          |        |  |
| estimate | std.err | pvalue |                | estimate  | std.err  | pvalue |  |
|          |         |        | BHMS429        | -2.40E-01 | 1.23E-01 | 0.048* |  |
|          |         |        | M run date     | 1.33E-02  | 6.48E-03 | 0.039* |  |
| WH       |         |        |                | WH        |          |        |  |
| estimate | std.err | pvalue |                | estimate  | std.err  | pvalue |  |
|          |         |        |                |           |          |        |  |
|          |         |        | OMM3085        | 0.383     | 0.137    | 0.005* |  |

2005



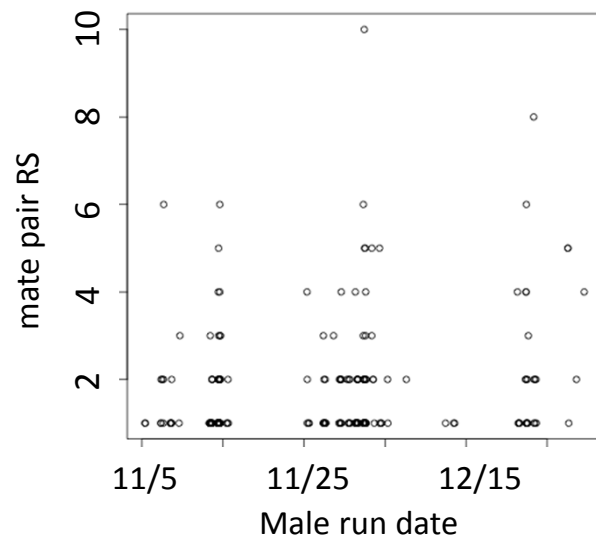
2006



# Objective 2: Results

| 2005           |           |          |            | 2006      |          |        |  |
|----------------|-----------|----------|------------|-----------|----------|--------|--|
| HH             |           |          |            | HH        |          |        |  |
| WW             |           |          |            | WW        |          |        |  |
| estimate       | std.err   | pvalue   |            | estimate  | std.err  | pvalue |  |
|                |           |          | BHMS429    | -2.65E-01 | 1.05E-01 | 0.011* |  |
|                |           |          | F run date | 7.80E-03  | 3.87E-03 | 0.044* |  |
| WH             |           |          |            | WH        |          |        |  |
| estimate       | std.err   | pvalue   |            | estimate  | std.err  | pvalue |  |
| F fork length  | 2.27E-03  | 1.12E-03 | 0.042*     |           |          |        |  |
|                |           |          |            |           |          |        |  |
| run date diff. | -9.73E-03 | 4.89E-03 | 0.046*     |           |          |        |  |
| WW             |           |          |            | WW        |          |        |  |
| estimate       | std.err   | pvalue   |            | estimate  | std.err  | pvalue |  |
|                |           |          | BHMS429    | -2.40E-01 | 1.23E-01 | 0.048* |  |
|                |           |          | M run date | 1.33E-02  | 6.48E-03 | 0.039* |  |
| WH             |           |          |            | WH        |          |        |  |
| estimate       | std.err   | pvalue   |            | estimate  | std.err  | pvalue |  |
| F fork length  | 0.002     | 0.001    | 0.011*     |           |          |        |  |
| OMM3085        | 0.383     | 0.137    | 0.005*     |           |          |        |  |

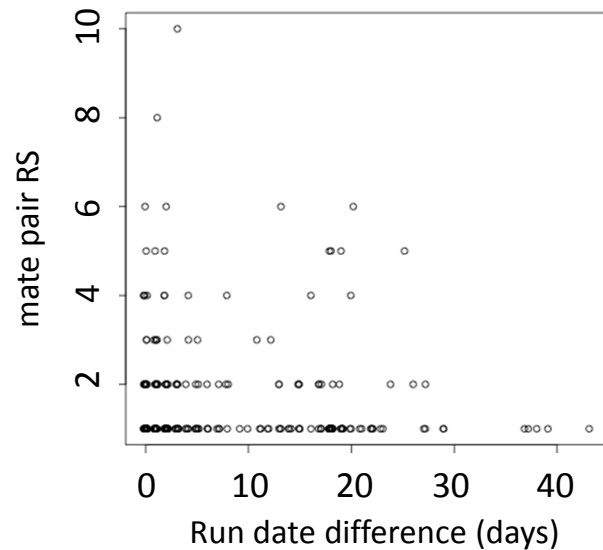
2005



# Objective 2: Results

| 2005 |          |         |        |            |           |          |        | WH            |          |          |        |
|------|----------|---------|--------|------------|-----------|----------|--------|---------------|----------|----------|--------|
| HH   |          |         |        | WW         |           |          |        |               |          |          |        |
|      | estimate | std.err | pvalue |            | estimate  | std.err  | pvalue |               | estimate | std.err  | pvalue |
|      |          |         |        | BHMS429    | -2.65E-01 | 1.05E-01 | 0.011* | F fork length | 2.27E-03 | 1.12E-03 | 0.042* |
|      |          |         |        | F run date | 7.80E-03  | 3.87E-03 | 0.044* | M run date    | 1.09E-02 | 3.87E-03 | 0.004* |
|      |          |         |        |            |           |          |        |               |          |          |        |
| 2006 |          |         |        |            |           |          |        | WH            |          |          |        |
| HH   |          |         |        | WW         |           |          |        |               |          |          |        |
|      | estimate | std.err | pvalue |            | estimate  | std.err  | pvalue |               | estimate | std.err  | pvalue |
|      |          |         |        | BHMS429    | -2.40E-01 | 1.23E-01 | 0.048* | F fork length | 0.002    | 0.001    | 0.011* |
|      |          |         |        | M run date | 1.33E-02  | 6.48E-03 | 0.039* | OMM3085       | 0.383    | 0.137    | 0.005* |

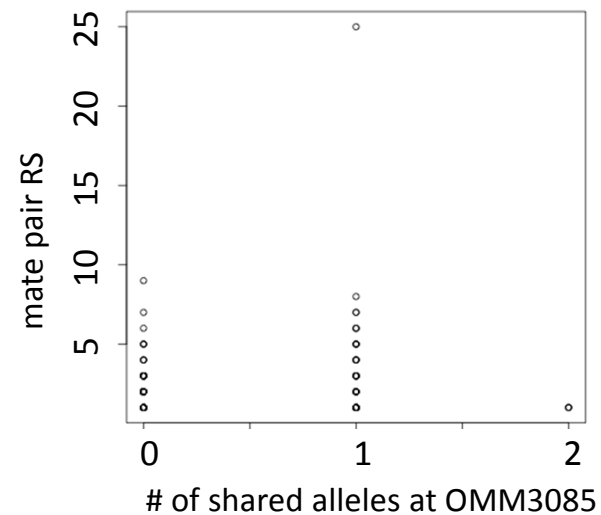
2005



# Objective 2: Results

| 2005           |           |          |            | 2006      |          |        |  |
|----------------|-----------|----------|------------|-----------|----------|--------|--|
| HH             |           |          |            | HH        |          |        |  |
| WW             |           |          |            | WW        |          |        |  |
| estimate       | std.err   | pvalue   |            | estimate  | std.err  | pvalue |  |
|                |           |          | BHMS429    | -2.65E-01 | 1.05E-01 | 0.011* |  |
|                |           |          | F run date | 7.80E-03  | 3.87E-03 | 0.044* |  |
| WH             |           |          |            | WH        |          |        |  |
| estimate       | std.err   | pvalue   |            | estimate  | std.err  | pvalue |  |
| F fork length  | 2.27E-03  | 1.12E-03 | 0.042*     |           |          |        |  |
| M run date     | 1.09E-02  | 3.87E-03 | 0.004*     |           |          |        |  |
| run date diff. | -9.73E-03 | 4.89E-03 | 0.046*     |           |          |        |  |
| WW             |           |          |            | WH        |          |        |  |
| estimate       | std.err   | pvalue   |            | estimate  | std.err  | pvalue |  |
|                |           |          | BHMS429    | -2.40E-01 | 1.23E-01 | 0.048* |  |
|                |           |          | M run date | 1.33E-02  | 6.48E-03 | 0.039* |  |
|                |           |          |            |           |          |        |  |

2006



# Objective 2: Immune Gene Diversity and RS Discussion

- Reinforced findings from previous studies<sup>11, 12</sup> –  
fork length and run date do play a role in RS

- After accounting for fork length, run date, and origin –

W x W mate pairs with increased MHC genetic diversity have  
increased mate pair RS

2006 W x H mate pairs MHC diversity correlated to mate pair RS

11. Petersson et al. (1999) 12. Quinn, (2005)



## Objective 2: Immune Gene Diversity and RS Discussion

- No correlation between immune gene diversity and RS
- No other variables correlated with RS



# Overall Study Conclusions

Is there a genetic difference between W x W, H x H, and W x H successful mate pairs spawning in the wild?

- Results indicative of wild mating complexities
  - number of intricate variables contribute to RS
  - each have different benefits and costs



# Overall Study Conclusions



W x H mate choice signature inhibited in 2005:

2005

Objective 1:

- No mate choice

Objective 2:

- Larger females, later returning males, and small run date differences  
= greater mate pair RS  
Not MHC diversity

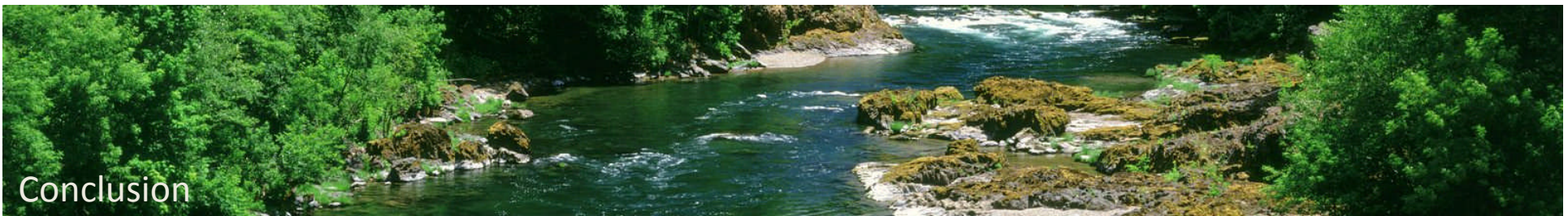
2006

Objective 1:

- Non-random mate choice

Objective 2:

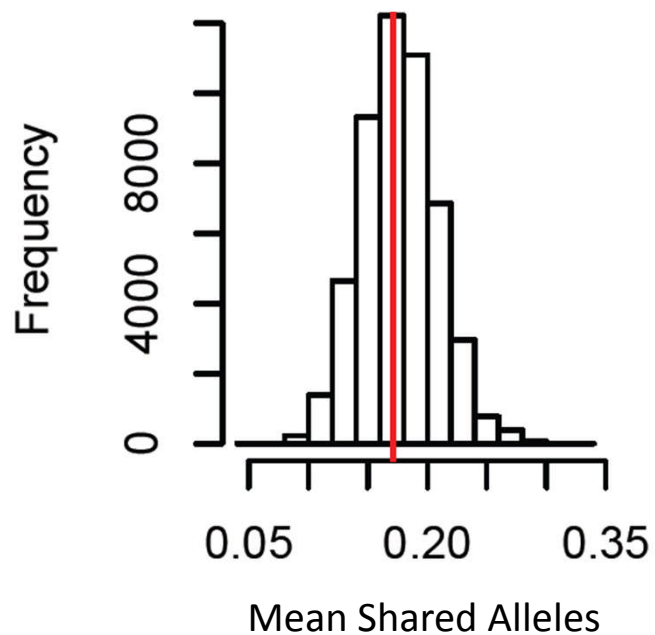
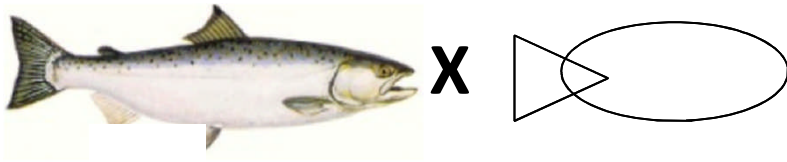
- MHC diversity correlated to mate pair RS



Conclusion

# Jack Mate Pair Study

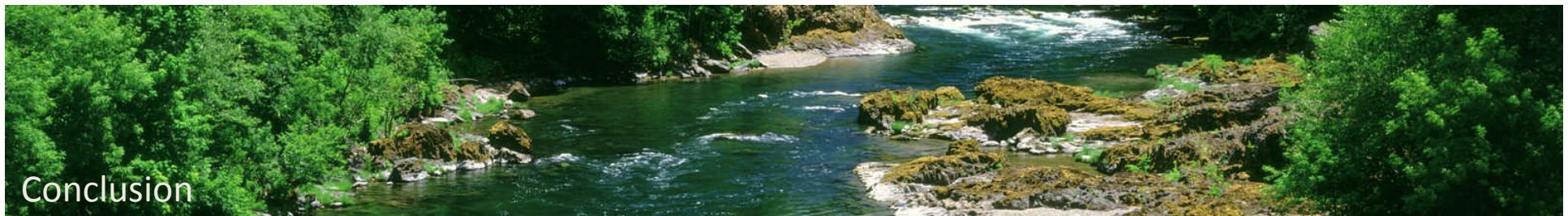
Jack mate pairs:



- 2005 and 2006 jack mate pairs (REU intern project)

Results:

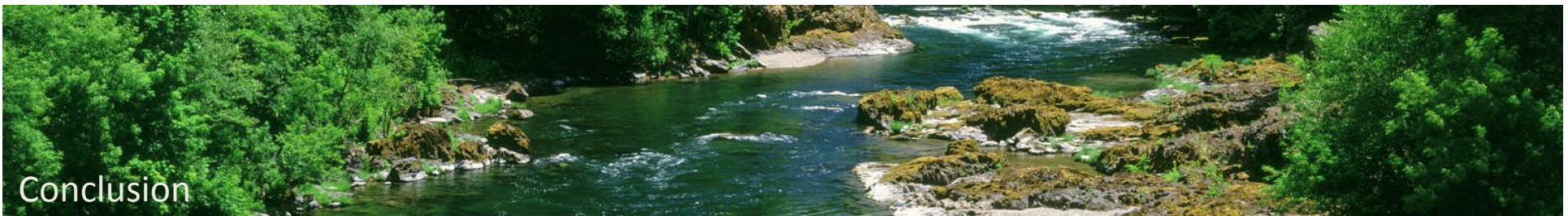
- No evidence for mate choice in jacks in both years
- Fork length, run date, origin, and run date difference not correlated to jack mate pair RS in both years



# Overall Study Conclusions



- No evidence for mate choice among in H x H mate pairs
- H x H mate pair RS not correlated with immune gene diversity or other variables demonstrated to affect RS
- Suggests there are genetic differences between mate classes
- H x H mate pairs lack mate choice



# Overall Study Conclusions

- Mate choice may be a mechanism contributing to differences in RS between wild spawning hatchery-reared and wild fish
  - species and systems are different
- Should we account for this in hatchery programs?

