Factors Limiting Growth of Juvenile Anadromous and Resident *Oncorhynchus mykiss* in the Duckabush and Hamma Hamma Rivers, WA.

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Acknowledgements

- Dave Beauchamp
- Thomas Quinn
- Barry Berejikian
- Beauchamp Lab
- WDFW Scale and Aging Lab
- WDFW Hatchery Evaluation and Assessment Team
- Joy Lee
- Rick Endicott
- Rob Endicott
- Katy Doctor
- Chris Ringlee
- Many others…
Background

- Coast-wide steelhead populations have declined in abundance over the past century.
- The Puget Sound DPS was listed as threatened in 2007.
  - Prior to the listing Western Hood Canal population segment was at 1.7% of historic abundance.
  - Supplementation program in started in the late 1990’s.
- Juvenile steelhead spend 1-3 years in freshwater and this may be a critical period for overall survival of steelhead.
  - Observed annual freshwater survival rates in Hood Canal watersheds low (~6% to 20%).
    - Decline with age in the upper reaches.
    - Improve with age in the lower reaches.

Duckabush River and Hamma Hamma Rivers, drain the eastern slope of the Olympic Mountains.

- Rain/Snow dominated
- Land use is minimal in both watersheds, primarily: logging and recreational.
- Both watersheds have barrier waterfalls.
  - Rkm 4.4 Hamma Hamma
  - Rkm 12.6 Duckabush
- Rainbow trout populations above the barriers and mixed rainbow trout and steelhead populations below.
  - Appear to have abundant rainbow trout populations.
Growth Potential of *O. mykiss* in freshwater

- **Objective**: Determine the growth performance for each age class of *O. mykiss* in the Duckabush and Hamma Hamma Rivers.
  - Are abiotic (temperature) or biotic (prey base) factors limiting growth?
- Take a bioenergetics approach to determine if and where annual growth is limited.
- Provides daily estimates of:
  - Energy needs
  - % maximum consumption rate (indicator of food availability)
  - Total biomass of invertebrates consumed
1. Thermal Experience (Temperature Loggers)

2. Temporal Diet Composition (Field sampling)

3. Consumer Growth (Field sampling)

Bioenergetics Model

4. Consumer Energy Density (~5800 J/g)

5. Prey Energy Density (Literature Values)

Consumption/Feeding Rate (g) Estimate
2. Diet Composition and Prey Supply - Methods

- Fish diets were collected from a subsample of fish via gastric lavage during the summer/fall of 2015.
  - June, August, September (all reaches) and October (lower rivers only)
- All diet items are identified to the order level and group by energy content.
2. Diet Composition

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Mean Percent Biomass

- Salmon Eggs
- Fish
- Salmon Flesh
- Sea Lice
- Adult Larvae
- Non-Insect
- Marine Derived/Fish

Month and Watershed

Energy Levels:
- High Energy Aquatic
- Low Energy Larvae
- Non-Insect
- Marine Derived/Fish
- Adult
- Larvae
- Non-Insect
- Marine Derived/Fish
The prey supply was analyzed by sampling drift invertebrates.

- Collected during June, August and September of 2015, in areas that correspond with fish collection sites.
  - Riffle habitat (<0.5 m deep, > 0.3 m/s velocity).

- Daily prey supply was calculated by multiplying drift (g)/hour by the hours of daylight between civil twilight.
  - Converted to prey energy available (J) and compared with the dietary needs to attain the observed growth.

- A selectivity analysis using Manly’s α compared prey items in diet with drift sample collections.
Prey Supply

- Above-barrier Duck
- U. below-barrier Duck
- L. below-barrier Duck
- Above-barrier Hamma
- Below-barrier Hamma

Prey Energy Available (J)

-20000
-10000
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000

June
August
September

Age 2
Age 3
Age 4

Reach

A) Above-barrier Duckabush

B) Below-barrier upper Duckabush

C) Below-barrier lower Duckabush

D) Above-barrier Hamma Hamma

E) Below-barrier Hamma Hamma

Fork Length (mm)
100 150 200 250 300

A) Above-barrier Duckabush
B) Below-barrier upper Duckabush
C) Below-barrier lower Duckabush
D) Above-barrier Hamma Hamma

Age 0
Age 1
Age 2
Age 3
Age 4
Age 5

Fork Length (mm)
100 150 200 250 300

Frequency

0 10 20 30 40

Age 0
Age 1
Age 2
Age 3
Age 4
Age 5

Frequency

0 10 20 30 40

Age 0
Age 1
Age 2
Age 3
Age 4
Age 5

Frequency

0 10 20 30 40

Age 0
Age 1
Age 2
Age 3
Age 4
Age 5

Frequency

0 10 20 30 40

Age 0
Age 1
Age 2
Age 3
Age 4
Age 5

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Age 2
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Age 4
Age 5

Frequency

0 10 20 30 40

Age 0
Age 1
Age 2
Age 3
Age 4
Age 5
## Bioenergetic Model Results

Consumption rate: Annual % Cmax

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<thead>
<tr>
<th>Reach</th>
<th>Age 1 to 2</th>
<th>Age 2 to 3</th>
<th>Age 3-4</th>
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<td>Above-barrier Duckabush</td>
<td>28.2</td>
<td>29.1</td>
<td>32.3</td>
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<td>Upper below-barrier Duckabush</td>
<td>25.4</td>
<td>26.7</td>
<td>31.7</td>
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<tr>
<td>Lower below-barrier Duckabush</td>
<td>20.1</td>
<td>21.7</td>
<td>28.1</td>
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<tr>
<td>Above-barrier Hamma Hamma</td>
<td>26.6</td>
<td>29.4</td>
<td>31.2</td>
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<tr>
<td>Lower below-barrier Hamma Hamma</td>
<td>19.6</td>
<td>22.5</td>
<td>25.0</td>
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(Skagit River Range 20-28%) (Thompson and Beauchamp 2016)
Model Results - Annual Growth
Upper River Growth Sensitivity

Growth (g·g\(^{-1}\)·d\(^{-1}\))

<table>
<thead>
<tr>
<th></th>
<th>0.00</th>
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<td>20% Cmax</td>
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<tr>
<td>25% Cmax</td>
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<td>30% Cmax</td>
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<tr>
<td>50% Cmax</td>
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Temperature °C

Age 1 Age 2 Age 3 Age 4

b) High energy 5,000 J/g

a) Observed 3,855 J/g
Lower River Growth Selectivity

Growth (g·g\(^{-1}\)·d\(^{-1}\))

- 0.00
- 0.02
- 0.04
- 0.06
- 0.08
- 0.10
- 0.12

20% Cmax
25% Cmax
30% Cmax
50% Cmax

Temperature \(\circ C\)

- 5
- 10
- 15
- 20

Age 1
Age 2
Age 3
Age 4

b) Salmon eggs 12,000

a) Observed 6,400 J/g
Conclusions

- Overall consumption rates are low indicating growth limitations are occurring.
  - Cold temperatures may limit late-fall to spring growth, but summer temperatures are near optimal.
  - There is very little scope for growth for age-2 and older fish in the upper watersheds.
  - Lower watersheds are less limited than the upper watersheds.
  - Prey quality and quantity appears to have a significant effect on growth, particularly for older fish.
- Growth limitations are likely influencing the low freshwater survival rates observed in the watersheds.
- Delayed smoltification due to poor growth opportunities and high freshwater mortality may be a significant factor limiting these populations.
Questions?