Taxocene patterns of benthic secondary productivity along an estuarine gradient

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Introduction

- Macrobenthic benthic communities are widely used to assess the ecological condition of aquatic, estuarine and marine ecosystems.
- A common concern is that assessment metrics are structural (diversity, abundance, biomass, etc.) and not functional. Functional metrics, such as secondary productivity, have the potential to be more widely applicable and comparable between ecosystems.
- With respect to environmental management, measures of secondary production can be used to assess
  1) the value of benthos as a food source for higher trophic levels (Dolbeth et al. 2005);
  2) the effects of anthropogenic inputs such loads of nutrients, sediment and contaminants on benthic communities (Dauer et al. 2000).
  3) the efficacy of restoration and environmental management particularly in an adaptive management and adaptive monitoring sense (Borja and Dauer 2008); and
  4) the impacts of climate change on macrobenthic communities (Dolbeth et al., 2011).

Figure 1. Eastern North America with insert showing the Chesapeake Bay region.

Methods

- Our study used the random probability data set from the Chesapeake Bay Benthic Monitoring Program collected from 1996 through 2014 (Figure 1). Each year 250 random samples are collected throughout the entire tidal portion of the estuary (Dauer and Llansó 2003).
- We used a modified version of Brey's (2001) formula for estimating P/B ratios based on mean body mass per individual *w* expressed in kJ, sample depth *D* in meters, temperature in °K and several discrete (dummy) variables which took the following form:

$$\log_{10}(P/B) = 7.947 - 2.294 \times \log_{10}(w) - (2409.856 \times 1/T) + (0.168 \times 1/D) + (0.194 \times Subtid) + (0.180 \times InfEpi) + (0.174 \times Tax1) - (0.188 \times Tax2) + (0.330 \times Tax3) + (582.851 \times \log_{10}(w) \times 1/T)$$

Subtid is a dummy variable that increases the P/B ratio if the organism is found in a subtidal habitat (i.e. a depth of > 1 meter) while *InfEpi* is set to 1 if the organism is infaunal also resulting in an increase in the P/B ratio. *Tax1*, *Tax2* and *Tax3* are dummy variables that identify specific effects on P/B ratio associated with membership in different taxonomic groups and that are set to 1 if the organism is: (1) an annelid or crustacean; (2) an echinoderm or (3) an insect, respectively, and 0 if otherwise. These terms result in an increase in P/B ratio for annelids, crustacean and insect species and a decrease in P/B ratio for echinoderm species.

Summary – Estuarine Gradient

- Both biomass and benthic secondary production were highest in the three lowest salinity zones (Figs. 2 and 3).
- Benthic biomass was generally **20 times higher** in the lower versus the higher salinity zones.
- In contrast, benthic secondary production was only **2 times high**er in the higher salinity zones.
- The difference in biomass and secondary production between the lower versus higher salinity zones was primarily driven by the dominance of bivalves with low P/B ratios in lower salinity zones versus the dominance of polychaetes with high P/B ratios in higher salinity zones.

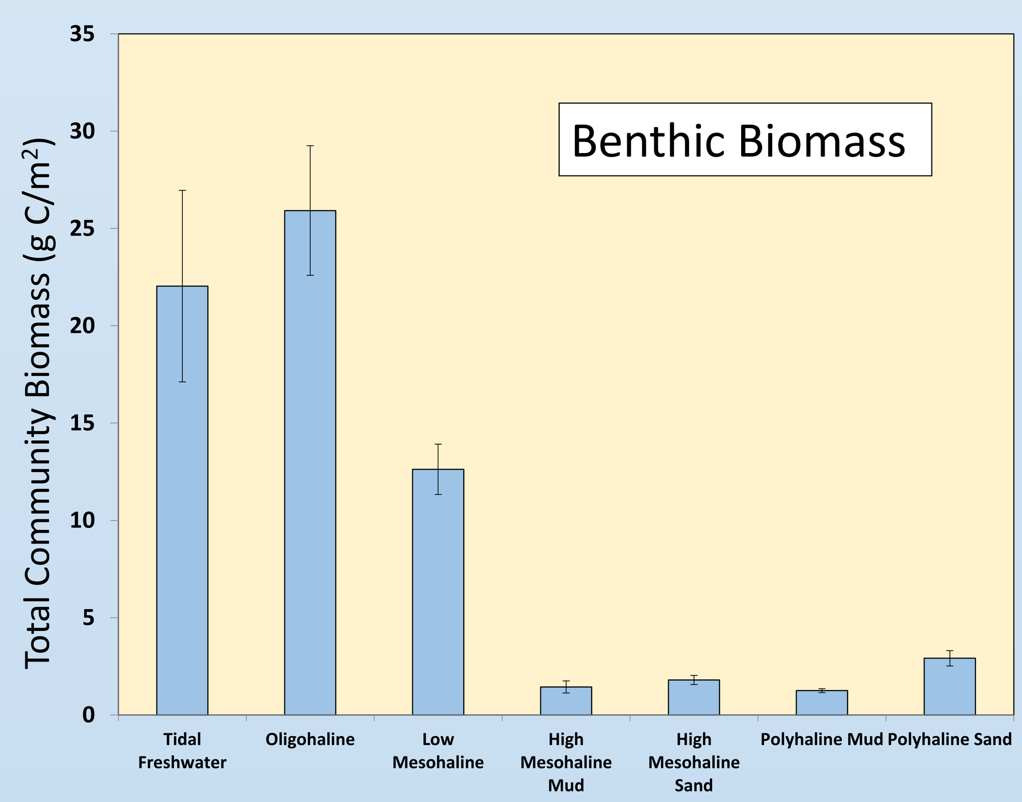

Figure 2. Mean standing stock biomass (gC/m²) by habitat type. Bar indicates one standard error.

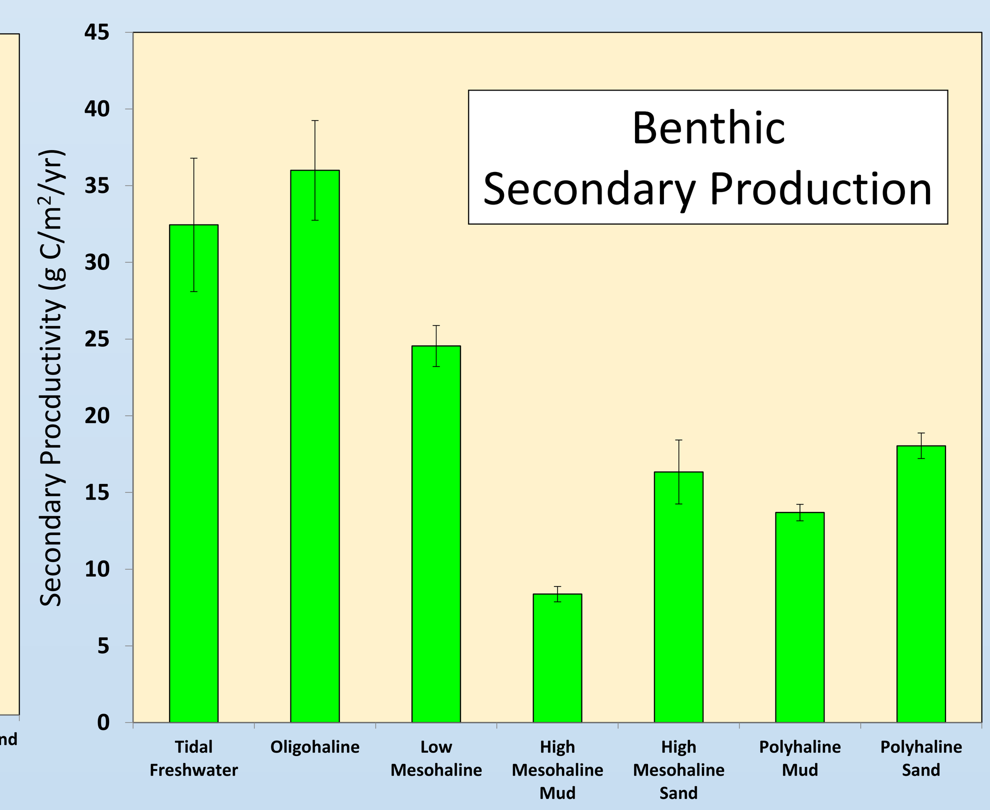

Figure 3. Mean secondary production (gC/m²/yr) by habitat type. Bar indicates one standard error

Summary – Taxocene Patterns

- At the estuary level, bivalves accounted for over 90% of the benthic biomass and 52% of the secondary production. This pattern was strongest in the three lower salinity zones. In the three higher salinity zones, bivalves accounted for 53.1% of the biomass and 25.9% of the secondary production.
- At the estuarine level, polychaetes had the second highest biomass (5.9%) and secondary production (29.3%) but had much higher secondary production in the higher salinity zones (61.4% compared to 11.0%).
- The next most important secondary producers were oligochaetes, amphipods and chironomid larvae.

Table 1. Taxocene patterns of biomass (AFDW gC/m²), secondary productivity (gC/m²/yr) and P/B ratios.

	All salinity zones (tidal freshwater through polyhaline)				
Taxon	Biomass	%	Secondary Productivity	%	P/B
Bivalvia	8.50	91.2	11.06	52.0	1.30
Polychaeta	0.55	5.9	6.23	29.3	11.35
Oligochaeta	0.10	1.0	1.41	6.6	14.60
Gastropoda	0.03	0.3	0.17	0.8	6.04
Amphipoda	0.04	0.5	0.86	4.0	19.92
Isopoda	0.04	0.4	0.45	2.1	11.29
Cumacea	0.01	0.1	0.10	0.5	19.73
Chironomidae	0.04	0.4	0.63	3.0	15.27
Insecta	0.02	0.2	0.35	1.6	15.66
Total	9.33	100.0	21.26	100.0	

Summary – Next Steps

- Develop a protocol to reflect the actual availability of the benthic production to higher trophic levels.
- Important ecological factors are
  1) protective coverings such has molluscan shells and crustacean exoskeletons that reduce predation,
  2) depth of dwelling within the sediment that might provide a refuge from predation,
  3) body size factors that affect strength of protective coverings and/or age-related sediment depth dwelling location, and
  4) general behaviors that can modify susceptibility to predation, e.g. rapid motility.

Table 2. Taxocene patterns of biomass (AFDW gC/m²), secondary productivity (gC/m²/yr) and P/B ratios.
Lower salinity habitats (0.5 – 12 ppt).

	Tidal Freshwater through Low Mesohaline zones (0.5 - 12 ppt)				
Taxon	Biomass	%	Secondary Productivity	%	P/B
Bivalvia	18.52	93.5	21.14	66.9	1.14
Polychaeta	0.29	1.5	3.47	11.0	11.98
Oligochaeta	0.21	1.0	2.78	8.8	13.42
Gastropoda	0.01	0.0	0.01	0.0	14.06
Amphipoda	0.05	0.2	1.06	3.3	21.63
Isopoda	0.07	0.4	0.85	2.7	12.26
Cumacea	0.01	0.0	0.02	0.1	23.70
Chironomidae	0.09	0.5	1.44	4.5	15.47
Insecta	0.05	0.3	0.81	2.6	15.65
Total	19.28	97.4	31.56	99.9	

Table 3. Taxocene patterns of biomass (AFDW gC/m²), secondary productivity (gC/m²/yr) and P/B ratios.
Higher salinity habitats (12 – 32 ppt).

	High Mesohaline through Polyhaline (12-32 ppt)				
Taxon	Biomass	%	Secondary Productivity	%	P/B
Bivalvia	0.99	53.1	3.50	25.9	3.54
Polychaeta	0.74	39.9	8.30	61.4	11.17
Oligochaeta	0.01	0.8	0.39	2.9	27.65
Gastropoda	0.05	2.7	0.30	2.2	5.98
Amphipoda	0.04	2.1	0.71	5.2	18.30
Isopoda	0.02	0.9	0.14	1.1	8.34
Cumacea	0.01	0.4	0.16	1.2	19.45
Chironomidae	0.00	0.1	0.03	0.2	10.37
Insecta	0.00	0.0	0.00	0.0	33.14
Total	1.86	100.0	13.53	100.0	

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