Loss of genetic integrity in hatchery steelhead despite juvenile-based broodstock and wild integration: conflicts in production and conservation

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Acknowledgements


• **The Washington Department of Fish and Wildlife provided assistance with sample collection.**
Conflicts between production and conservation

– Many agencies are facing litigation for harm caused by hatchery fish.
– “Maximizing offspring production and minimizing the loss of genetic variation are often viewed as separate and competing goals.”—Fiumera et al. 2004
– Can alternative practices be used to produce hatchery fish that retain the genetic characteristics of endemic populations?

“presence of hatchery fish lowers the number of offspring produced by wild populations, disrupts local adaptations, and leads to loss of genetic diversity.”
Abernathy Fish Technology Center

- **Production goal:** 20,000 1-year steelhead smolts annually
- **Conservation goal:** provide demographic boost while maintaining genetic profile of endemic population
Methods 1: Culture

- Broodstock of captivity-reared *endemic juveniles*.
- Subsequent *integration* of wild adults in broodstock.
- Spawning / rearing protocols designed to prevent reductions in hatchery effective population size.
Methods 2: **Genetic analysis**

- Sample captive broodstock and wild and hatchery juveniles over nine years.
- Analyze 10 genetic markers in all samples.
- Compare genetic diversity, effective size, and population structure among collections.
Broodstock management: What was planned versus what occurred.

Number of spawners

Mates per spawner

Number of Families

140 spawners planned

1 mate per spawner planned (pairwise, monogamous)

70 families planned
Broodstock management: What was planned versus what occurred.

1-to-1 sex-ratio planned

10% wild planned
Production goal was met in 6 of 9 years

<table>
<thead>
<tr>
<th>Brood Year</th>
<th>Number of smolts</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>29,724</td>
</tr>
<tr>
<td>2003</td>
<td>20,009</td>
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<tr>
<td>2004</td>
<td>19,049</td>
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<td>2007</td>
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<td>2008</td>
<td>24,538</td>
</tr>
<tr>
<td>2009</td>
<td>21,222</td>
</tr>
<tr>
<td>2010</td>
<td>20,491</td>
</tr>
</tbody>
</table>
Relationship between broodstock size and effective size

$r^2 = 0.80$
Relationship between proportion of wild fish in broodstock and genetic diversity in hatchery offspring

$r^2=0.74$
Decreased diversity and $N_e$ in hatchery fish

- Allelic richness
- $N_b$

![Graph showing decreased diversity and $N_e$ in hatchery fish](image)
Hatchery fish diverged from wild fish

Juvenile Broodstock approximated wild fish

2005 and 2008

2007 and 2010
Temporal population structure in hatchery fish

2006 and 2009

2007 and 2010
Conclusions

• The hatchery effectively met production goals, but wild-type genetic integrity of hatchery fish was degraded every year.
• Despite substantial conservation efforts, hatchery steelhead rapidly diverged from the wild component.
  – Increased drift, inbreeding, and temporal structure
• 60% reduction in the effective number of breeders in the hatchery.
• Data not shown, but substantial reduction in reproductive success of hatchery fish relative to wild.
Conclusions

• Increasing broodstock size and proportion of wild fish in broodstock both reduced genetic drift.

• The juvenile-based broodstock represented an adequate *sample* of genetic variation, but the mating design did not emulate the effective number of breeders that spawned naturally in Abernathy Creek.
Conclusions

• Spawning protocols should be based on both realistic expectations for the availability of spawners and on scientific theory: for example, partial factorial designs.

• If conservation issues are determined to be the most important issue for hatchery propagation, then production goals may need to be forfeited.
Questions

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