Hybridization of *Sebastes maliger*, *Sebastes caurinus*, and *Sebastes auriculatus* in the Puget Sound Basin, Washington

Piper Schwenke, Linda Park, & Lorenz Hauser

Photo by Jade Leutenegger
Importance of Hybridization

Evolution – Genetic diversity & speciation

African cichlids (Cichlidae family)
  – Ancestral hybridization
  – Model of rapid speciation
  – Species-rich group
  – Intraspecific variation

Speciation Reversal Theory (Seehausen et al. 2007)
  – Speciation occurs by way of divergent adaptation in heterogeneous environments
  – Loss of habitat heterogeneity allows for more interspecific gene flow
  – Genetic homogenization reduces biodiversity
Importance of Hybridization

Conservation

– Introduced species
  • Secondary contact of introduced species
  • Native Cutthroat Trout (*Oncorhynchus clarki*) – endangered native populations
  • Rainbow trout (*O. mykiss*) - out of basin hatchery stocking

– Altered habitats
  • Mississippi River dikes changed natural water flow
  • Pallid sturgeon (*Scaphirhynchus albus*) - endangered
  • Shovelnose sturgeon (*S. platorynchus*) – large abundance
Research Organisms

Copper Rockfish
*Sebastes caurinus*

Brown Rockfish
*Sebastes auriculatus*

- Closely related species
- Demersal adults associated with substrate structure
- Near shore species
- Long lived (30-55 yrs.)
- Pelagic juvenile life history
- Internal fertilization & live bearers

Photos: [http://www.jongrossphotography.com](http://www.jongrossphotography.com)
• *Sebastes* is a species-rich group with over 65 species in the NE Pacific Ocean

• Copper, quillback, and brown rockfish closely related (Pteropodus sub genus)
Puget Sound Hybrids

- Previous genetic work identified hybrids in Puget Sound (L. Seeb, V. Buonaccorsi, and others)
- Puget Sound is a unique and changing environment where a species interaction such as hybridization is important to quantify
Research Questions

• Where and how much hybridization is going on in Puget Sound copper, quillback, & brown rockfish?

• Is there a direction to interspecific introgression
  – Is there a species bias in hybrids?
  – Is there evidence of female (or male) mediated gene flow?

• Can we estimate the timing of hybridization events?
Coastal Samples

- SWFSC collection
- Coastal range represented in samples

<table>
<thead>
<tr>
<th>Species</th>
<th>N</th>
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<tbody>
<tr>
<td>Brown</td>
<td>13</td>
</tr>
<tr>
<td>Copper</td>
<td>12</td>
</tr>
<tr>
<td>Quillback</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>41</td>
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**Puget Sound Samples**

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<thead>
<tr>
<th>Species</th>
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<tr>
<td>Brown</td>
<td>24</td>
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<tr>
<td>Copper</td>
<td>33</td>
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<tr>
<td>Quillback</td>
<td>40</td>
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<tr>
<td><strong>Total</strong></td>
<td>97</td>
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</tbody>
</table>

- North Puget Sound (NPS)
- Whidbey Basin (WB)
- Hood Canal (HC)
- Central Puget Sound (CPS)
- South Puget Sound (SPS)

**Morphological species ID**

2002 WDFW Groundfish Survey – Wayne Palsson
Analysis Methods

• Sequence 5 DNA markers
  – One mtDNA (maternally inherited) & 4 nuclear DNA markers (bi-parentally inherited)

• Phylogenetic analysis using mutation model implemented maximum likelihood (ML)
  – ML haplotype trees used to identify species specific groups (clades)

• Identification of hybrid:
  – Mismatch of DNA & morphological ID at one or more markers
Using trees to evaluate DNA introgressive hybridization

- More DNA markers are required to detect later generation hybrids
- Misidentified specimen: All DNA markers ≠ morphology
- Hybrid: on or more DNA marker ≠ morphology

- Partial tree results from one DNA marker
- Individual fish in tree is color coded by morphological ID at collection
36 hybrids were identified in Puget Sound
Most were collected as copper or brown
2 quillback hybrids were identified on the coast
Fewer Puget Sound quillback were identified as hybrids
Results:

Hybrid counts by region – 3 species combined

✓ North Puget Sound - fewer hybrids
✓ North Puget Sound ~ coastal
✓ No differences among PS regions
✓ ~1/2 to 1/3 of samples were hybrids south of Admiralty Inlet

Hybrids by Region (all species)
Results

Brown Rockfish

46% of Brown Rockfish in Puget Sound were hybrids (N = 24)

Zero from the coast (N=13)
Results

Copper Rockfish

61% of Copper Rockfish in Puget Sound were hybrids (N = 33)

Zero from the coast (N = 12)
Results

Quillback Rockfish

14% of Quillback Rockfish from Puget Sound were hybrids (N = 40)

13% from the Coast were hybrids (N=16)
# Detailed Results for hybrids

## Species direction of hybridization

- Species bias in hybrids

<table>
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<th>Collection ID</th>
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<tbody>
<tr>
<td>Quillback</td>
<td>Copper</td>
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</table>

- Marker cannot resolve

## Male/Female direction of hybridization

- Sex bias in hybrid mating (mtDNA ≠ nDNA)

<table>
<thead>
<tr>
<th>mtDNA</th>
<th>ETS</th>
<th>S7</th>
<th>MEP</th>
<th>MDH</th>
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Summary of Results

- One third of our Puget Sound copper, quillback, and brown rockfish samples were hybrids.
- All hybrids were later generation hybrids (no F1s).
- A few hybrids were found with mixed ancestry from 3 species.
- No hybridization in coastal copper and brown rockfish were detected.
- Both coastal quillback and Puget Sound quillback samples had a lower incidence of hybrids.
- Most of the hybridization is between copper/quillback.
- No evidence of sex bias in hybrid mating.
What does this mean?

**Management** – How do we protect species hybrids or species with hybrids?

**Evolution** – Hybridization may be a natural process in post glacial fjord populations.

**Conservation** – Impact of hybrids on depleted stocks and their ability to recover
- Do nearshore habitat alterations impact species hybridization?
- Is there a potential for speciation reversal?
Thank you

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SWFSC-Russ Vetter & John Hyde