

# Diurnal variations in the corrosiveness and acidification of porewater and its effects on population dynamics of marine bivalves



## dynamics of marine bivalves

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### Introduction

The ability of marine bivalves to precipitate a shell may become increasingly compromised as ocean acidification increases throughout the century as predicted. In coastal ecosystems where bivalves are ubiquitous, the surface sediment provides habitat for certain species of newly settled pediveliger larvae. Anthropogenic inputs such as atmospheric CO<sub>2</sub> and eutrophication from river runoff have the potential to work synergistically with biotic respiration and hydrodynamics to decrease the pH and increase the corrosiveness of this upper sediment layer. Due to these various processes the composition of the sediment chemistry is highly variable and can exhibit continuous states of lowered pH which can exacerbate undersaturation of CaCO<sub>3</sub>.

The hard shell clam *Mercenaria mercenaria* is one such bivalve that begins its juvenile stage in the surface layer sediments of coastal systems. The ability for this bivalve to survive and recruit to the adult population is essential for the vitality of the population. During this critical life stage, the bivalve must overcome the extreme environmental pressure of dissolution due to undersaturation of CaCO<sub>3</sub>. The development of vital organs and growth are essential to survival in the early life stages.

### Objectives

The presented model aims to investigate by what degree the saturation state of CaCO<sub>3</sub> ( $\Omega_{\text{aragonite}}$ ) influences the population dynamics of marine bivalves. Model simulations will represent the diurnal variability in the saturation state of CaCO<sub>3</sub>. Variations in this parameter will enable the assessment of population dynamics for settling pediveligers and juveniles at specific developmental sizes: ~0.2mm (Pediveliger), ~0.2mm+ (Dissoconch I) and ~1.0mm+ (Dissoconch II). It has been determined that larger juveniles have decreased mortality in undersaturated conditions (Green et al. 2009), which corroborates a targeted "escape size" of 2.0mm to be the final stage in the model. The 2.0mm size correlates with adequate development of vital organs that allows juveniles to overcome dissolution to a degree. Therefore, identification of hourly mortality rates will be an essential component to understanding trends in response. Additionally, specific growth and survival rates of each size class will help determine which stages are more susceptible to undersaturation, and at what specific time during development will these pressures be alleviated by successful development and growth. Proper interpretation of vital rate responses will allow for an accurate assessment of future adult populations.

- 1) Assess stage class with highest sensitivity to changes in vital rates
- 2) Evaluate hourly mortality rates given varying diurnal cycles in saturation state
- 3) Identify specific time in days that population reaches stable age distribution and survivors converge to ultimate size class
- 4) Compare population growth rate of large diurnal shift or small shift at constant undersaturation

### References

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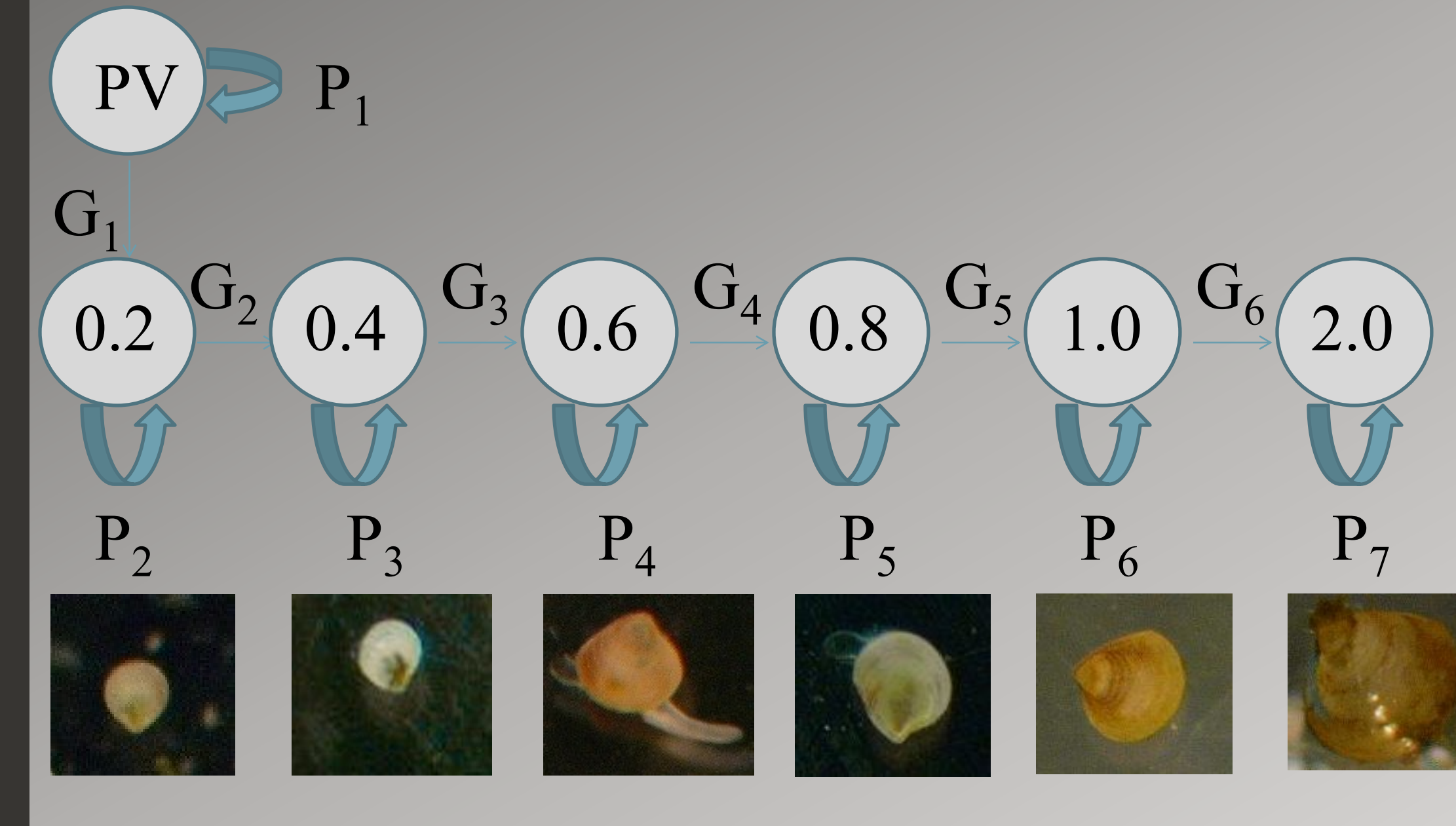
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### Conceptual Model & Stage Based Matrix Model



$$\begin{bmatrix} P_1 & 0 & 0 & 0 & 0 & 0 & 0 \\ G_1 & P_2 & 0 & 0 & 0 & 0 & 0 \\ 0 & G_2 & P_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & G_3 & P_4 & 0 & 0 & 0 \\ 0 & 0 & 0 & G_4 & P_5 & 0 & 0 \\ 0 & 0 & 0 & 0 & G_5 & P_6 & 0 \\ 0 & 0 & 0 & 0 & 0 & G_6 & P_7 \end{bmatrix}$$

Figure 1. Probability matrix for population of seven stage sizes representing growth to next stage. Stages categorized by size (shell height) of individual. Time step is hourly running for a total of 1440 hours or 60 days.

### Results

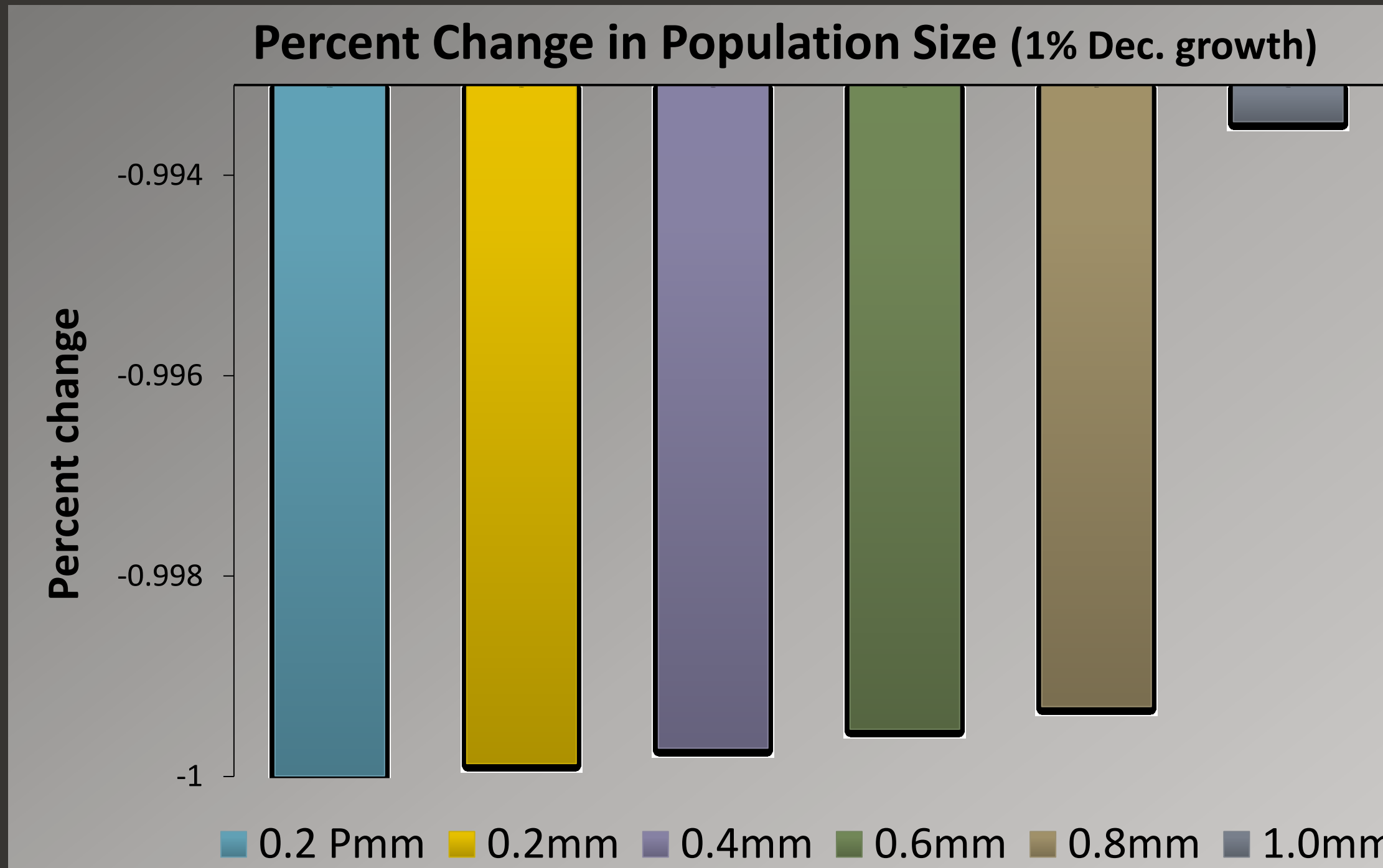


Figure 2. An elasticity analysis was run for all sizes classes that have the potential to grow to the next stage. The proportional change in population size is shown with a decrease in growth rate by 1%. The 0.2mm pediveliger growth stage contributes most to the overall population size. Analysis was run at a constant saturation state.

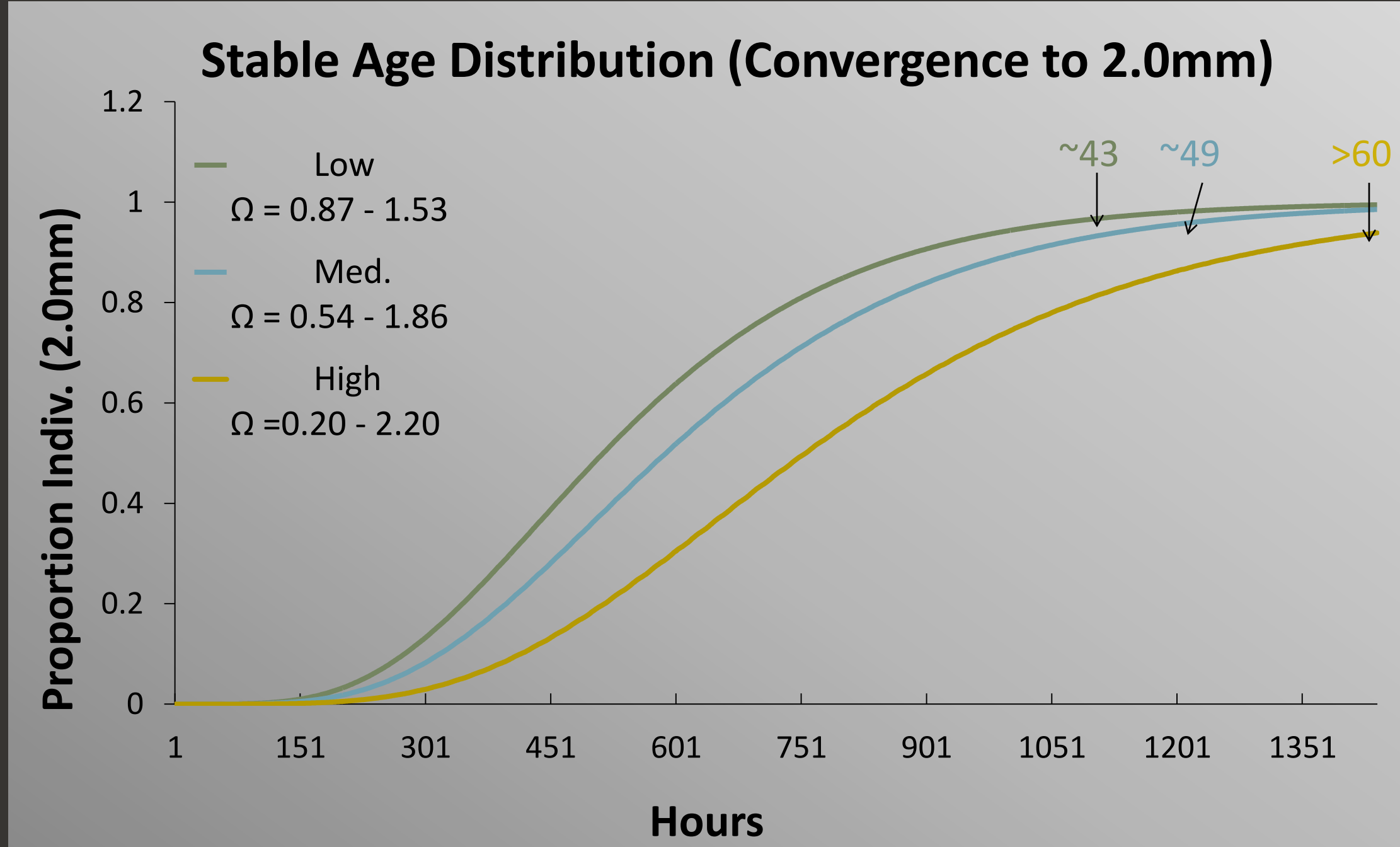


Figure 4. The convergence to a 2.0mm size for the entire population is given for high, medium and low diurnal variations. ~43, ~49 and >60 days where the durations it took for 95% of the population to reach the final size stage.

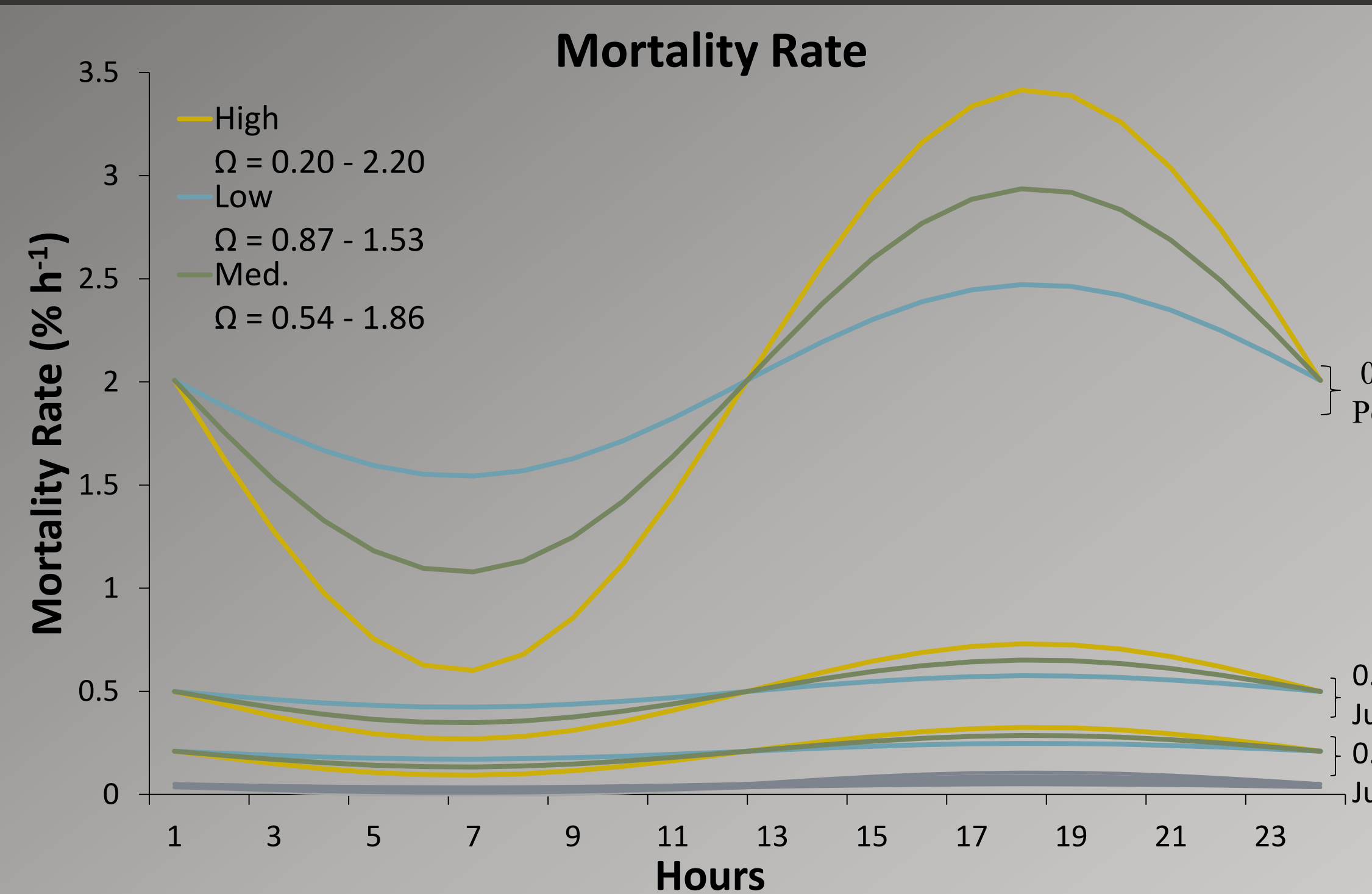


Figure 3. Hourly mortality rate over a 24hour period representing each simulation. Colored mortality rates are for class sizes 0.2mm Peds, 0.2mm and 0.4mm Juvs. The larger sizes (0.6mm -1.0mm) are represented in gray as the mortality rate significantly decreases with larger class sizes.

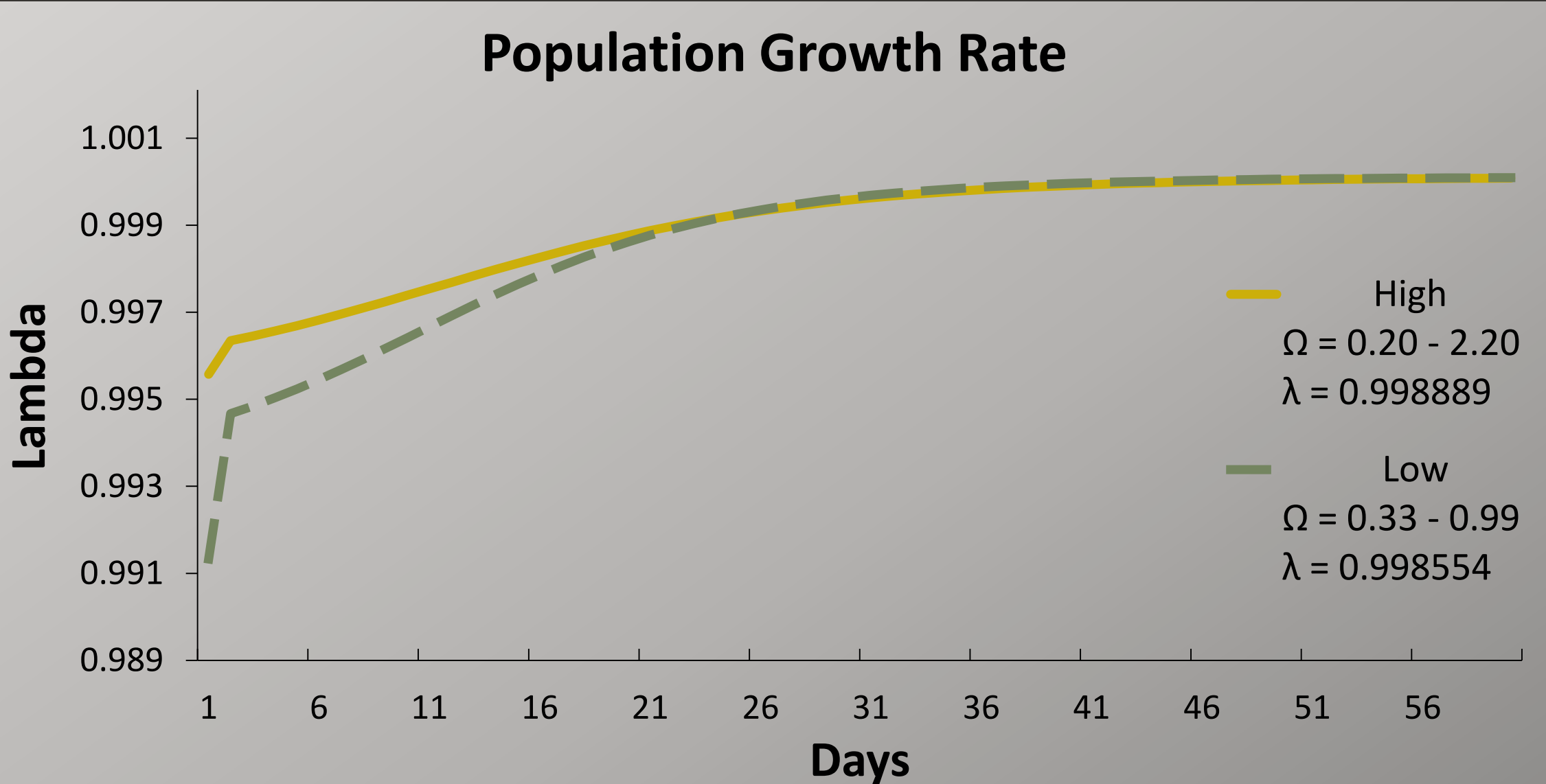


Figure 5. The population growth rate of a high diurnal shift ( $\Omega = 0.20 - 2.20$ ) resulted in an Avg.  $\lambda$  of 0.998889 (p-value < 0.001). A low diurnal shift with constant undersaturated conditions ( $\Omega = 0.33 - 0.99$ ) resulted in an Avg.  $\lambda$  of 0.998554 (p-value < 0.001). It should be noted growth rates of both simulations did not incorporate a fertility component, and had a different mean (vertical shift) when being run.

### Methods

Representative  $\Omega_{\text{aragonite}}$  values will be obtained from published studies to input a broad range of conditions that juveniles and settling pediveligers may be exposed to. A stage based population model was constructed to assess hourly population dynamics for this specific life stage of hard clams; which has dependence on the sediment porewater saturation state. A diurnal cycle in saturation state was implemented into the model which affects probabilities of growth and survival for each time step.

- Stage based model with seven stages from settling pediveligers to dissoconch II. Sizes of individuals are classified according to shell-height. The probability of growing to the next size ( $G_x$ ) or remaining static within that stage ( $P_x$ ), are vital rates that have been calculated from previous lab and field studies (fig.1). All  $G_x$  and  $P_x$  values incorporate saturation state ( $w$ ) to the probability values.
- Varying diurnal shifts of saturation state resulted with a mean vertical shift, and values that ranged from: high (0.20 – 2.20), medium (0.54 – 1.86) and low (0.87 -1.53). The values represent amplitudes of 0.33, 0.66 and 1.0 within a diurnal cycle.

Equation 1.  $w = (\text{amp}) * \sin(b / (1.165 * \pi)) + v$

Variables 1, 2: vector (b) = [0-23] vertical shift (v) = 1.2

### Conclusions

- 1) The larval pediveliger stage is most sensitive to changes in vital rates such as growth and survival. A change in growth rates for pediveligers will reflect the greatest change in population size.
- 2) Diurnal shifts in saturation state affect mortality rates and total abundance disproportionately across linear amplitude changes
- 3) Larger diurnal shifts result in higher variability in individual growth rates, mortality and total population growth. Larger shifts result in a decreased population size when compared to medium and low shifts.
- 4) Larger diurnal shifts with periods of supersaturation and undersaturation may be more favorable in regards to fast population growth when compared to low shifts under constant undersaturation.

### Constraints and future work

- Population dynamics is only determined by dissolution pressures, and the need for additional influences such as predation will result in a more accurate model.
- A fertility component is lacking which will influence a true stable age distribution for the model. Fertility will be parameterized as propagule rain which will allow for a continuous dispersal over a given time into the population; rather than a single pulse of individuals at the initial time start.
- An independent carbonate chemistry model will be incorporated to run parallel with the population model. The focus will be to manipulate the individual variables that drive saturation state, such as organic matter content, overlying water conditions (pCO<sub>2</sub>) and sediment composition of CaCO<sub>3</sub>.

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INCREASING DIVERSITY IN EARTH SCIENCES

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