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Review and assessment of definitions of chaos in biological studies

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This project was a review of the uses and definition of chaos in the modelling of biological systems.

Much early study of chaos was intimately connected with applications in biology and ecology, in particular Lorenz's work on weather modelling in the 1960s and Robert May's work on insect population models in the 1970s. However, after that time the study and analysis of chaotic systems became mostly the province of mathematicians. Mention of chaos in biology was largely confined to observations that models were chaotic or even that observed data ``appears chaotic'' with little attempt to make positive use of chaos in modelling.

The last ten years or so have seen a strong increase in both the rigour and use of chaos in biological modelling. A need has been seen for a commonly accepted usable definition of chaos. Among mathematicians there are several independent, though connected, definitions. One of these is the presence of a positive Lyapunov exponent, which is increasingly being seen as a highly practical measure in biology and ecology. The Lyapunov exponent, a measure of divergence in a system, has the advantage that it is most readily calculated numerically, and so chaos in systems can be observed without necessarily an explicit model.

Increasingly, chaos is not only observed in systems but the presence of chaos is explicitly used to both predict and control models. A common theme is leveraging the sensitive dependence on initial conditions which is characteristic of chaos.

An interdisciplinary research group on nonlinear population dynamics, known as the Beetle Team (http://caldera.calstatela.edu/nonlin/) is one of the leaders in this respect, with chaotic models predicting the response of beetle populations to external influence and these predictions being borne out in long term experiments.

Similar studies have proposed methods of leveraging chaotic systems to control systems, and have met with experimental success. Systems studied include population control, preventing both over-population and extinction, as well as controlling and stabilising other biological systems such as cardiac arrhythmia, cellular development and neuron networks.

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See www.ice-em.org.au/students.html#scholarship.