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Fish and Zooplankton Distributions in a Seasonally Hypoxic Fjord

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Fish and Zooplankton Distributions in a Seasonally Hypoxic Fjord

April 30 2014

Mei Sato, John Horne, Sandra Parker-Stetter

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Hypoxia Impacts on Ecosystems

- Compress favorable habitat for predators and prey
- Shift in community composition
- Alter energy flow in food webs

(Newton & Devol 2012)
Hypoxia Impacts on Ecosystems

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- Shift in community composition
- Alter energy flow in food webs

(Newton & Devol 2012)
Limitations in previous studies

Lack of direct observation of how responses to hypoxia alter food-web coupling

Goal

To understand how hypoxia affects

• distribution: predator/prey overlap,
• zooplankton community composition, and
• physiological/behavioral responses of fish.

If so, does hypoxia affect energy flow from zooplankton to fish?
Limitations in previous studies

Lack of direct observation of how responses to hypoxia alter food-web coupling

Goal

To understand how hypoxia affects

- **distribution**: predators/prey overlap,
- zooplankton community composition, and
- physiological/behavioral responses of fish.

If so, does hypoxia affect energy flow from zooplankton to fish?
Does hypoxia affect vertical distributions of predators and prey?
Does hypoxia affect vertical distributions of predators and prey?
Does hypoxia affect vertical distributions of predators and prey?
Study site

Hood Canal

Survey period
Jun – Oct in 2012 & 2013
Multi-frequency Echosounder

- 38 kHz
- 70 kHz
- 120 kHz
- 200 kHz
- 38 kHz
Transect lines
Transect lines

$S_v = \text{proxy for density}$

Depth (m)

Latitude (°N)

Longitude (°W)

$S_v$ (dB re 1 m$^{-1}$)

(http://www.simrad.com)
<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Separation of fish vs. zooplankton</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
</tr>
<tr>
<td>500 m</td>
<td></td>
</tr>
</tbody>
</table>

**Sv**

- **Sv**<sub>38 kHz</sub>
- **Sv**<sub>120 kHz</sub>
Separation of fish vs. zooplankton

Depth (m)

-50
-60
-70
-80
-90

$S_v$ (dB re 1 m$^{-1}$)

$S_{v120\ kHz} - S_{v38\ kHz}$
Separation of fish vs. zooplankton

$S_v_{120 \text{ kHz}} - S_v_{38 \text{ kHz}}$

Depth (m)

Distance

$S_v_{38 \text{ kHz}}$ (fish)

$S_v_{120 \text{ kHz}}$ (zooplankton)

$\Delta S_v$ (dB re 1 m$^{-1}$)

$500 \text{ m}$
Net Samplings

- Pacific herring
- Pacific hake
- Euphausiids
- Amphipods
- Copepods
- Chaetognaths
- Jellyfish
Hypoxia: $O_2 < 2 \text{ mg/L}$
Hypoxia: $O_2 < 2$ mg/L

Depth (m)

North

South

Dabob

Duckabush

Hoodsport

Union

Oxygen
Do zooplankton avoid hypoxic water?

$S_v_{120\ kHz}$ (zooplankton) : 2012 Aug
Do zooplankton avoid hypoxic water?

$S_v_{120\ kHz}$ (zooplankton) : 2013 Aug
Do zooplankton avoid hypoxic water?

- $S_v_{120\ kHz}$ (zooplankton)
- Oxygen
- PAR
Do zooplankton avoid hypoxic water?

- **Sv**$_{120 \text{ kHz}}$ (zooplankton)

- **Oxygen**

- **PAR**
Do zooplankton avoid hypoxic water?

Sv$_{120 \text{ kHz}}$ (zooplankton)

Oxygen

PAR

No upward movement of daytime scattering layer due to hypoxia
Do fish avoid hypoxic water?
Do fish avoid hypoxic water?

High density

Low density

Median $S_v$ (dB re 1 m$^{-1}$) vs. Near-bottom $O_2$ (mg/L)

- Union
- Hoodsport
- Duckabush
- Dabob
Do fish avoid hypoxic water?

No avoidance of near-bottom hypoxic waters

High density

Low density

Median $S_v$ (dB re 1 m$^{-1}$)

Near-bottom O$_2$ (mg/L)
Conclusions

- Hypoxia does not affect vertical distribution of fish and zooplankton

- Survey period in 2012-2013 is moderately hypoxic ($O_2 = \sim 2$ mg/L)

- Possibility of horizontal and vertical movements in distributions

(ORCA buoy data provided by Newton, Devol & Ruef)
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Capt. David Duggins, Scott Lindgren
Behavior and physiology responses

- Impact on growth/abundance in cod
- Impact on squid spawning
- Impact on hatching length in herring
- Decrease of squid catches
- Active selection of normoxic areas
- Drastically lowered catches demersals
- Distribution limit in sprat/horse mackerel
- Reduced growth/gonad size flatfish
- Disruption of schooling in herring
- Distribution limit jellyfish
- Impact on squid occurrence
- Impact on copepod swimming/filtering/abundance
- Impact on copepod egg development and hatching

(Shuler et al. 2010)
Benthic metazoans species

(A) Median Lethal Concentration (mg O₂/liter)
- Crustacea
- Fishes
- Bivalva
- Gastropoda

(B) Sublethal thresholds (mg O₂/liter)
- Fishes
- Crustacea
- Mollusca
- Polychaeta
- Echinodermata
- Cnidaria

(Vaquer-Sunyer & Duarte 2008)
Benthic macrofauna

(Vaquer-Sunyer & Duarte 2011)
Comparison of near-bottom $O_2$ vs. Sv fish at 38 kHz

Comparison of $O_2$ vs. Sv zoop at 120 kHz where peak of zoop layer is observed.
$S_v_{120 \text{ kHz}}$
Vertical Distributions

Fish Zooplankton

Jun 2012  Oct

Jun 2013  Oct

Depth (m)

Sv (dB)