Spatial and Temporal Variability in Oyster Food Quality in the Delaware Estuary

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Abstract

Like other suspension-feeding bivalves, oysters are “ecosystem engineers” that can regulate water quality and plankton dynamics and furnish habitat for fish and other fauna. Factors that in turn affect oysters include recruitment, mortality, harvest pressure, disease, and food resources (that fuel growth). Of these, we know little about “bottom-up” food limitation of oysters in nature.

Oysters need to filter vast quantities of microparticulate suspended matter (seston) to balance their nutritional demands. Population production can be limited quantitatively or qualitatively because the demands of oysters vary with age and season, and the amount and type of seston in the water column also varies widely in time and space, rarely being in balance with the animal’s demands.

To examine how oyster food availability and quality varies in the Delaware Estuary, water samples were collected at eighteen sites in Delaware Bay and the upper Estuary in 10 months during 2009. Seston was collected on filters from water samples, and replicates were examined for total particulate matter (PM, a.k.a. TSS), particulate organic matter (POM), organic content, and the proximate biochemical composition of protein, lipid and carbohydrate.

Seston quantity and quality varied widely throughout the year and among locations. In general, seston quantity was greater in spring and fall and also was more abundant in the upper Estuary than in Delaware Bay. The concentration of POM followed a similar pattern, but the seston organic content (% w/w) was inversely related to PM and POM concentrations, being greater downbay than upbay. Particulate protein, lipid and carbohydrate concentrations declined as the year progressed.

Oyster condition (sampled in the fall) appeared related to seston composition, especially late summer seston quantity and quality. If confirmed with additional years of surveys, these findings will yield new insights into factors governing the effect of bottom-up resource dynamics on oyster productivity in Delaware Bay.

Introduction

To understand whether and how oyster populations might be affected by the quality or abundance of food resources requires careful analysis of their physiological ecology and nutrition as well as the resource dynamics of the system. Like most bivalves, oysters are obligate suspension-feeders that feed on a rich soup of microparticulate material (seston) (Fig. 1). Although they filter indiscriminately, they are capable of sorting particles prior to ingestion as well as fractionating ingested material to optimize assimilated rations.

Despite these tactics, oysters are susceptible to both the quantity and quality of food in the water, both of which vary widely in space and time. The specific nutritional demands of oysters also vary with changing physiological status (age, body size, season, reproductive state). Therefore, oyster production results from the interplay between the ever changing nutritional demands and available foods.

The most productive oyster beds in the Delaware Estuary are situated in areas where river-derived material carried by freshwater mixes with seaward sources of suspended matter (Fig. 2). Despite the historical and modern ecological and economic importance of oysters, the availability and composition of oyster foods has rarely been studied. The goal of this project was to quantify and biochemically characterize seston throughout the year at numerous reefs to better understand factors that regulate oyster production in Delaware Bay.

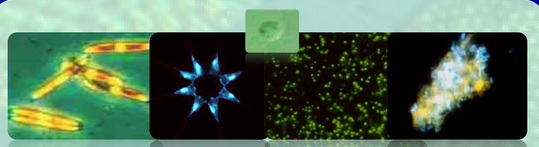

Figure 1. *Seston consists of a diverse array of microscopic algal cells, bacteria, protists, detritus, organic flocs, and inorganic matter.*

Figure 2. *Names and locations of oyster reefs in the Delaware Estuary.*

Methods

Three water samples were collected from the F/V Dredge Monster at each of 18 stations in the Delaware Estuary monthly during 2009, except for February and December. Each 4 L sample was taken one foot below the surface with a submersible pump.

At the Haskin Shellfish Research Laboratory, each water sample was sieved to 100 µm to remove large particles and then vacuum filtered through four replicate glass fiber filters, one of which had been pre-weighed. Filtration volumes were recorded and filters were frozen until analyzed.

At Drexel University, one filter was subjected to the loss-on-ignition method to determine total particulate matter concentration (PM), and particulate organic matter concentration (POM) relative to filtered volumes. The other 3 filters per sample were analyzed for particulate protein, carbohydrate and lipid using standard proximate biochemical methods as described and modified by Kreeger et al. (1997).

Concentrations and relative percentage contents for various food metrics were contrasted with the condition index (fatness) of oysters sampled in fall 2009 from a subset of 7 co-located reefs and then analyzed by Rutgers staff. Linear regressions were used for these exploratory comparisons.

Results

- Both the quantity and quality of seston varied widely across Delaware Bay and among the ten months sampled in 2009.
- Total particulate matter concentrations (PM) were greater upbay and decreased with increasing salinity (Fig. 3a). Exceptions were stations nearer to shorelines.
- Concentrations of particulate organic matter (POM) and various aspects of food quality (protein, carbohydrates) were more abundant at southern stations (Figs. 3b, 4) when averaged across the year.
- Comparison of seston metrics to the fall condition index of oysters suggested that oyster fatness is negatively related to PM and lipid *concentrations*, and was unrelated to POM, protein, lipid or carbohydrate *concentrations*.
- However, the *relative balance* of dietary constituents appeared to strongly relate to oyster fatness. The attribute most tightly correlated with oyster condition index was the dietary protein content (% w/w, Fig. 6, p=0.0003 for regression slope), which was higher in downbay areas (Fig. 3c).
- Carbohydrate content (% w/w, Fig. 3d) was also positively correlated with condition index (p=0.004).
- Summer protein and carbohydrate contents correlated best with fall oyster condition (p=0.0002).
- Interestingly, the protein:POM and protein:(CHO+Lipid) ratios also were strongly positive with oyster condition, indicating that protein was most important (Fig. 5).

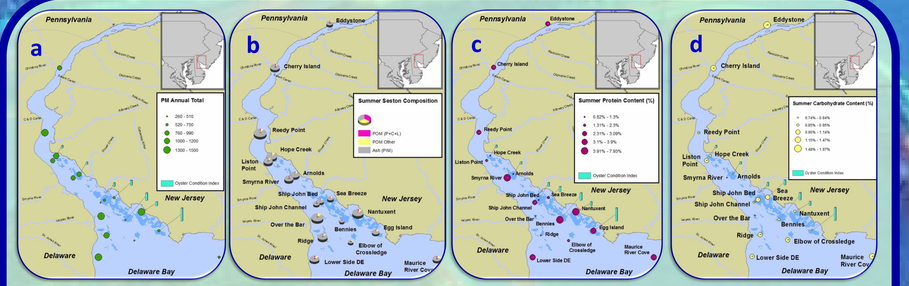

Figure 3. *Spatial variation in the **a)** mean annual concentration of PM, **b)** mean summer portions of PM as either POM (protein+carbohydrate+lipid), POM (other) or ash (inorganics, PIM), **c)** summer percent protein content (w/w PM), and **d)** summer percent carbohydrate content (w/w PM).*

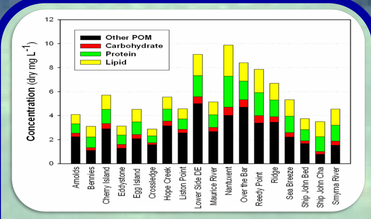

Figure 4. *Annual mean concentration of protein, carbohydrate, lipid and other POM in seston collected from various stations.*

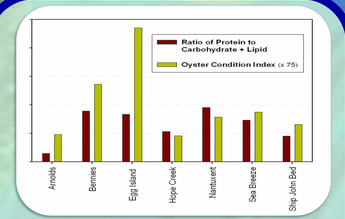

Figure 5. *Comparison of an example food quality index with fall oyster condition at sites in Delaware Bay.*

Conclusions and Next Steps

Both the proximate biochemical composition (quality) and the overall concentration (quantity) of seston vary widely across the Delaware Estuary and throughout the year. Preliminary comparisons with fall oyster condition suggest that seston protein content and overall seston concentrations were positively and negatively associated with oyster fatness, respectively.

Additional sampling is needed to look at interannual seston variability. Hydrodynamic modeling is also needed to link seston composition and oyster productivity at specific locations. Nevertheless, bottom-up factors might partially explain spatial variation in oyster population dynamics, and food composition should therefore be considered in oyster management and restoration planning.

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