Zooplankton productivity, trophic dynamics and size spectra in the Oregon shelf areas

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Achievement: Integrated SeaSoar-CTD-AC9-OPC
Achievement: Distributions at 5 m (US GLOBEC 2002 spring cruise)
Achievement: Size structure (depth averaged in 0–153 m)

Remaining questions:

What causes the difference between the biomass spectra?

Can we interpret the shape of a biomass spectrum in terms of physical and biological processes?
Theory 1: Growth & mortality rates
(Zhou & Huntley 1997; Edvardsen et al. 2002; Zhou 2006)

$$g \Delta t$$

$$\ln b_t$$

$$\ln b' = \ln b - \ln b_t$$

$$g \Delta t$$

$$\mu \Delta t$$

$$g_t = -\frac{\Delta \ln b'}{\Delta t} / \frac{\Delta \ln b'}{\Delta \ln w}$$

$$\mu_t = g_t \left( \frac{\partial \ln b_t}{\partial \ln w} \right)$$

$$\frac{\partial \ln b}{\partial t} + g \frac{\partial \ln b}{\partial \ln w} = \mu - \frac{\partial g}{\partial \ln w}$$
Example: Zooplankton growth and mortality rates estimated from repeated samplings

\[ \ln \mu_t = g_t \left( \frac{\partial \ln b_t}{\partial \ln w} \right) \]

\[ g_t = -\frac{\Delta \ln b'}{\Delta t} / \frac{\Delta \ln b'}{\Delta \ln w} \]

\[ \partial \ln b_t \]
Theory 2: Slope, assimilation & trophic levels

Net biomass change:
\[ \int_{w_1}^{\infty} gbdw \]

Total biomass used:
\[ (wgb)_{w_1} - (n-1) \int_{w_1}^{\infty} \mu bdw \]

Community assimilation efficiency:
\[ \eta_n = \frac{\int_{w_1}^{\infty} gbdw}{(wgb)_{w_1} - (n-1) \int_{w_1}^{\infty} \mu bdw} \]

\[ n = -\frac{1 + \eta_n}{\eta_n \times \text{slope}} \]

\( n \): an index for the \# of trophic levels
Example: Trophic level differences

\[ n = -\frac{1 + \eta_n}{\eta_n \times \text{slope}} \]

<table>
<thead>
<tr>
<th># of levels</th>
<th>Recycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearshore:</td>
<td>2.0</td>
</tr>
<tr>
<td>Offshore:</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Considering to use the slope as an indicator for the food-web.
Anomalies on biomass spectra

\[ g \Delta t \]

\[ \frac{\mu}{g} \]

\[ \mu \Delta t \]

\[ \frac{\partial \ln b}{\partial t} + g \frac{\partial \ln b}{\partial \ln w} = \mu - \frac{\partial g}{\partial \ln w} \]

Can the mortality be zero?
Anomalies on biomass spectra

\[ \text{slope} = -\frac{1 + \eta_n}{\eta_n \times n} \]

\( n \): # of trophic levels

\( \eta_n \): Community assimilation efficiency

Can the biomass be recycled infinitely?
The general size spectrum theory

Biomass spectrum equation
(Silvert & Platt 1978; Zhou & Huntley 1997)

\[
\frac{\partial b}{\partial t} + \frac{\partial (u_x b)}{\partial x} + \frac{\partial (u_y b)}{\partial y} + \frac{\partial (wgb)}{\partial w} = gb + \mu b
\]

- **Advection**:\n  - \(u_x, u_y\): geostrophic current
  - \(b\): biomass spectrum

- **Biomass flow in sizes**:\n  - \(g\): specific rate of individual body growth
  - \(\mu\): specific rate of abundance (concentration) change

\[
\frac{\partial \ln b}{\partial t} + \frac{\partial (u_x \ln b)}{\partial x} + \frac{\partial (u_y \ln b)}{\partial y} + g \frac{\partial \ln b}{\partial \ln w} = \mu - \frac{\partial g}{\partial \ln w}
\]
Biomass spectrum theory

\[
\frac{\partial \ln b}{\partial \ln w} = \frac{\mu}{g} \left\{ \frac{\partial (u_x \ln b)}{\partial x} + \frac{\partial (u_y \ln b)}{\partial y} \right\}
\]

\[
\frac{\partial \ln b}{\partial \ln w} = \frac{\mu - 1}{g} \left\{ \frac{\partial (u_x \ln b)}{\partial x} + \frac{\partial (u_y \ln b)}{\partial y} \right\}
\]

\[
\frac{[u_x]}{\Delta x} = \frac{0.1 \sim 0.2 \text{ m s}^{-1}}{50 \text{ km}} = 0.2 \sim 0.3 \text{ day}^{-1}
\]

\[
g : 0.1 \sim 0.3 \text{ day}^{-1}
\]
Is the mortality of small ones balanced by advection of small ones?
Geostrophic current

Zooplankton biomass

Normalized convergence

\[- \frac{\partial (u_x \ln b)}{\partial x} + \frac{\partial (u_y \ln b)}{\partial y}\]
Physical processes can significantly affect the size structure of a zooplankton community.

The same rule should be applied to species based structure, that is, the advection affects the community structure.
Summary

- Size spectrum measurements and theories have provided quantitative methods to access zooplankton distributions, growth, mortality and trophic interaction.

- Physical processes have significant effects on the zooplankton community structure which may bias the interpretation of their population dynamics and trophic interaction.