Bivalve molluscs: barometers of climate change in Arctic marine systems.

Roger Mann[1], Daphne M. Munroe[2], Eric N. Powell[3], Eileen E. Hofmann and John M. Klinck[4]

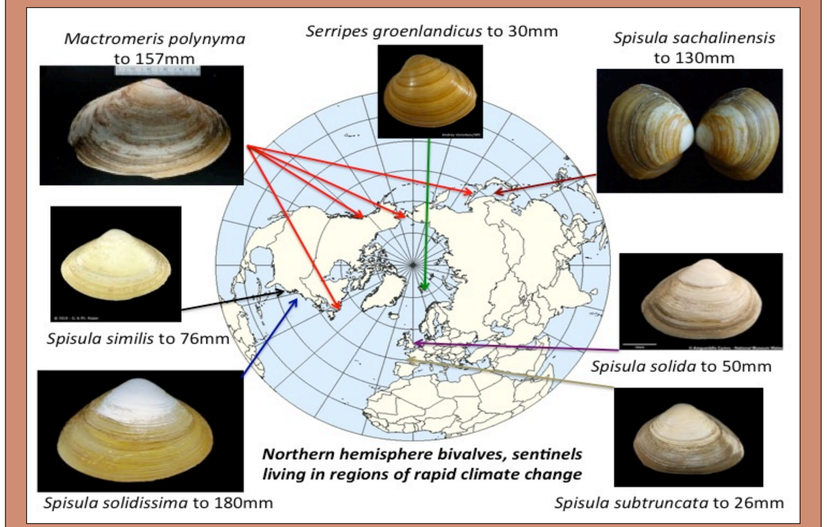
1 Virginia Institute of Marine Sciences, The College of William and Mary, Rt. 1208 Greate Road, Gloucester Point, VA 23062-1346 (e-mail: rmann@vims.edu)
2 Haskin Shellfish Research Laboratory, Rutgers University, 6959 Miller Ave., Port Norris, NJ 08349
3 Gulf Coast Research Laboratory, University of Southern Mississippi, 703 East Beach Drive, Ocean Springs, MS 39564
4 Center for Coastal Physical Oceanography, Department of Ocean, Earth and Atmospheric Sciences, 4111 Monarch Way, 3rd Floor, Old Dominion University, Norfolk, VA 23529

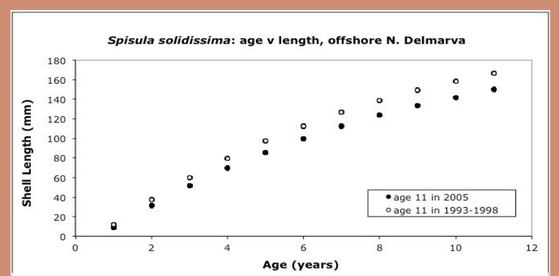
ABSTRACT

Bivalve molluscs store a complete history of their life in the growth lines in their valves. Through sclerochronology in combination with isotope signatures, it is possible to reconstruct both post-recruitment growth history at the individual level and commensurate environmental records of temperature and salinity. Growth patterns are integrators of local primary productivity; spatial and temporal changes in growth illustrate commensurate patterns of food availability. Mactrid clams are long lived benthic dominant species found on inner continental shelves throughout the northern hemisphere where they variously support major fisheries (*Spisula solidissima* in the Middle Atlantic Bight, *Mactromeris polynyma* in eastern Canada, *Spisula sachalinensis* in Japan), recreational fisheries (*M. polynyma* in Alaska), and serve as dietary items for charismatic species such as bearded seals (*Erignathus barbatus*) and walrus (*Odobenus rosmarus divergens).* Ongoing studies, employing both sophisticated adult growth and larval dispersal models, of the response of *Spisula solidissima* to climate change in the Middle Atlantic Bight suggest that Mactids may be generally used as barometers of climate change over broader geographic footprints. *M. polynyma* is a candidate species for shallow Arctic marine systems, having a pan-Arctic distribution from the Gulf of Maine in the Atlantic to the Bering Sea and Gulf of Alaska in the northern Pacific. The longevity of extant individuals (≤25y) provides opportunity for detailed reconstruction of the benthic environment and food regimes at the decadal level.

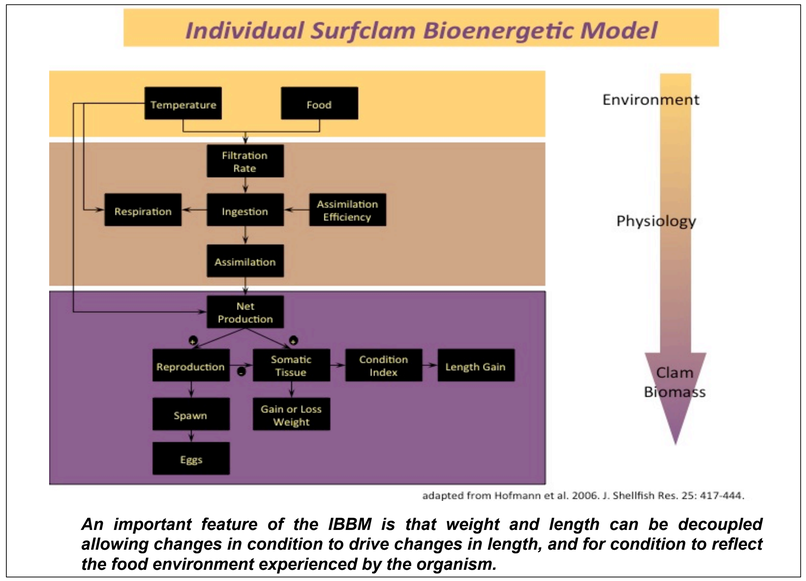
Introduction

The Arctic continental shelves are similar to those of northwest Europe, the middle Atlantic coast of North America, and much of the northwest rim of the Pacific in having wide and gentle sloping topography with the opportunity for seasonal, wind-induced vertical mixing of the water column. Surface-generated primary productivity is mixed to the benthos and available for grazing by infauna (Hofmann et al. 2008, Xu et al. 2011, Munroe et al. 2013). Shelf bathymetry does not preclude benthic production of diatom mats as additional food sources for benthic grazers and infauna (Munroe et al. 2013). Arctic benthos and associated fauna include a large component that is a continuum of boreal species from lower latitudes. We explore the application of individual based bioenergetic and growth models (IBBM's), originally developed for lower latitude species, to long-lived bivalve molluscs exposed to changing primary productivity and thermal regimes in high latitude systems.

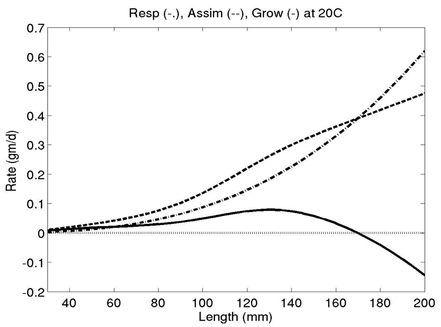




Recent impacts of climate change (increased summer temperature and thermals stress) are demonstrated by decreased growth rate in* Spisula solidissima *(Picariello, unpublished data) .

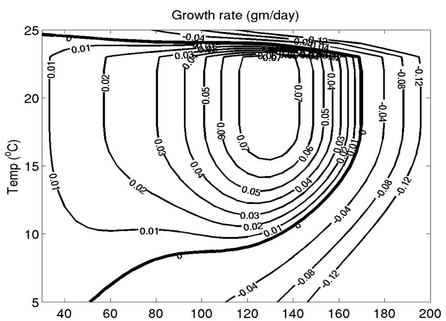


An important feature of the IBBM is that weight and length can be decoupled allowing changes in condition to drive changes in length, and for condition to reflect the food environment experienced by the organism.



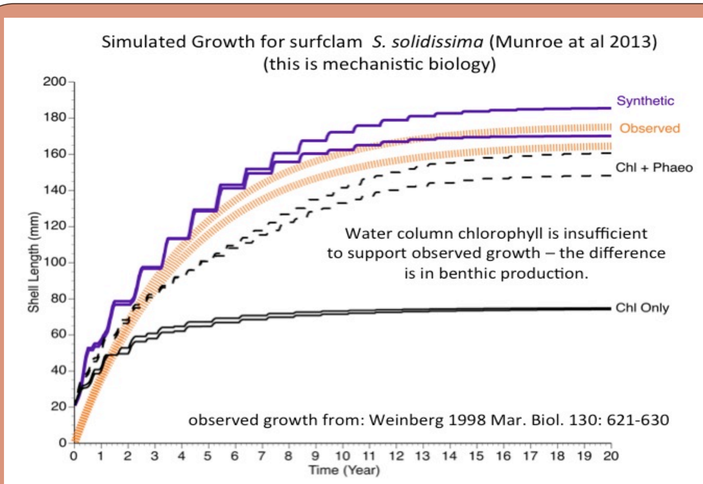
Scope for growth (SFG) for
S. solidissima
20°C & 1mg/L food.

- ***Differences between assimilated energy and respiration (dotted lines) result in gradually increasing SFG to 130 mm length.***
- ***Beyond 130mm SFG decreases to zero at about 170 mm.***
- ***Above 170 mm SFG is negative under these conditions.***
- ***Equations for assimilation and respiration are given in Munroe et al (2013).***



Scope for growth (SFG) for
S. solidissima
varying temperature
constant (1mg/L) food.

- ***Maximum SFG occurs between 15 - 23°C and 120 - 140 mm length.***
- ***The contour of zero SFG, (thick line) tracks with with increasing length as temperature increases to approximately 18°C, remains stable until 23°C, the decreases rapidly to <40mm at 25°C.***



Simulated growth for Spisula solidissima illustrates the inability of water column chlorophyll to support observed growth and the importance of benthic primary production. Both are subject to change with long term climate change.

CONCLUSIONS

Individual based bioenergetic models provide tools to elucidate those environmental parameters regulating bivalve growth in response to primary production and food availability over broad temporal and spatial scales.

LITERATURE

Ambrose WG, Carroll ML, Greenacre M, Thorrold SR, McMahon KW. 2006. Variation in *Serripes groenlandicus* (Bivalvia) growth in a Norwegian high-Arctic fjord: evidence for local- and large- scale climatic forcing. Global Change Biology, 12: 1595–1607.

Hofmann E, Druon JN, Fennel K, Friedrichs M, Haidvogel D, Lee C, Mannino A, McClain C, Najjar R, O'Reilly J, Pollard D, Previdi M, Seitzinger S, Siewert J, Signarini S, Wilkin J. 2008. Eastern US continental shelf carbon budget integrating models, data assimilation, and analysis. Oceanography 21: 86-104

Hofmann EE, Klink JM, Krauter JN, Powell EN, Grizzle R, Buckner S, Bricelj VM. 2006. Population dynamics model of the hard clam, *Mercenaria mercenaria*: development of the age- and length-frequency structure of the population. Journal Shellfish Research 25: 417–444.

Mann, R., Munroe DM, Powell EN, Hofmann EE, Klinck JM. 2013. Bivalve molluscs: barometers of climate change in Arctic marine systems. In Responses of Arctic Marine Ecosystems to Climate Change. Alaska Sea Grant.

Munroe DM, Powell EN, Mann R, Klinck JM, Hofmann EE. 2013. Underestimation of primary productivity on continental shelves: evidence from maximum size of extant surfclam (*Spisula solidissima*) populations. Fisheries Oceanography. doi:10.1111/fog.12016

Xu Y, Chant R, Gong DL, Castelao R, Glenn S, Schofield O. 2011. Seasonal variability of chlorophyll a in the Mid-Atlantic Bight. Continental Shelf Research 31: 1640-1650.

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