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CPM 135 : Statistics in Biology

Population Growth in a Random Environment: Which Stochastic Calculus?

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Abstract: Autonomous stochastic differential equation (SDE) models of population growth in a random environment apparently give different qualitative predictions on population extinction and persistence depending upon one uses Ito or Stratonovich calculus, posing some puzzling questions on which calculus should one trust. For the linear noise term considered by many models, under Stratonovich calculus and appropriate conditions, one gets extinction or existence of a stationary density according to whether the deterministic term of the SDE (interpreted as the "average" growth rate) takes a negative or a positive value at low population sizes. This behaviour is similar to the deterministic model. However, under Ito calculus, extinction occurs even for positive (small) values. In a previous paper, we have shown that the differences between the two calculi are only apparent and due to the fact that, contrary to common interpretation, the deterministic part of the SDE does not represent the same type of "average" growth rate. Under Ito calculus, it represents the arithmetic average. Under Stratonovich calculus, it represents the geometric average. Taking into account the difference between these two averages, the two calculi have completely coincidental solutions and behaviours. For both calculi, one gets extinction or existence of a stationary density according to whether the geometric average growth rate takes a negative or a positive value at low population sizes. We now extend these conclusions to different types of noise terms not necessarily linear. The deterministic term of the SDE still represents the arithmetic average growth rate under Ito calculus. However, under Stratonovich calculus, it represents different types of averages depending on the noise term; for appropriate regularity conditions, all those averages approach the geometric average at low population densities.

Key words and phrases: Population growth, stochastic differential equations, Ito calculus, Stratonovich calculus, random environments.

Animal Growth in Random Environments: Estimation with Several Paths

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Abstract: This paper will consider stochastic models for animal growth that take into account the effect on growth of the random fluctuations in the animal's environment. Let $X(t)$ be the body weight or size of the animal. The traditional deterministic models assume the form of a differential equation $dY(t) = b(g(a) - Y(t))dt$, where g is a strictly increasing function, $Y(t) = g(X(t))$, a is the asymptotic size or size at maturity of the animal, and b is the rate of approach to maturity. For instance, the Bertalanffy-Richards model corresponds to g being a power function and the Gompertz model to g being a logarithmic function. In early work we have considered, for animals growing in a random environment, stochastic differential equations models $dY(t) = b(g(a) - Y(t))dt + sdW(t)$, where $W(t)$ is a Wiener process and s measures the intensity of the random environmental fluctuations. We have considered the problems of parameter estimation and prediction for one path. Here we study the extension to several paths, in which case we have data at several time instants coming from several animals. The results and methods are applied to bovine growth data provided by Carlos Roquete (ICAM-University of Évora).

Key words and phrases: Animal growth, stochastic differential equations, estimation, several paths.