Using a sclerochronological approach to determine a climate-growth relationship for waved whelk in the U.S. Mid-Atlantic

Sarah Borsetti[1], Daphne Munroe[1], Philip Hollyman[2]

[1]Haskin Shellfish Research Laboratory, Rutgers University, US

[2]British Antarctic Survey, Cambridge, UK

BACKGROUND

- Recent expansion of the unmanaged waved whelk (*Buccinum undatum*) fishery on the Mid-Atlantic Bight (MAB) region of the US has prompted investigation into local life-history parameters of this species.
- Due to a combination of factors (slow growth rate, relatively sedentary, and direct development) this species is vulnerable to over-exploitation
- Understanding life-history traits such as growth and longevity are fundamental in understanding population dynamics and for age-structure population models
- This study establishes the age-length and climate-growth relationship of waved whelk in the New Jersey region.

METHODS

A random subset of whelk, representative of all observed lengths, was collected using a scallop dredge (Fig. 1).

Statoliths, small (~200-300 µm) calcareous structures within the nervous system of a whelk were dissected and photographed. Validated annual growth rings were counted and measured in an image analysis software and used to estimate age (Fig. 2a).

Two candidate models including the *von Bertalanffy (VBGM)* (Fig. 3) and the *Gompertz* growth models were applied to the length-at-age data to determine which was a better fit for both sexes combine and separate. Best fit growth model was compared between this and other whelk populations (Fig. 4)

Using the statolith growth increments (Fig. 2b) a biochronology was created and used in combination with mixed-effects models (Table 1) to examine how past climate variation (Fig. 5) has affected whelk growth (Fig.6). This analysis can assist in forecasting how future warming could affect this population.

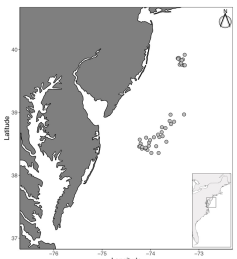

Fig. 1. Map of the MAB region, showing location of the 45 sites sampled from 2016 to 2019. Locations of each dredge sampling station shown with grey circles.

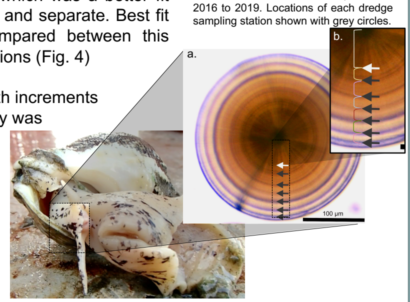

Fig. 2. a. A photomicrograph of a statolith of a 6-year-old waved whelk. Annual growth rings are marked with black arrows and the hatching ring with a white arrow. Diameters of each rings were measured. **b.** Increment distance between each annual ring was measured. Growth year of each ring was assigned by back-calculating from date of capture.

RESULTS

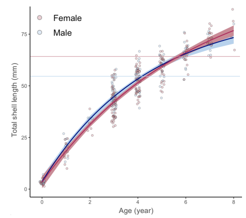

Fig. 3. The VBGF had the lowest AICc, R^2, and MSRe values when compared to the Gompertz growth model which suggests it provides a better fit. VBGM length-at-age curves for males (blue) and females (red) and associated 95% confidence intervals. Size at first maturity for males (blue) and females (red) from the region have been overlaid.

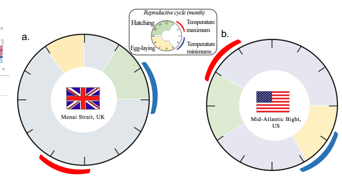

Fig. 4. A possible explanation of the variation in performance of the growth model between the US and UK could be linked to differences in life-history strategies due to local environments. Clocks show the typical reproductive period by month for whelk in the US and UK. Each hour represents the associated month. Months highlighted – Yellow: egg-laying periods; Green: hatching periods. Minimum and maximum temperature time periods (blue and red). **a.** US: eggs deposited in cold water and hatch into warming waters, encouraging rapid early growth. Juvenile whelk are likely not subjected to cooling temperatures, which may slow growth, for approximately 6 months. This could explain why the VBGF (which typically is used to illustrate rapid initial growth) was a better fit **b.** UK: eggs deposited in cooling water and hatch into cold water with annual temperature minimums after hatching, which could slow early growth. This shorten window of warm bottom water could depress early growth and explain why the Gompertz growth curve (which typically is used for species that exhibit slow initial growth) was a better fit.

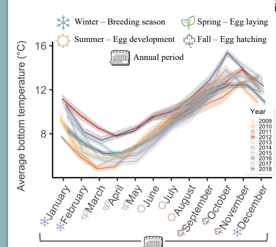

Fig. 5. 10-year times series of average daily bottom temperature with 95% confidence intervals obtained from DOPPIO ROMS for model grids coincident with the sample sites. Because the annual temperature cycle is so variable these temperatures were also grouped by season to examine their impacts on growth (symbols)

Parameter	Description
Fixed effects	
Age	Age (year) when statolith increment was formed
Sex	Male or female
Age at Capture (ACC)	Final age (year) at time of capture. Measure of potential selectivity on growth
Temperature	Annual & seasonal average bottom temperature (°C)
Random effects	
individual whelk ID	Unique identifier for each whelk
Year	Year in which increment was formed. Quantifies inter-annual growth variability

Annual growth (increment), age, and AAC were naturally log-transformed to satisfy model assumptions, and all predictor variables were mean-centered to facilitate model convergence and interpretation of interaction and polynomial terms

Table 1. A series of mixed-effects models were developed to examine internal and external forces on whelk growth. The optimal model include– Random effects structure: *Age | individual whelk + Age | Year* ; fixed effects: *Age + Age at Capture*

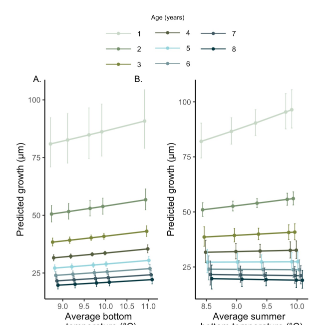

Fig. 6. The optimal model was used to determine how growth varies due to changes in bottom temperature. Using the optimal model, a series of models were fit with different combinations of annual and seasonal bottom temperatures. Predicted differences in statolith growth by age (year) of waved whelk and associated 95% confidence intervals under different bottom temperatures. **a.** Average annual bottom temperature was the best explanatory bottom temperature covariate. Whelk growth increased across all ages with increasing temperature **b.** Certain seasonal bottom temperatures added to the optimal model they were also supported. The inclusion of the interaction between age and summer bottom temperatures resulted in age-dependent growth response.

DISCUSSION

- Growth curves for waved whelk from US show that maturity is reached between 4-6 years
- Growth curves of US population differs from other assessed whelk populations likely due to differences in life-history strategies between populations
- Using statolith chronologies and mixed-effects models' growth was found to fluctuates through time with higher annual temperatures increasing growth
- It appears that whelk in this region display plasticity in their ability to cope with a range of temperatures
- Increases in seasonal temperatures had age-dependent impacts on growth
- Waved whelk are a cold-water species, and the warming bottom waters of the Mid-Atlantic could have negative impacts on growth if temperatures warm sufficiently during certain seasons (above animals' thermal tolerance)
- This data from an unfished population can serve as a model to understand how other heavily exploited populations may be impacted by fishing and climate.

For more information on this study: Estuarine, Coastal and Shelf Science 252 (2021) 107255

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: http://www.elsevier.com/locate/ecss

Using a sclerochronological approach to determine a climate-growth relationship for waved whelk, *Buccinum undatum*, in the U.S. Mid-Atlantic

S. Borsetti[a,*], P.R. Hollyman[b], D. Munroe[a]

[a] Haskin Shellfish Research Laboratory, Rutgers University, 6959 Miller Ave., Port Norris, NJ, 08349, United States
[b] British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, United Kingdom

ACKNOWLEDGMENTS

We would like to thank the captains and crews of both the F/V *Elise G.* and the F/V *Nancy Elizabeth* for assisting with sample collection. This work would not have been possible without the oceanography model output generously provided by J. Wilkin. We are also grateful to the researchers who assisted with sample collection: J.P. Shinn, J.Gius, I. Burt, M. Acquafredda, and D. Bushek. This work was funded by NOAA Saltonstall-Kennedy Grant Program.

@sarahborsetti

sarahbor@rutgers.edu

Haskin Shellfish Research Laboratory, Rutgers University