Introduced populations in a stochastic world

Nicolas Bajeux, Frédéric grognard, Ludovic Mailleret & Vincent Calcagno

INRIA Sophia-Antipolis, BIOCORE Team.
INRA Sophia-Antipolis, M2P2 Team

Modelling the dynamics of introduced populations is a challenge of main importance in conservation and restoration biology. By assuming that introductions may occur repeatedly, we provide a model in which the population growth is represented by an Ordinary Differential Equation. Population growth is disrupted by discrete time introduction events that are stochastically distributed in propagule size and over time.

Because the considered introduction schemes involve essentially small population sizes, the model can include strong demographic Allee effects, which implies that a population is doomed to extinction when its size is below some threshold. Moreover, invasion success can be hampered by environmental stochasticity, such as the occurence of catastrophes caused by external factors, that can drastically reduce the number of individuals in the population. This is also included in the model.

Assuming constant propagule pressure, i.e. the mean number of individuals introduced by unit time is constant, we investigated introduction schemes over a trade-off ranging from frequent and small sizes introductions to rarer and larger ones. The computation of the probability to reach a target size leads to an integral equation of the Mean First Passage Time (MFPT) to reach the target. A fixed point study proved that there exists a unique solution to this equation, which can be numerically computed to identify the introduction strategy leading to the population target size in least time.

To comfort our investigation, we proceed in a numerical computation of the MFPT using Monte Carlo numerical solutions of a purely stochastic model representing the population growth with a birth-death process.

Literature reports that, in case of strong demographic Allee effects, it is preferable to favor rare and large introductions. Here we show how environmental stochasticity arising as catastrophes, coupled to stochastic fluctuations in propagule size and introduction timing, make intermediate strategies able to minimize the time to population establishment.