Biotic vs. physical control of zooplankton in estuaries

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Outline

• Physical conditions for zooplankton
• How they cope
• Evidence for biotic control
• Top down or bottom up?
  – A false dichotomy

Examples from our work in the upper San Francisco Estuary and from the literature
Challenges for Estuarine Zooplankton

- Seaward residual flow
- Tidal mixing
- Salinity gradient
- Shallow water
- Things people do
Distributions in salinity space

**Eurytemora affinis 1972 - 1986**

- **Abundance at S = 0.5 - 6**
  - (color = Temperature)

- **See:** Laprise & Dodson 1993 MEPS

**Abundance**

- $m^{-3}$
- $10^1$ to $10^4$
- $10^2$ to $10^3$
- $10^3$ to $10^4$
- $10^4$ to $10^5$

**Surface Salinity**

- $0.02$ to $0.1$
- $1$ to $10$
- $10$ to $20$

**Freshwater Flow**

- $m^3 s^{-1}$
- $100$ to $1000$
- $1000$ to $10000$

- **See:** Laprise & Dodson 1993 MEPS
Distributions in salinity space: the Remane diagram

<table>
<thead>
<tr>
<th>Salinity</th>
<th>Number of Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater species</td>
<td>Benign</td>
</tr>
<tr>
<td>Brackish species</td>
<td>Harsh?</td>
</tr>
<tr>
<td>Marine species</td>
<td>Benign</td>
</tr>
</tbody>
</table>
Distributions in salinity space
San Francisco Estuary, 1997-1999

Intermediate-salinity habitat is smaller than freshwater or marine habitat

Kimmerer 2004 SFEWS & unpubl.
Kimmerer et al. 2009 E&C
Species distributions I

Species abundance curves in southern Australia

Low diversity within bay despite high salinity
Similar patterns in several Japanese estuaries

Species abundance curves in southern Australia

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Species distributions II

**Acartia** congener in high-salinity estuaries

**Similar patterns in:**
Maizuru Bay, Japan (Ueda 1987 ECSS)
Westernport, Australia (Kimmerer and McKinnon 1989 MEPS)
Tomales Bay, CA (Kimmerer 1993 Estuaries)
Distributions in salinity space: *E. affinis*

North and Houde 2003 MEPS

Kilometers from River Mouth

Salinity

Depth, m

BUT:
Physiologically they do better at 5 – 30

Roddie et al. 1984 JEMBE
Kimmel & Bradley 2001 JEMBE
Devreker et al. 2004 JEMBE, 2007 JPR
Cailleaud et al. 2007 Comp. Biochem.
How to Avoid Dispersive Losses

- Be prolific
  - Produce resting eggs
- Stay near the bottom
- Migrate tidally
- Migrate to the bottom
- Migrate dielly (with suitable phasing)
“Estuaries are some of the most productive ecosystems in the world”

http://www.estuaries.gov
Chlorophyll in estuaries and coastal waters

Cloern and Jassby 2008 Ecol. Letters

Onset of food limitation

North America: 63
Europe: 50
Asia: 19
Australia/NZ: 9
South America: 8
Pacific: 4
Israel: 1

Chlorophyll, μg L$^{-1}$

Rank
Evidence for Biological Control I

Abundance in Low-Salinity Zone

Corbula amurensis

Limnoithona tetraspina

Abundance in Low-Salinity Zone

T. dextrilobatus
Acartiella sinensis
Ps. forbesi
Sinocalanus doerrii
Eurytemora affinis
Acartia spp.

IEP Monitoring Data

0 1 2 3 4 5 6
Year

Abundance (number L⁻¹)


IEP Monitoring Data
Evidence for Biological Control


Means for salinity < 0.5, all stations

Each line = 1 year

Population doubles every ~ 6d

IEP Monitoring (A. Hennessey)
Birth and Death in an Estuary

**Pseudodiaptomus forbesi**

Egg Production Rate, eggs female$^{-1}$ d$^{-1}$

**Birth and Death in an Estuary**

Egg production declined after introduction of 2 other spp.: Competition? Predation?

Very high mortality of adults in freshwater: vertebrate predation?

See posters: A. Slaughter S2-7082 and T. Ignoffo S2-7119
Predatory Effects on Zooplankton

Apparent control of mesozooplankton abundance by gelatinous predators
Narragansett Bay, 1974

Deason & Smayda 1982 JPR

Apparent control of microzooplankton abundance by zebra mussels
Hudson River

What are the effects of vertebrate predation?

Birth of the “size efficiency hypothesis”

Invasion of a lake by alewives shifted the zooplankton to a smaller size distribution

Brooks and Dodson 1965 Science
1750 citations
How to Deal with Predators

Stay in turbidity maximum
Be small
Be still
Avoid the surface
Be prolific
Stay near the bottom
Feed at night
Migrate to the bottom
Migrate dielhy
Armor?
Resting stages?
Top-down vs. Bottom-up: a false dichotomy

It’s nearly always both at once!
Top-down vs. Bottom-up

- Food limitation $\rightarrow$ population growth rate
- Losses incl. predation $\rightarrow$ species & size distribution
- Depends on modes of loss, esp. predation
- Both control abundance

Wanted:
more information on mortality
and its causes
¡Gracias!

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