Vision and Initial Population in Sugarscape I & II

Aim

In Sugarscape I and Sugarscape II, turtles move to locations with maximum sugar resources within their perception, and their population stabilises over time. These simulations represent competition for resources in societies or ecologies. By varying initial population and turtle vision, I explore dynamics arising from population size and information access.

I am interested in how the models behave at stable final population levels, which reflect the carrying capacity of initial conditions. At carrying capacity, I investigate average vision and average metabolism in the population, which reveal selective pressures on each phenotype. Finally, I look at the average displacement of turtles after a time limit to compare the socioeconomic mobility in the types of society each model represents.

Methods

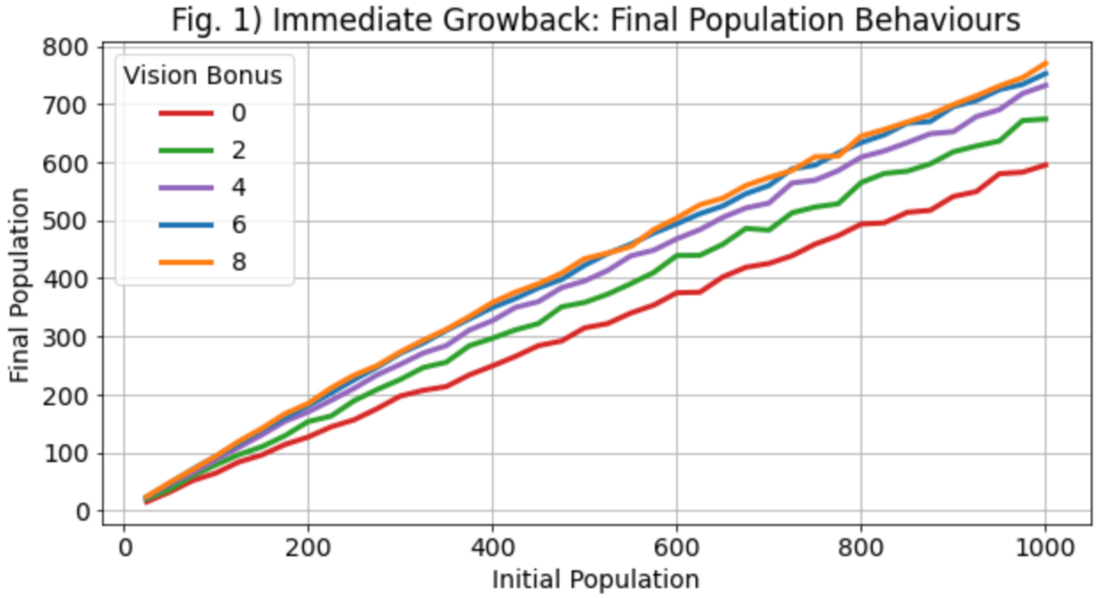
The experiments for Sugarscape I and Sugarscape II are similar. I vary two parameters for both models in BehaviorScape. For the Initial Population parameter, I examine nearly the full default range of 25 to 1000 in increments of 25, to generate a sample size of 40. I manipulate the turtle Vision parameter by adding a global slider variable to the minimum and maximum values. With highest initial populations for both Sugarscape I and Sugarscape II, raising Vision Bonus to eight or higher results in most turtles aggregating towards the centre, so for the experiment I use Vision Bonus values from zero to eight in increments of 2. I repeated each combination of parameters three times.

I created four reporters to measure model behaviours. For time limits, I ran Sugarscape I until 100 ticks and Sugarscape II for 1000 ticks for when all measures of model behaviour stabilise. Survival Rate is the ratio of Final and Initial Populations. Final Population represents the carrying capacity of the model at the set time limit. Average Vision and Average Metabolism are the mean values of these traits for surviving turtles at the set time limit. To create the Mean Displacement reporter, I added two new turtles-own variables, start-patch and displacement and set them in the code.

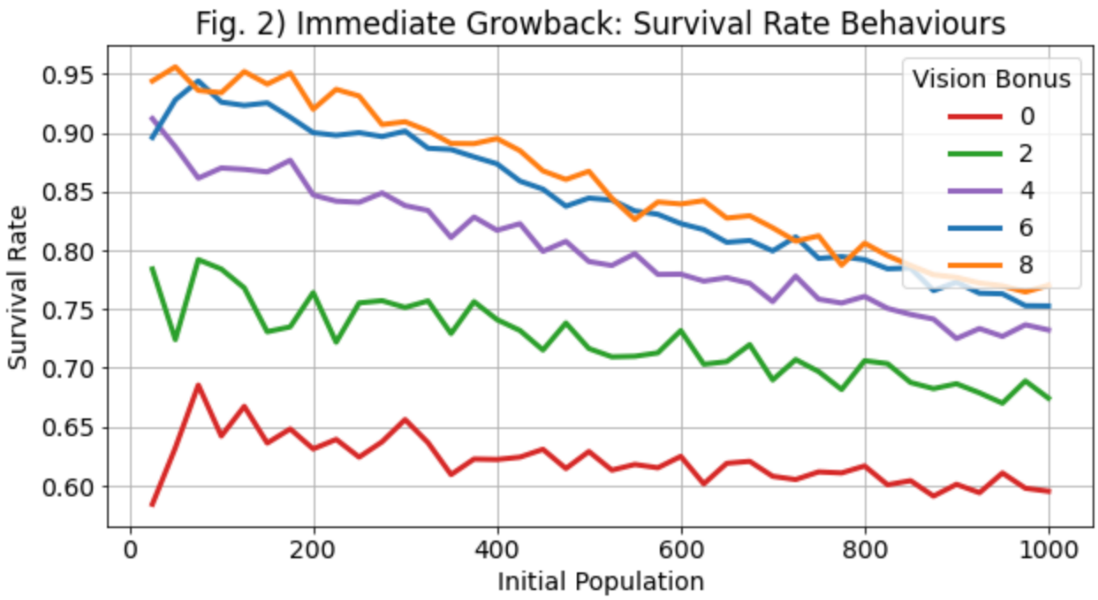
Results

Sugarscape I: Immediate Growback

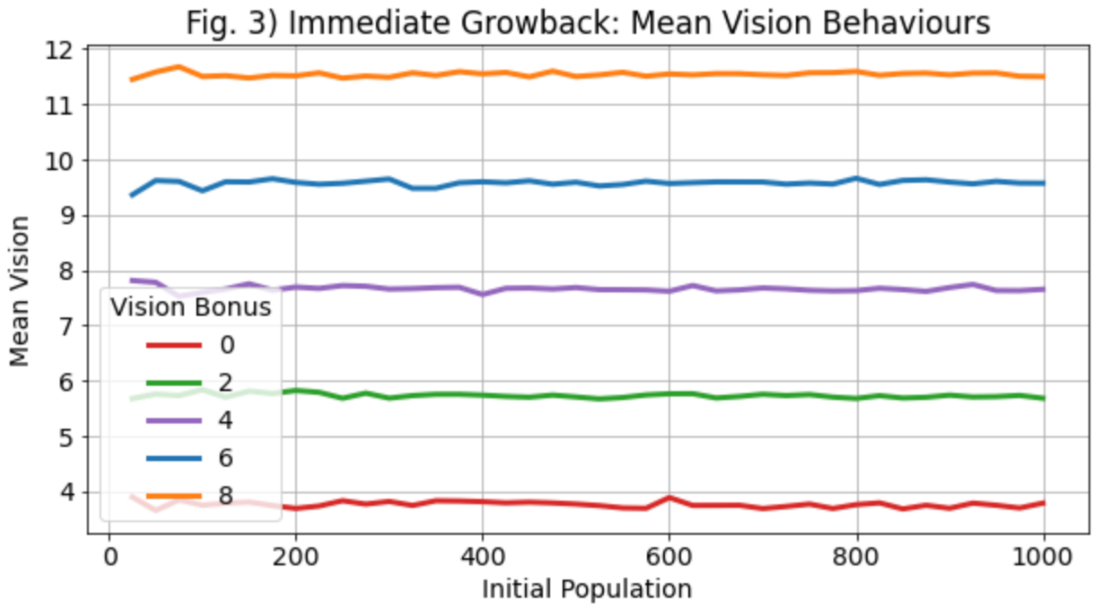
Final Population is directly proportional to Initial Population (Fig 1). Final population changes at a slower rate than Initial Population, since some turtles die of starvation within the time limit. Increased Vision aids in the survival of turtles, with decreasing impact per unit of Vision increase, as a slope of 1 is the limitation where no turtles die.



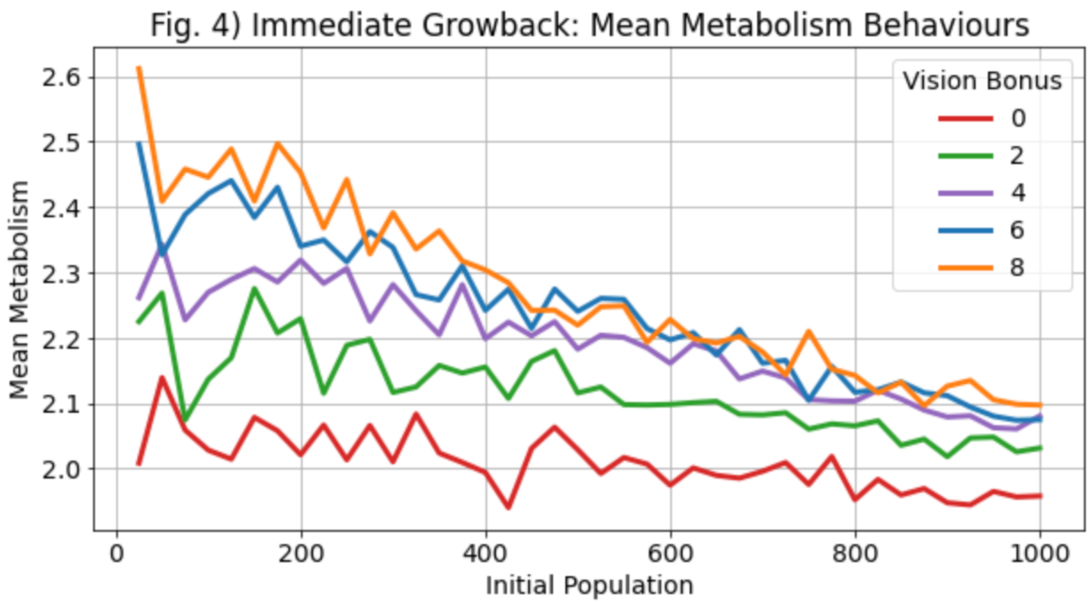
The rate of survival decreases as Initial Population increases (Fig. 2). Higher Vision boosts survival rate with decreasing impact per unit of Vision increase, as the limit is 100% survival rate. The rate of survival decreases faster with greater Vision.



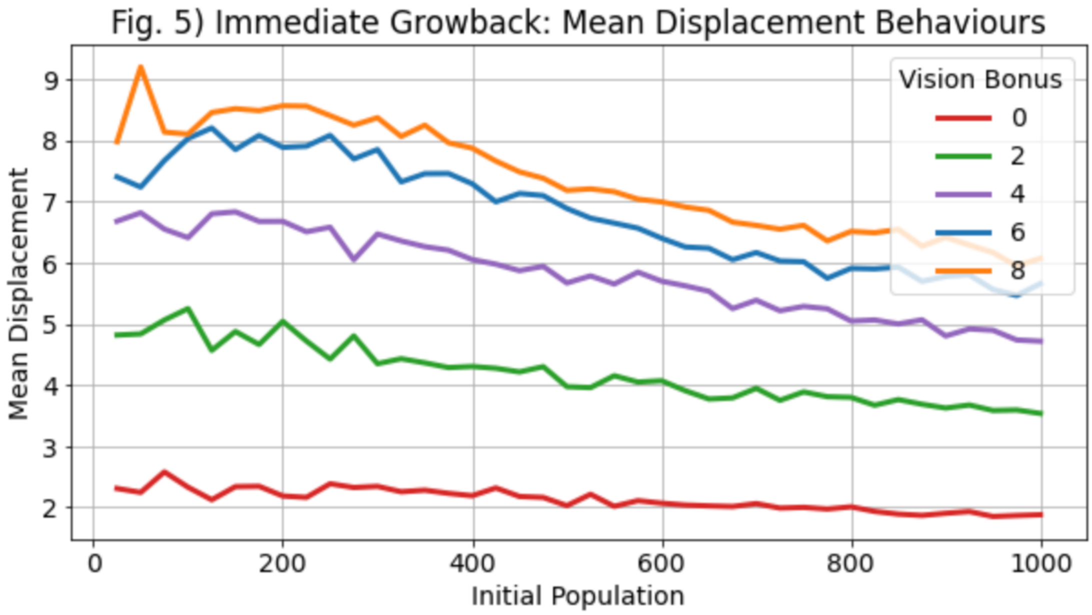
The average Vision of turtles at environmental carrying capacity is the same for any Initial Population size (Fig. 3).



The average Metabolism of turtles at environmental carrying capacity decreases with larger Initial Populations (Fig. 4). Increased Vision links yields higher Mean Metabolism in the population, but less substantially so at larger Initial Populations. In model conditions with greater Vision, Mean Metabolism decreases faster for larger Initial Population sizes.

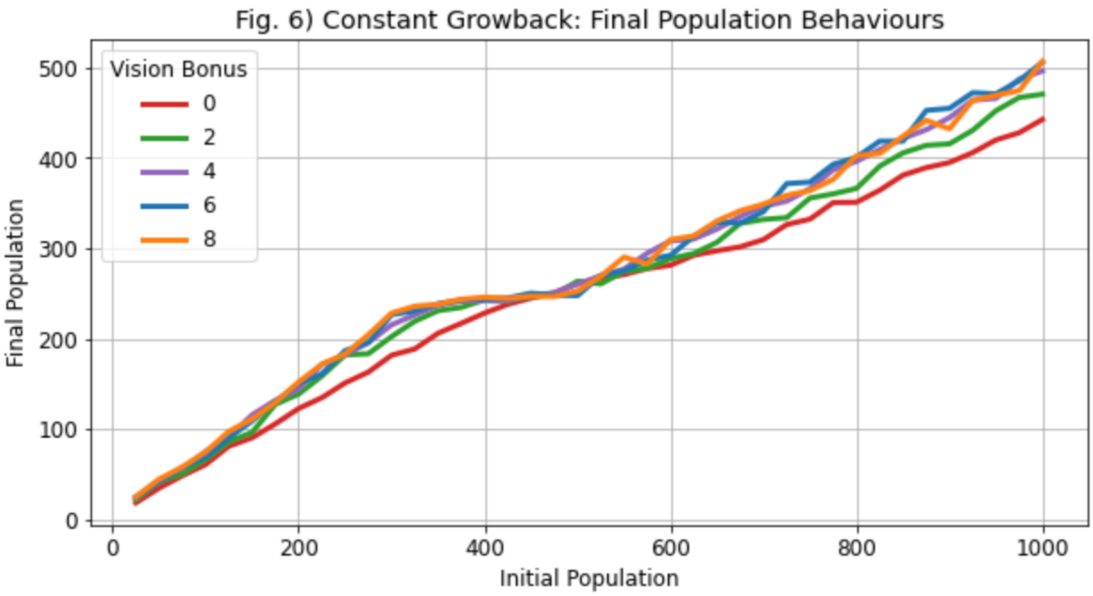


Mean Displacement decreases with larger Initial Populations (Fig. 5). Greater Vision increases economic mobility.



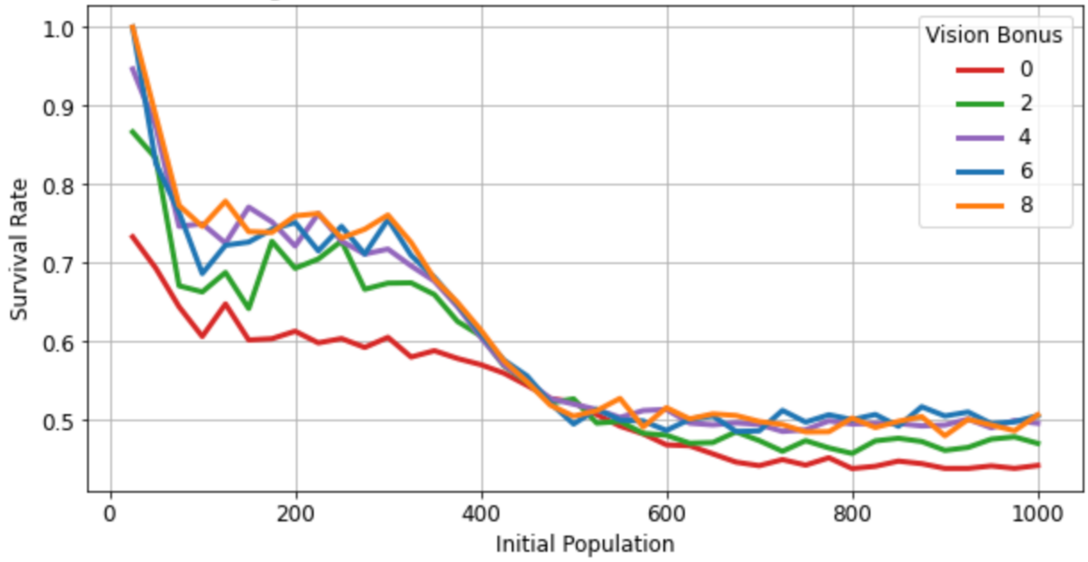
Sugarscape II: Constant Growback

Final Population increases as Initial Population increases but more slowly for Initial Populations of 300 to 500 turtles (Fig. 6). With stronger Vision, Final Population increases faster outside the Initial Population interval of 300 to 500 turtles, but slower inside the interval.



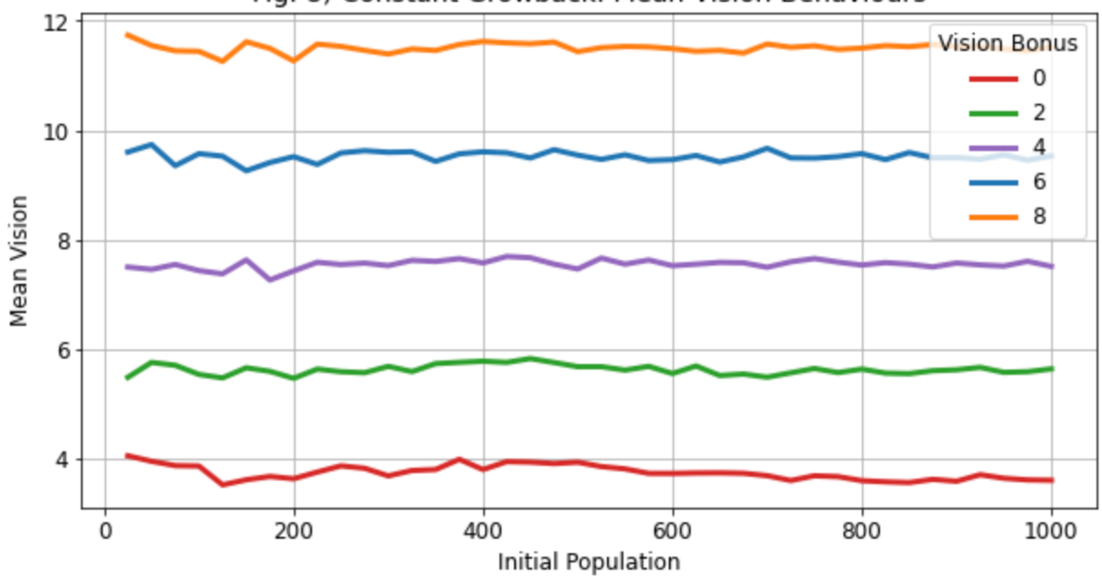
Survival rates decrease rapidly over Initial Populations less than 100 turtles and for Initial Populations between 300 and 500 turtles (Fig. 7). It remains constant at other intervals. Vision increases Survival Rate during the constant periods.

Fig. 7) Constant Growback: Survival Rate Behaviours

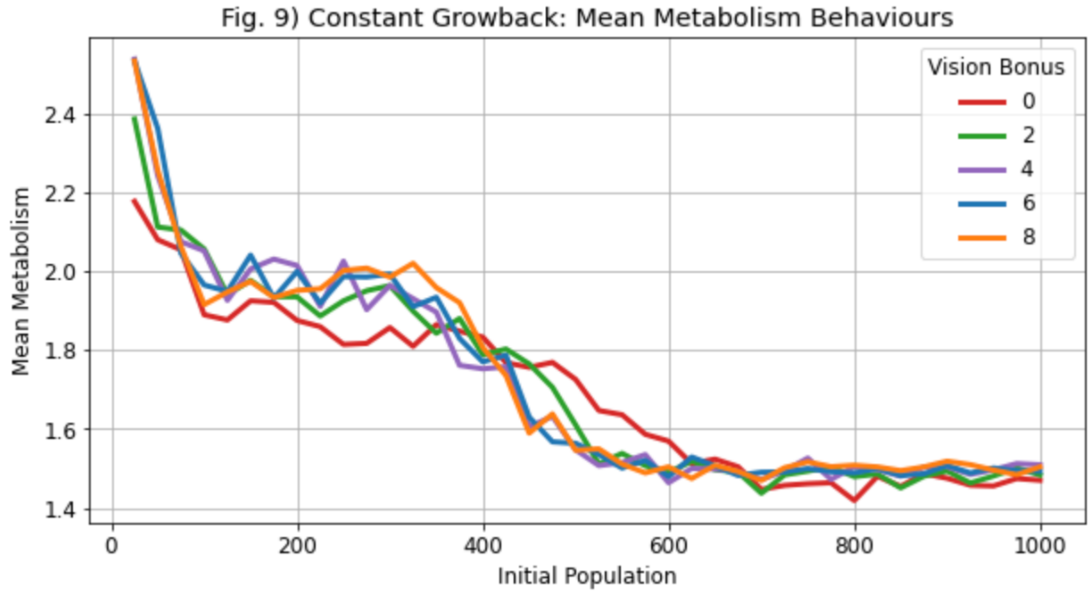


The average Vision of turtles at environmental carrying capacity is the same for any Initial Population size (Fig. 8).

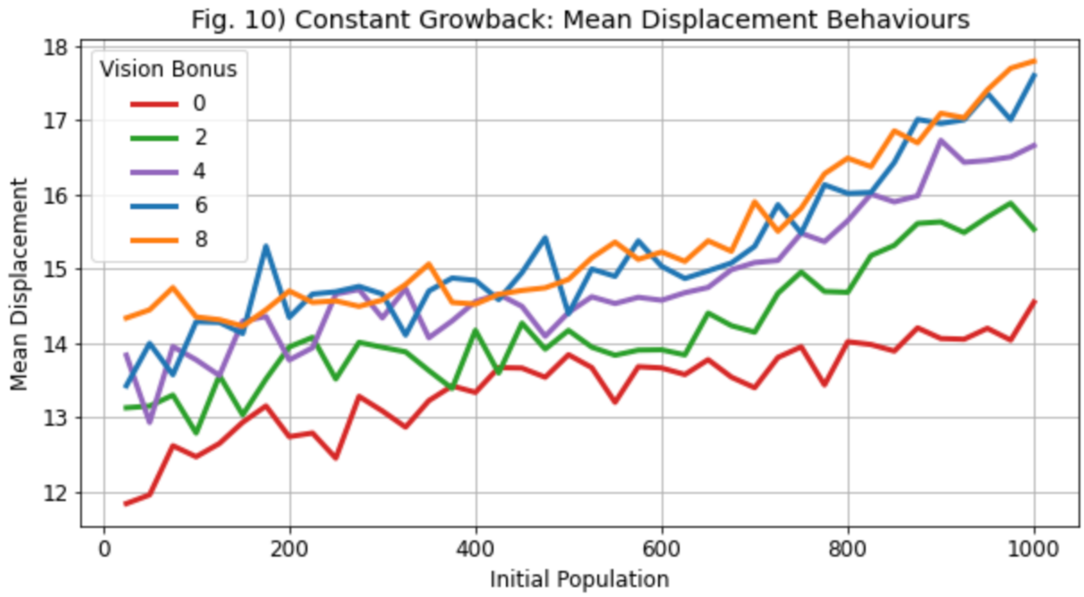
Fig. 8) Constant Growback: Mean Vision Behaviours



Average metabolism decreases rapidly over Initial Populations less than 100 turtles and for Initial Populations between 300 and 500 turtles (Fig. 9). It remains constant at other intervals.



Mean Displacement increases with Initial Population (Fig. 10). Greater Vision lends to greater Mean Displacement.



Discussion

Varying the Initial Populations of these models reveals differential scaling behaviours; linearity under Immediate Growback and phases under Constant Growback model. Phases in the Constant Growback model arises from an interval of particularly rapid survival rate decrease between Initial Populations 300 and 500. The 300-turtles threshold for Initial Population may be where competition for sugar-rich patches intensifies such that high metabolism turtles, which require more sugar-per-tick-per-patch to survive, die more rapidly. This loss of high metabolism turtles would explain the steeper decline in Mean Metabolism during this interval and account for much of the survival rate decrease. Mean Vision remains constant regardless of Initial Population size, suggesting that Vision is not under similar selection pressure.

This rapid loss of high metabolism turtles slows around Initial Population 500, where Mean Metabolism and Survival Rate curves flatten. After this threshold, most high metabolism turtles have died and crowding density may have equalised selection pressures for high and low metabolism turtles, so metabolism selection pressure steadies. The Immediate Growback model lacks such a phase of increasing selection pressure perhaps because turtles stop changing patches before such competition interaction effects accumulate.

Increased Vision overall increases survival rate. It also leads to higher Mean Displacement, which represents economic mobility. In other words, in runs with higher Vision parameters, more turtles approach the sugar-wealthy hilltop. Comparing the two models, economic mobility is more difficult with larger Initial Populations under Immediate Growback but easier under Constant Growback. Since turtle sugar consumption drives sugar level dynamics, larger populations create more opportunities for economic mobility even as competition increases.

Conclusion

Under various conditions of initial population size and information access, the Sugarscape models, Immediate Growback and Constant Growback, demonstrate the allometry of static and dynamic societies. On the one hand, they share some similar behaviours. In terms of carrying capacities, higher initial populations have lower survival rates. Under high population pressures, lower metabolism turtles outcompete higher metabolism turtles. Greater vision or information access raises survival rate and social mobility.

On the other hand, the two models differ strongly in competition dynamics and economic mobility. In the Immediate Growback model, turtles aggregate along boundaries where sugar levels change, quickly finding and remaining on their local richest sugar patch. In Constant Growback, hilltop turtles continuously change positions. This results in greater economic mobility for the dynamic Constant Growback model, as competitors create opportunities for each other through consumption. In fact, economic mobility increases with greater populations. Another emergent effect is higher selection pressure against high metabolism turtles under certain population sizes: a sweet spot arising from competition interactions.

Appendix

Additional Code in both Sugarscape models:

Addition in turtles-own:
start-patch ;; the patch where turtles start at tick = 0
displacement ;; the distance from which turtles start and from where they end up at each tick

Additions in turtle-setup:
set start-patch patch-here
set vision random-in-range (1 + v) (6 + v)

Addition in go procedure, ask turtles context:
set displacement distance start-patch

Reporters in both Sugarscape models:

```
to-report Final_Population
  report count turtles
end

to-report Survival_Rate
  report (count turtles / initial-population)
end

to-report Mean_Vision
  report mean [vision] of turtles
end

to-report Mean_Metabolism
  report mean [metabolism] of turtles
end

to-report Mean_Displacement
  report mean [displacement] of turtles
end
```