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Elasticity analysis of random matrices in matrix population models

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Projection matrix models are known to provide us with a plenty of population statistics, such as population growth rate, steady size-class distribution, and sensitivity and elasticity for population growth rate. Hundreds of academic papers using the model have been published these last forty years and a database on many of their matrices is now available on the internet (COMPADRE and COMADRE), which contains the demographic data on more than a thousand species. Silvertown *et al.* (1996) published a famous paper, where they mapped elasticity vectors of survival, growth and fecundity for 84 plant species in a triangle simplex and found that they are located in a specific region. The same trend is found on the map for 1230 plant populations in the above plant database. To understand and clarify why they are located in a specific region, we constructed five types of random matrices. 4 by 4 random matrices were composed of two parts: fecundity and transition probabilities from a stage to another. The distribution of fecundities followed a Poisson distribution. The transition probabilities range from zero to one, whose row sums are less than 1. The elasticities for survival, growth and fecundity were calculated using 3000 random matrices and the elasticity vectors were plotted in the triangle map. The five types of matrices were as follows: (1) random matrices with no zero-element, (2) random matrices with no zero-element and the survival probabilities increase as individuals grow, (3) random matrices which have non-zero elements only on diagonal and sub-diagonal positions, (4) random matrices which have non-zero elements only on diagonal and sub-diagonal positions and the survival probabilities increase as individuals grow, (5) random matrices in semelparous species. The results are: (a) the distribution of the elasticity vectors moves to upper-left region of the triangle map as average of fecundity increases, (b) In the third and fourth types of random matrices, the distribution is located on a line whose slope is equal to 46 degrees. The slope can be described by a formula depending on the matrix dimension, n and ranges from 30 to 60 degrees with $n = 2$ to infinity. (c) In semelparous species, the distribution moves to the upper left along the 46-degree line. (d) There are no elasticity vectors in the bottom half of the triangle map.

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