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Adult Survival in Partridge–Barton model of Biological Aging

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A Monte Carlo simulation of the Partridge–Barton model is presented which in a limiting case gives extreme senescence in the sense of immediate death after sexual maturity.

KEY WORDS: Biological aging; mutations; simulations.

The problem of aging or senescence is somewhat perplexing since there is weak selection pressure if, as is common, reproduction occurs relatively early in life. Genes which express themselves later in life, irrespective of the effects on the organism, do not participate in the Darwinian scrutiny of selection. Deleterious mutations accumulate during the life of the organism and these diminish the life expectancy of the individual. The life expectancy of the individual is a property of the species. Partridge and Barton[1] (PB) proposed a model based on antagonistic pleiotropy in which the survival probability of the juvenile (J) and adult (A) are coupled in a manner where a beneficial mutation for the juvenile, increase in J, is damaging for the adult and vice versa:

$$J + A^x = 1$$

where J and A appear in the Euler–Lotka equation[1,2]:

$$mJe^{(t-1)r} + mAJe^{(t-2)r} = e^{tr}$$

m is the number of babies per age level, which in this work is set to 1 or very close to 1 to ensure a stable or slowly increasing population, t is the

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time, and $\exp(r)$ is the growth factor of the population. PB solved the mean-field version of this model and reported optimal values (maximal r) for J and A of 0.935 and 0.505, respectively, for $x = 4$.

Stauffer and Jan[3] looked at the stochastic version of the model with random somatic mutations, random variations in J, but A constrained by the above equation for a fixed x (set equal to 4). The results found were in general agreement with the mean-field conclusions, although PB reported a sharp transition in the population of adults to zero with increased mutation rate. This was shown in ref. 3 to be a property of the variables used in presenting the data, and not an intrinsic property of the model. In this note we extend the analysis of ref. 3 to observe the effect of varying x on J and A. I set the mutation rate (u) of the juvenile to 1 and the relative ratio of the adult mutation to the juvenile mutation (v) to 2. Ray[4] gives a more detailed description of the Monte Carlo implementation of the PB model and Vollmar and Dasgupta[5] investigate alternatives involving both advantageous and deleterious mutations without the antagonistic pleiotropy constraint of Eq. (1). Lynch and Gabriel[6] simulated the effects of deleterious mutations on a small population and observed its demise via "mutational meltdown."

Figure 1 shows the variation of J and A as a function of x. The value of J is slowly varying from 0.92 at $x = 4$ to 0.9 at $x = 1.5$ and then increases to 0.96 at $x = 0.80$. The change in A is more dramatic, varying from about

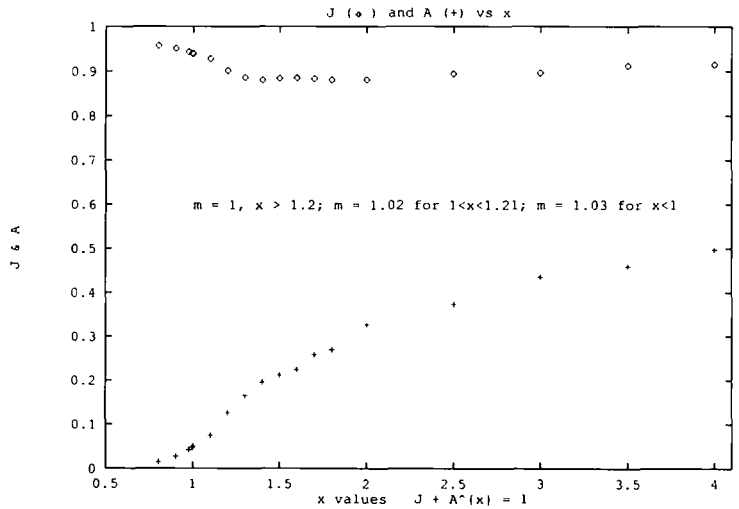

Fig. 1. Diamonds represent J, the juvenile survival probability, and plusses represent the adult survival probability as a function of x. See text for details. The adult fertility m is set equal to the juvenile fertility and its value is increased from 1 to ensure a stable population.

0.5 at $x = 4$ to 0.05 at $x = 1$. The mean-field result for $x = 1$ is $A = 0$ with log corrections.[7] The catastrophic demise of the adult population as $x \to 1$ may reflect the behavior of the Pacific Salmon and other species, where the attainment of sexual maturity is a catastrophic event.

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