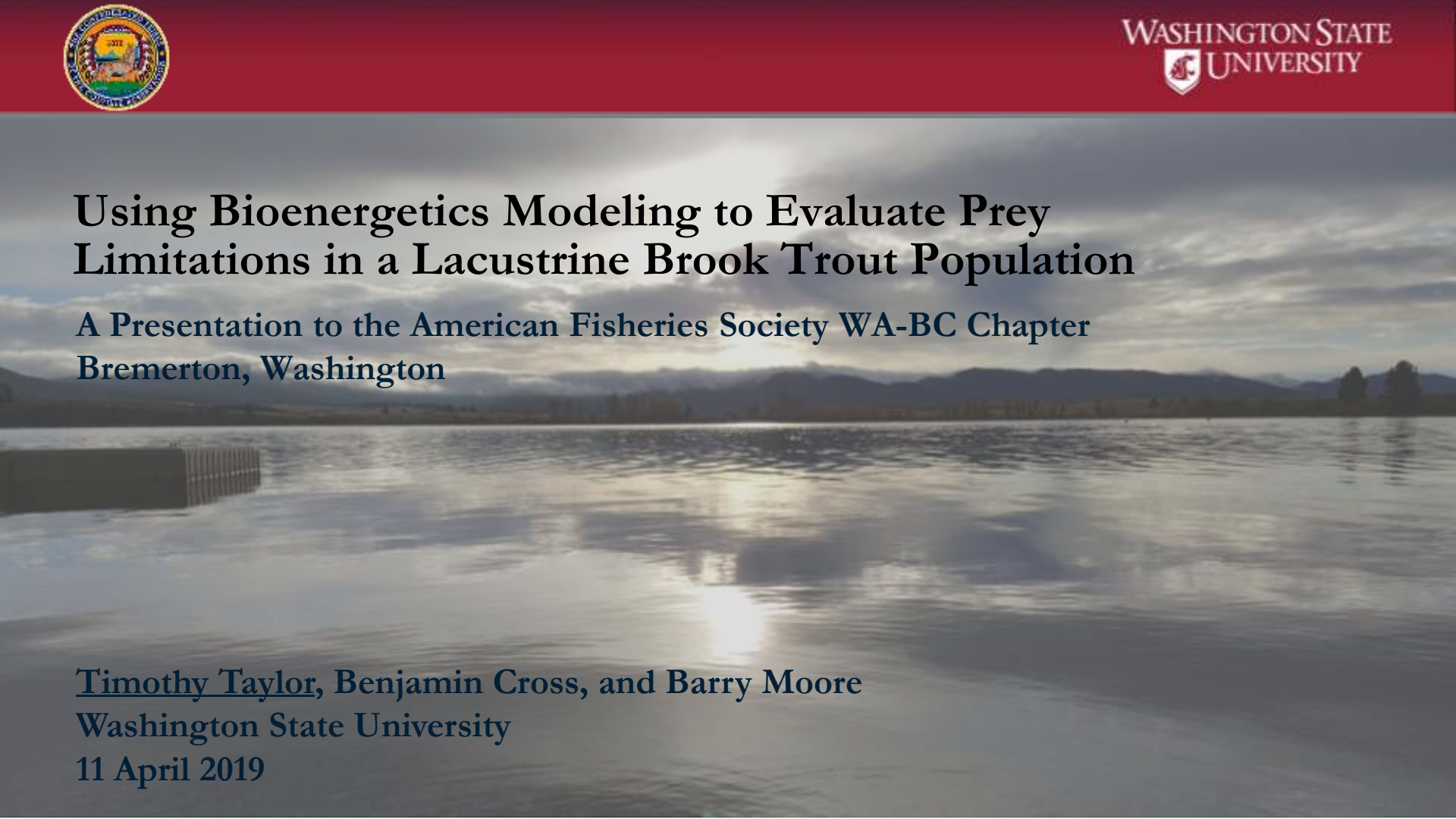

Using Bioenergetics Modeling to Evaluate Prey Limitations in a Lacustrine Brook Trout Population

A Presentation to the American Fisheries Society WA-BC Chapter
Bremerton, Washington

Timothy Taylor, Benjamin Cross, and Barry Moore
Washington State University
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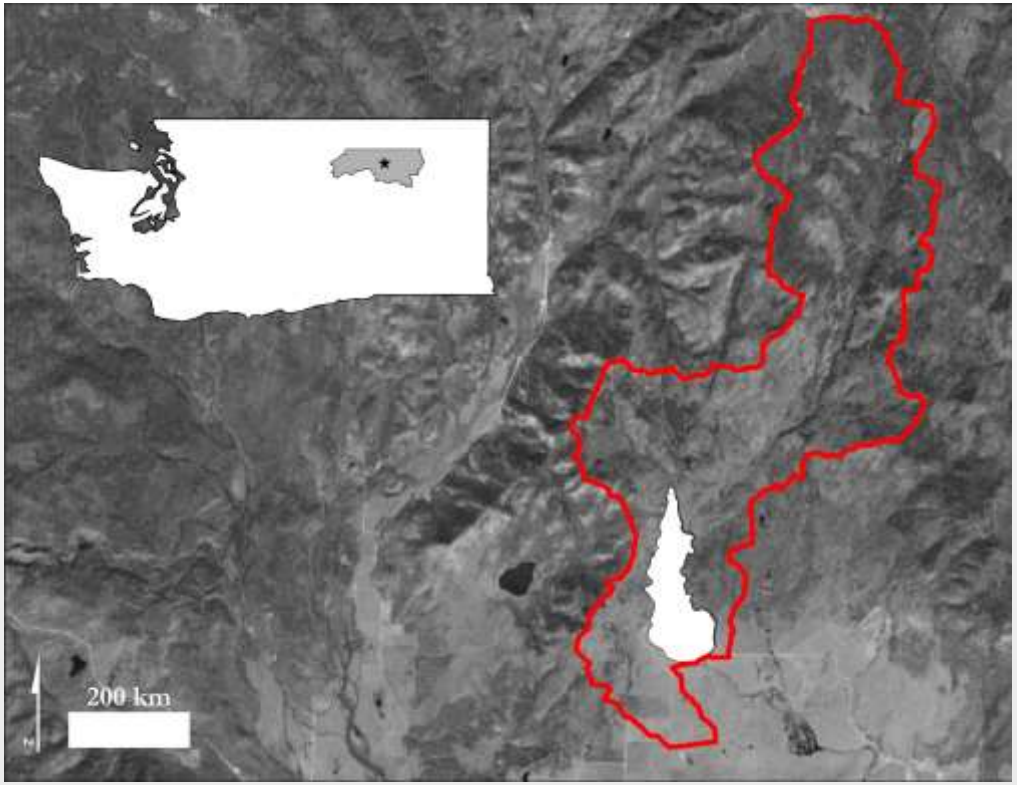
Owhi Lake, Washington

Location	Okanogan County, WA
Elevation (m)	782
Watershed Area (ha)	3,440
Surface Area (ha)	202
Volume (m^3)	2.65×10^7
Max Depth (m)	23.5
Mean Depth (m)	13.1
Mean Secchi Depth (m)	6.0
Mean Volume-Weighted Total Phosphorus (mg/l)	0.13



Taylor (2016)

Owhi Lake, Washington

- Single fish species, Brook Trout (*Salvelinus fontinalis*)
- Brook Trout naturally recruitment, but contributions from natural production are unknown
- Supplement natural production with previous year's progeny
- Carrying capacity?
  - Density-dependent effects?
  - Is there enough food?
  - Balanced?

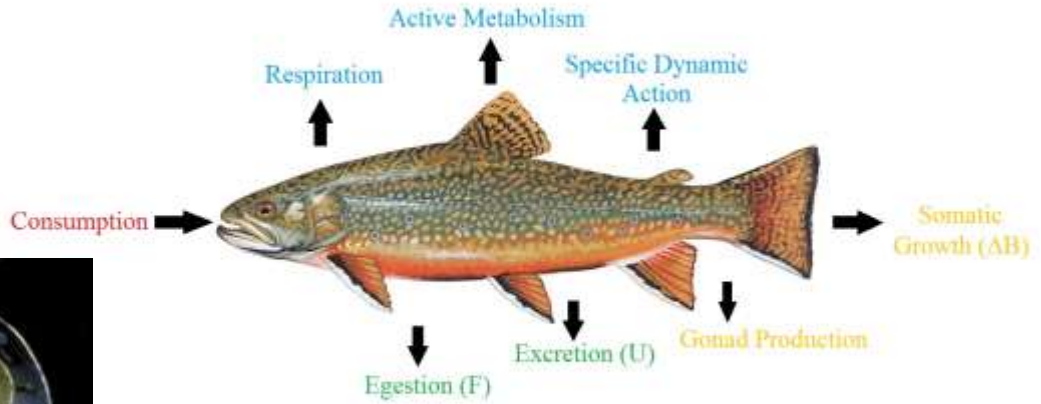
Supply and Demand

"How much food is enough?"

"How much food is there?"

- Supply-demand comparisons (Rand et al. 1993; Cross et al. 2005; Raborn et al. 2007; Negus et al. 2008; Evans et al. 2014)
- Caution when making comparisons (Evans et al. 2014)
  - Demand from a management perspective
  - Prey dynamics and predator encounter rate
- Need additional support

Supply and Demand



$$C = (R + A + S) + (F + U) + (\Delta B + G)$$

Supply and Demand

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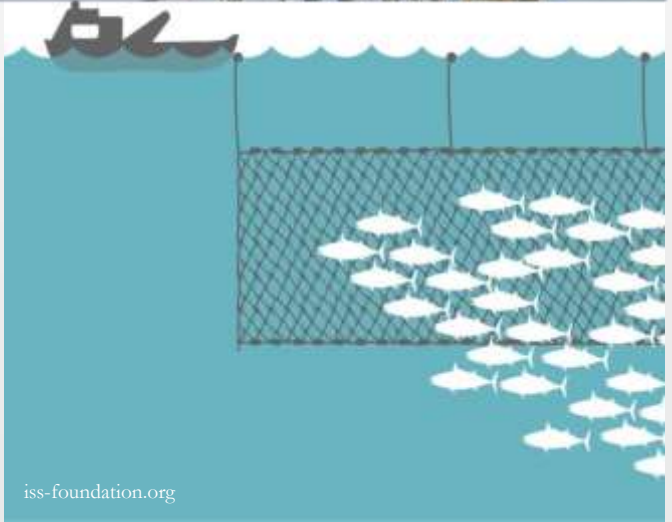
Objectives

- Quantify annual fish population dynamics (growth and mortality) and seasonal diet composition
- Compare seasonal prey production with fish demand
- Evaluate maximum feeding rates and growth efficiencies
- Determine how model input variation affects consumption estimates

Brief Methods

- Collected fish seasonally from spring 2015 to fall 2017, excluding winters
- Boat electrofishing and gill nets
- Enumerated fish (length, weight, diet, age) and prey (length, calorie content)
- Calculated growth (linear regression models) and mortality (Chapman-Robson estimator)
- Calculated biomass and production (size-frequency method)
- Bioenergetics modeling (Fish Bioenergetics 4.0), and data required to model
- Calculated growth efficiencies, maximum consumption rates, and performed sensitivity analyses



Brief Methods

- Growth efficiency:

$$\frac{\text{Daily mass accumulated by predator}}{\text{Daily mass of prey consumed}}$$

- pC_{max} (p):
  - Bioenergetics model ouput
  - High values = high food availability
  - Also reflects variations in activity, energy content, and diet

The basic form of the consumption function:

$$C = C_{max} \cdot p \cdot f(T)$$

$$C_{max} = CA \cdot W^{CB}$$

where:

C	specific consumption rate ($g\ g^{-1}\ d^{-1}$)
C_{max}	maximum specific feeding rate ($g\ g^{-1}\ d^{-1}$)
p	proportion of maximum consumption
f(T)	temperature dependence function
T	water temperature (°C)
W	fish mass (g)
CA	intercept of the allometric mass function
CB	slope of the allometric mass function

RESULTS

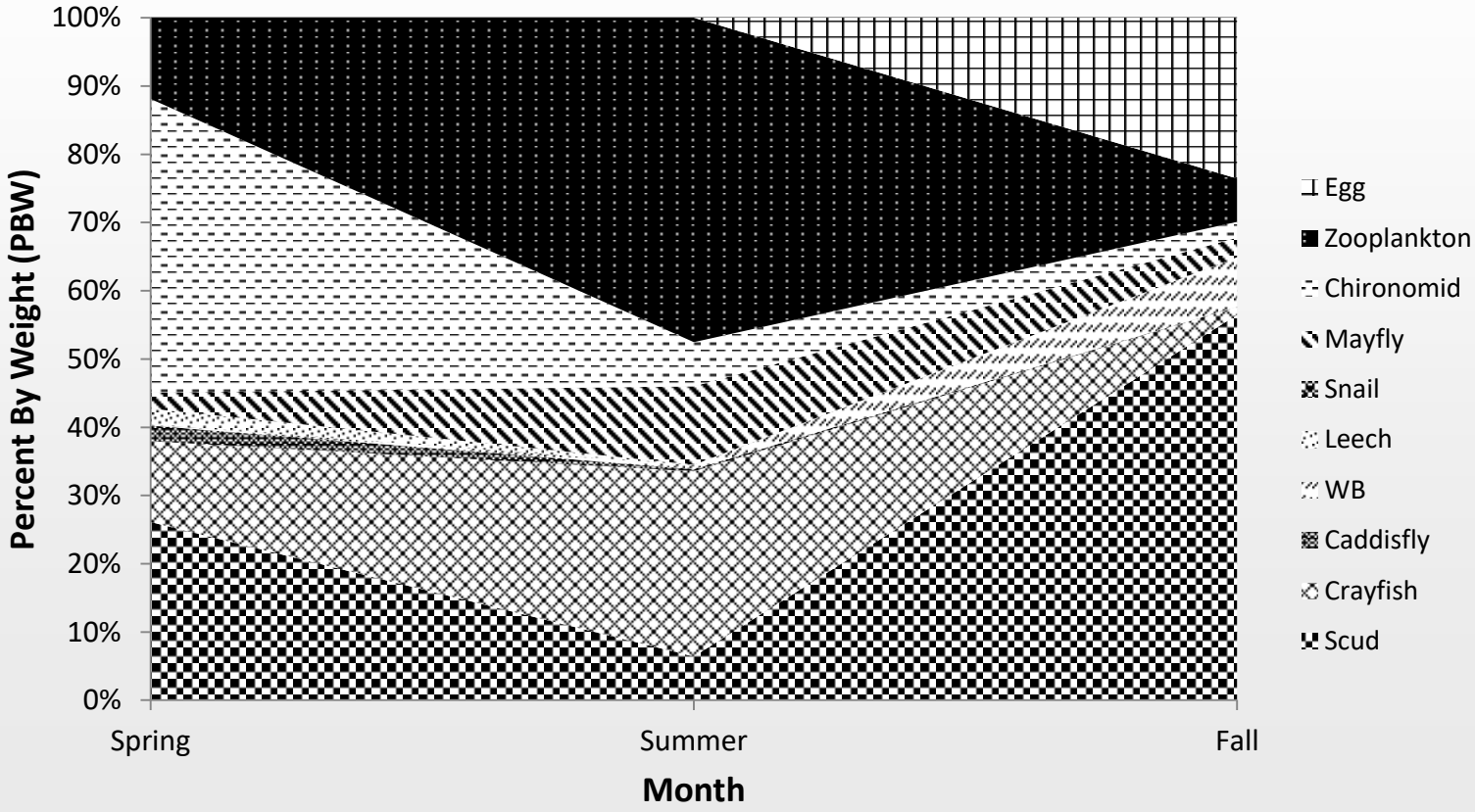
Abundances and Mortality Rates

Abundances and Mortality Rates

Year	Population Size	Annual Mortality Rate
2015	9,344 ± 4,604	0.41 ± 0.04
2016	5,581 ± 2,907	0.49 ± 0.06
2017****	**21,801 ± 7,051**	**0.52 ± 0.05**

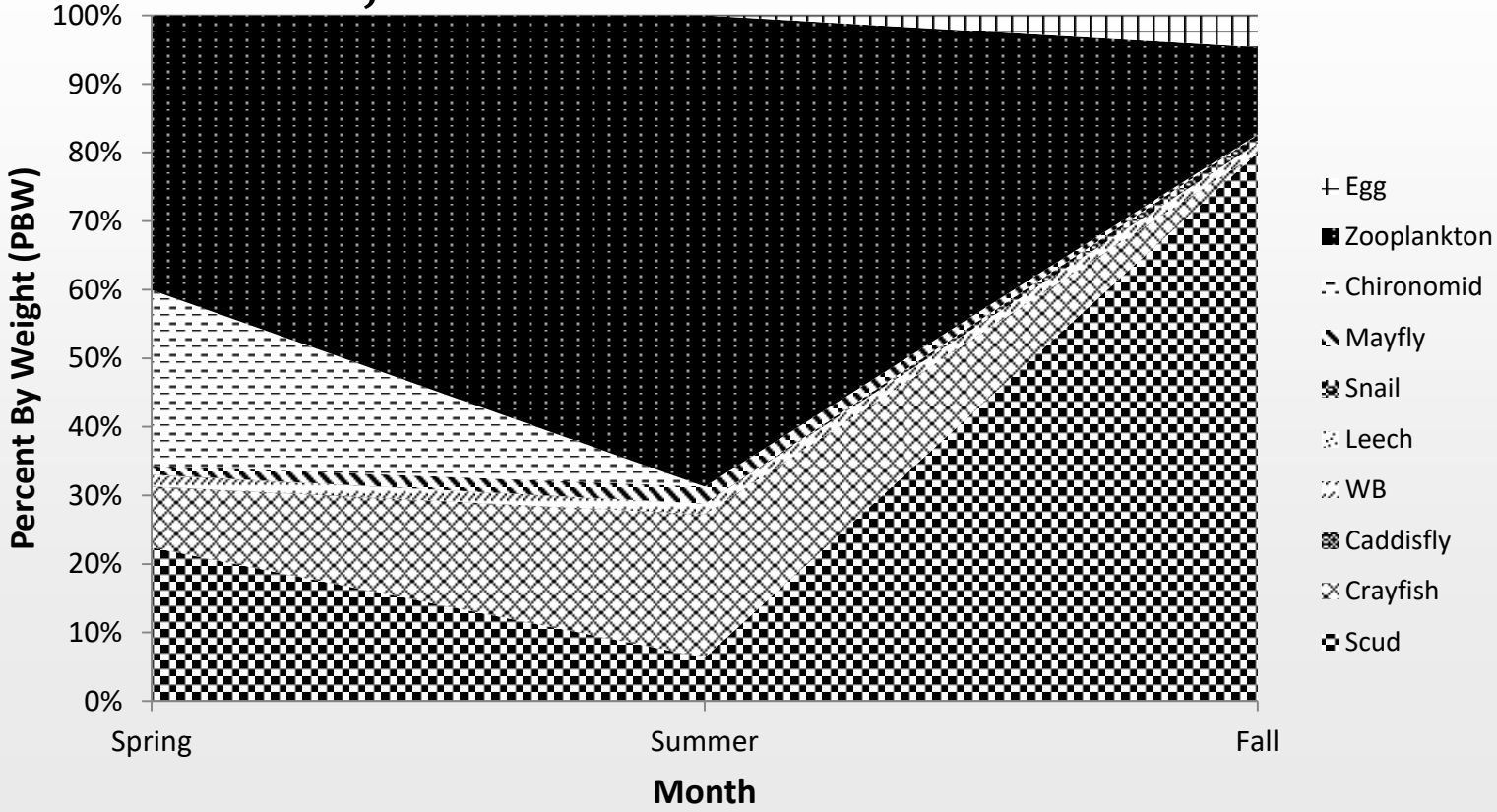
Brook Trout Diet

Brook Trout Diet, 2015



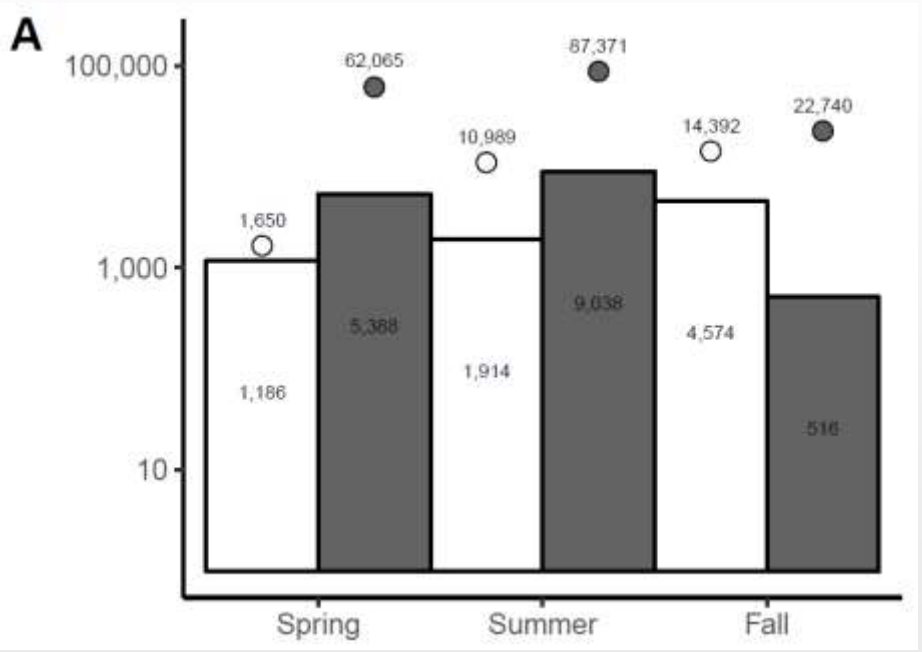
Brook Trout Diet, 2016

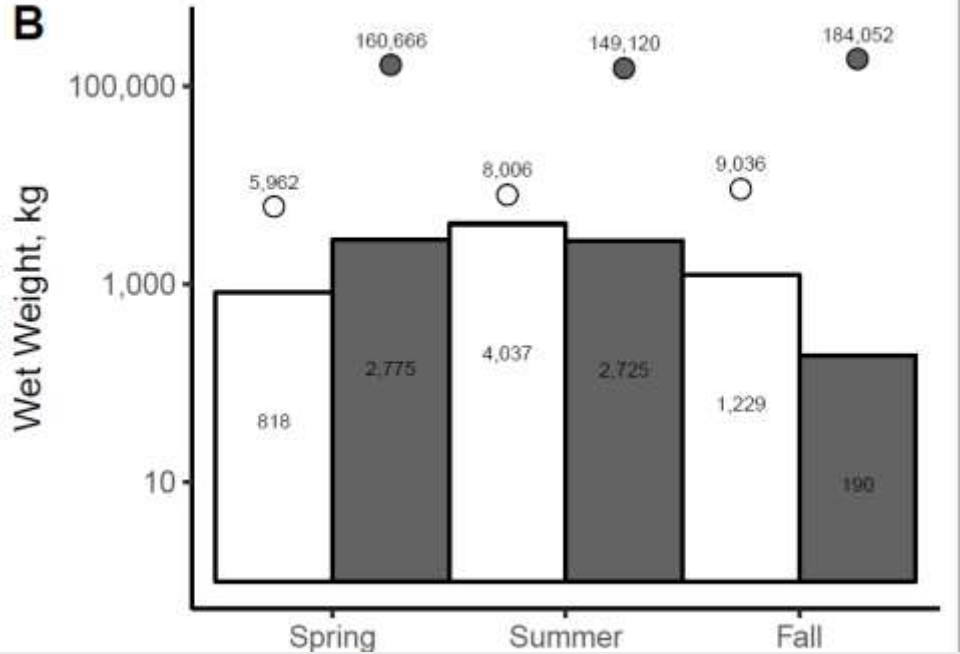
Brook Trout Diet, 2017



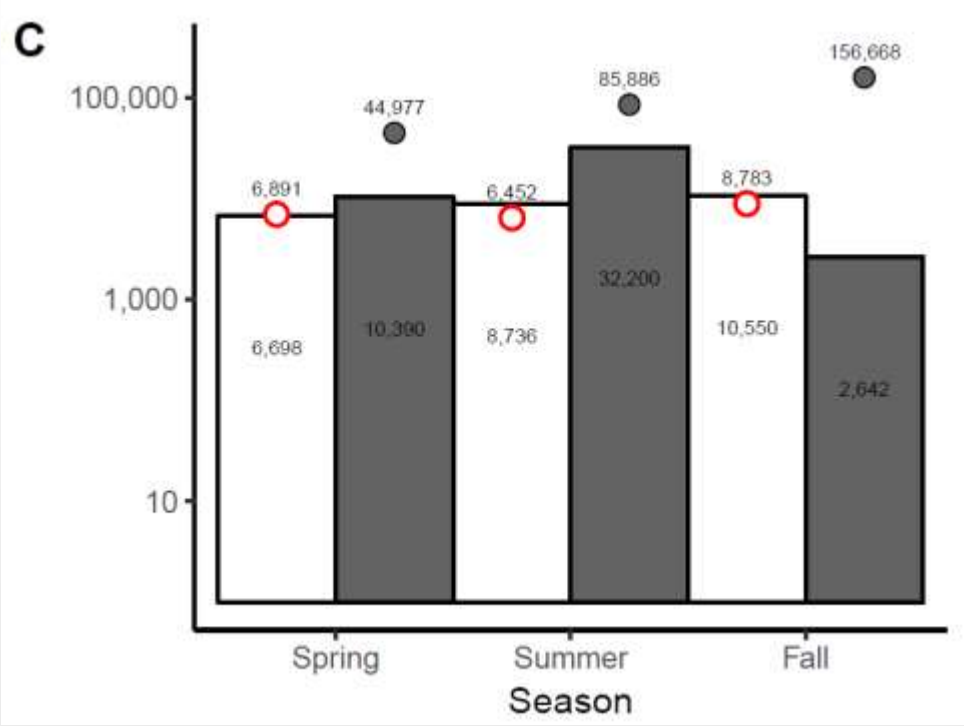
Supply-Demand Comparisons

Supply-Demand Comparisons



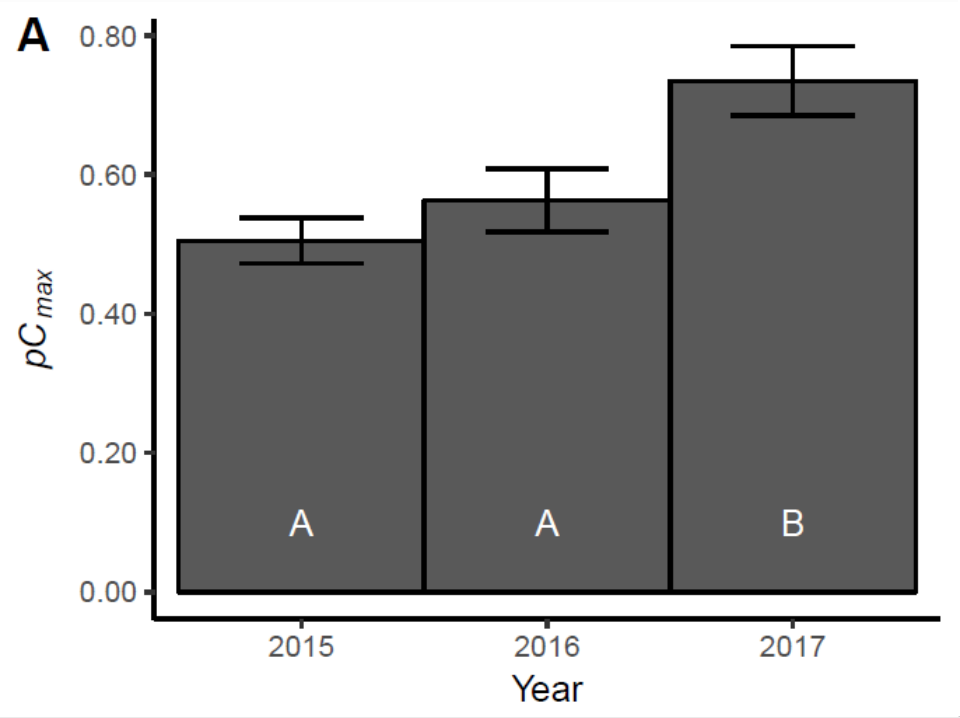


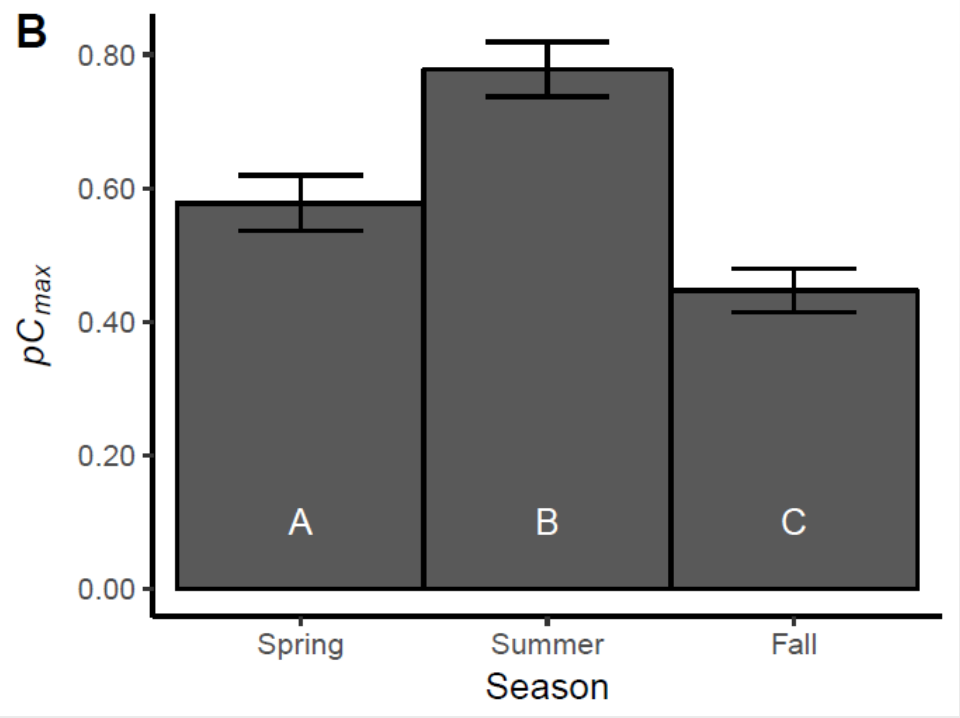
Supply-Demand Comparisons



Maximum Feeding Rates and Growth Efficiency

Maximum Feeding Rate

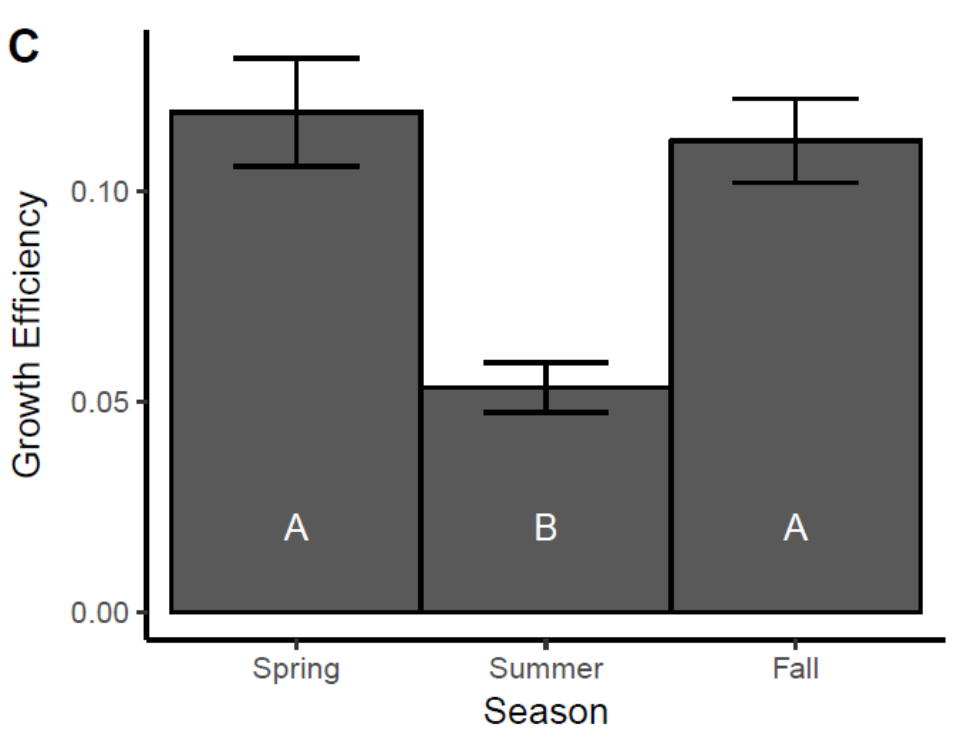




Results

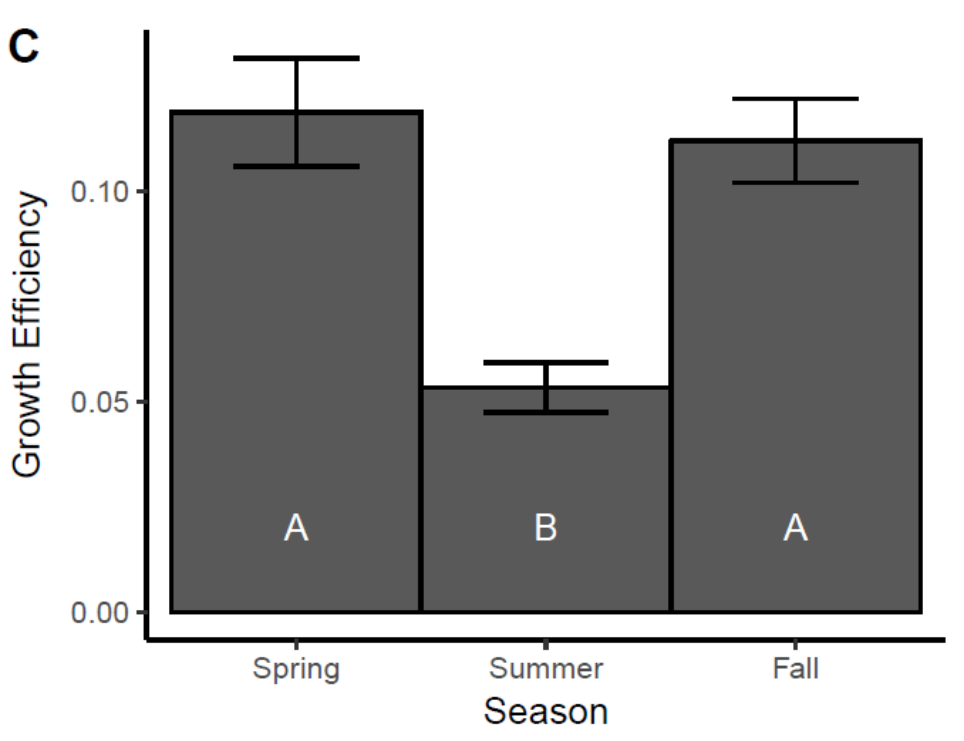
- Total prey supply exceeded total demand, but….
- Brook Trout diet switched to more zooplankton in 2016 and 2017 summers
    - Increased feeding activity
    - Increased metabolic costs
- Prey switching may indicate depleted prey supply (littoral invertebrates)

Growth Efficiency



- Growth efficiencies were lowest in summers
- Brook Trout not growing efficiently in summers, likely due to metabolic costs and feeding behavior
- Suggests summer limitations

Growth Efficiency



- Growth efficiencies were lowest in summers
- Brook Trout not growing efficiently in summers, likely due to metabolic costs and feeding behavior
- Suggests summer limitations

Discussion

- Is there an adequate prey supply?
  - For most years and seasons, yes
    - 2017 supply did not meet demand
    - Ecological bottleneck: summer season
    - Winter may also be limiting, but no data for this period

Year	Population Size	Annual Mortality Rate
2015	9,344 ± 4,604	0.41 ± 0.04
2016	5,581 ± 2,907	0.49 ± 0.06
2017****	**21,801 ± 7,051**	**0.52 ± 0.05**

- Model was most sensitive to variation in Brook Trout abundances, major prey energy densities, and mortality rates
  - Conclusions:
    - Importance of low confidence intervals around population abundances and mortality rates
    - Researchers should estimate energy densities in study systems

Acknowledgements

- Washington State University faculty and staff
- Dr. Barry Moore Graduate Students
- Colville Confederated Tribes Fish and Wildlife Department
- Various scholarship and grant supporters

Kelly Creek Flycasters Club

Questions?