Seasonal Variation in the Metabolic Performance of Walleye Pollock and the Influence of Temperature

PCCRC Progress Report

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Kodiak, Alaska
Study Site: Kodiak, Alaska
Gulf Apex Predator prey study: 2001-2006
Pollock abundance and commercial removals

FISHERY REMOVAL 2002

~3 K mt in March

11 K mt total

2002 nearshore (<10 km) Pollock

~74K mt

kg/km² x 10⁴

May

June

July

August

September

Age class

1

2

3

4

5

6

7
Pollock Distribution: What could affect the local biomass?
Local temperature and pollock abundance

Bottom water temperature (°C)

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Local temperature and pollock abundance

Bottom water temperature (°C)

Bottom temperature

Pollock abundance from bottom trawl

May
August
November

Fishery (area 630) B season
Objectives: Pollock metabolism ~ temperature

1. Determine how metabolic scope of walleye pollock is altered by seasonal physiological changes
   a. Does metabolic rate change independent of temperature?

2. Determine extent water temperature influences metabolic rate and swimming performance
   a. Changes in SMR ~ temperature dictate energy available for growth, reproduction, and condition

3. Assess the use of organismal and plasma indices as bioindicators of fish condition
   a. Swim performance stress measured from changes in hormone release, ion regulation, increases in lactate, protein, and glucose.
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First Step: CATCH FISH!
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Acclimation vs. Immediate Response

Acclimation
Physiological changes that occur in an organism to maintain homeostasis, may take several weeks to occur.
  • mitochondrial density
  • metabolic rate
  • swimming performance
  • muscle fiber recruitment
  • enzyme activity

Immediate response
  • shock
  • stressful
  • changes in metabolic rate
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Metabolism Methods

Experiment 1

• 50-60 cm fish captured trawl (2 week acclimation)

• Immediate swim in 3 Temperature treatments (1.5, 4.5, 8.5 °C)
Methods: Temperature influence on physiology

Metabolism Methods

**Experiment 1**
- 50-60 cm fish captured trawl (2 week acclimation)
- Immediate swim in 3 Temperature treatments (1.5, 4.5, 8.5 °C)

**Experiment 2**
- Acclimated to 2 Temperature treatments (4 and 10 °C) for 3 months prior to experiment
Metabolism Methods

- Routine metabolic rate (RMR)
- Increased swimming speed at 0.1 BL/sec in 30 minute intervals until exhaustion
- $\text{VO}_{\max} @ U_{\text{crit}}$
- Metabolic scope: $\text{VO}_{\max} - \text{RMR}$
- Index of Activity: MS/RMR
Methods: Temperature influence on physiology
Methods: Temperature influence on physiology
Results: Temperature influence on physiology

Metabolism Results: Short Acclimation

**Temperature vs. O2 consumption**

- **8.5 °C**
  - Equation: \( y = 35.801e^{0.1509x} \)
  - \( R^2 = 0.8423 \)

- **4.5 °C**
  - Equation: \( y = 55.732e^{0.0915x} \)
  - \( R^2 = 0.5771 \)

- **1.5 °C**
  - Equation: \( y = 27.866e^{0.1435x} \)
  - \( R^2 = 0.5128 \)

**Swimming speed (BL/s)**

- **O2 consumption (mg/kg/hr)**
1) How is MS altered by season?
   - Greater RMR in Spring
   - Reduced MS in Spring

2) How does temperature affect RMR and $U_{\text{crit}}$?
   - Greater RMR in higher temperature
   - Increasing $U_{\text{crit}}$ with increasing temperature

3) Are plasma and organosomatic indices useful indicators of fish condition?
   - Increases in Na$^+$ and Cl$^-$ concentrations after swim trials
   - Currently analyzing blood and tissue samples
Results Summary

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Seasonal alteration in metabolism independent of temperature

- Different energy requirements
- Summer pollock have more energy to dedicate to other activities other than basic metabolism

Temperature impacts on metabolism and swim performance

- Increased temperatures associated with increased swim performance and RMR
- Increased energy requirements with increased temperature
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- Increased temperatures associated with increased swim performance and RMR
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Application: Costs of swimming

Energetics of swimming

Cost (cal/kg/hr) vs. Swimming speed (BL/s)

- 8.5
- 10

Graph showing the relationship between cost and swimming speed.
Application: Costs of swimming

Cost of Transport (cal/kg/km)

Swimming Speed (cm/sec)

Walleye pollock
Pacific Cod
Application: Temperature influence on consumption/growth

**Metabolism** = Respiration (RMR) + active metabolism + specific dynamic action

Hewett and Johnson 1992
Application: Temperature influence on consumption/growth

Metabolism = Respiration (RMR) + active metabolism + specific dynamic action

Hewett and Johnson 1992

Consumption = Metabolism + Waste + Growth
Application: Temperature influence on consumption/growth

1000 g/ fish increase @ 7 °C

Specific consumption (g/g/d)

Days

7.0 °C
4.5 °C
Future Objectives

- Complete plasma analyses
- Model growth & consumption ~ small scale variability in temperature and prey availability
Acknowledgements
PCCRC, NPRB, NOAA, ADFG

Iluhi Schimetka, Mike Trussel, Andreas Winter

FV Laura, RV Resolution

Katie Brenner, Sharon Buck, Casey Clark, Cathy Foy, Brook Gamble, Lei Guo, Brian Knoth, Mary Beth Loewen, Katie Murra, Christy Newell, Jennifer Ng, Petra Reimann, Jordy Thomson, Carrie Vorholt, Xian Wang, Bree Witteveen, Kate Wynne.
Current Models

- Bering Sea Bioenergetics model (Buckley and Livingston 1994)
- Activity multiplier ~ Metabolic Scope
  - MS/RMR

- Simulations
  - 90 days (summer)
  - Constant temperatures
    - 4.5 and 7 °C
    - ACT ~ temp
  - Typical diet (Euphausiids, copepods, fish)
  - Typical energy density of predator (~4 KJ)
    and prey (~1-4 KJ)
Future Models

- Multi-season and interannual data sets
- Improved allometric relationships
- Apply to large scale movement patterns in Bering Sea and Gulf of Alaska

- Simulations
  - Entire year
  - Dynamic temperatures
    - Diurnal
  - Short acclimation: seasonal
  - Long acclimation: decadal
  - Dynamic diet
  - Dynamic energy density of predator and prey
  - Cost of Transport

Application: Temperature influence on consumption/growth
Bering Sea pollock seasonal migration

Kotwicki et al. 2005; EIT survey

- Northward and inshore shifts in pollock distribution during warm years.
- 50-80% of pollock < 50 cm moved north wrt temperature

Dark=biomass increases with temperature
Light=biomass decreases with temperature
Consumption Model
\[ C = M + W + G \]
**Application: Temperature influence on consumption/growth**

**Consumption** = Metabolism + Waste + Growth

**Metabolism** = Respiration (RMR) + active metabolism + specific dynamic action

\[
\text{Respiration} = RA \times WRB \times f(T) \times ACT
\]

- \( R \) = specific rate of respiration (g * g\(^{-1}\) * d\(^{-1}\))
- \( W \) = fish mass
- \( RA \) = intercept of allometric mass function
- \( RB \) = slope of allometric mass function
- \( f(T) \) = temperature dependence function
- \( T \) = Water temperature
- \( ACT \) = Activity multiplier

Hewett and Johnson 1992
## Metabolism Results

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<td>U$_{crit}$</td>
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Pollock: Temperature influence on physiology

Metabolism Results: Long Acclimation

10 °C
$y = 71.945e^{0.1482x}$
$R^2 = 0.9785$

4 °C
$y = 67.527e^{0.1288x}$
$R^2 = 0.8294$
Pollock: Temperature influence on physiology

Metabolic Scope

![Graph showing VOmax-RMR against Temperature C with Long and Short Acclimation lines.](image-url)
First Step: CATCH FISH!