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P5_9 Wolves, Deer, and a Python...Model

M. Sharman, G. Knott, B. Rayson, D. Molloy

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

In this paper, we present our Python model which determines the consequences of Grey Wolf reintroduction on Red Deer numbers in a small area of Scotland. The model is constructed using the Lotka-Volterra method and integrated via the Runge-Kutta method. We find that introducing a single pack of 10 wolves reduces the deer numbers and creates an oscillation in the populations with a period of ∼10 years.

Introduction

The possibility of reintroducing Grey Wolves into Scotland has been a topic discussed for many years. The key purpose of this move would be to help reduce the significant threat that deer overpopulation poses to biodiversity and habitat stability. The grazing of the deer prevents new trees from growing, and the lack of predators means that annual culls are necessary to control numbers.

Alladale estate was suggested as a possible way to test the reintroduction on a smaller scale [1]. The idea would be to release a small number of wolves to the area and contain them with fencing to see the impact on deer numbers. Depending on the results, this could then be used as justification for a larger-scale reintroduction program.

We want to formulate a model for this reintroduction and study the effect a pack of grey wolves would have on the deer population.

Method

The Lotka-Volterra model is a famous simple method for modelling population levels in a prey-predatory system [2]. It uses two coupled first-order differential equations to model the variation in populations and the dependence on each for their birth/death rates. This model has some important assumptions: **1.** Without predators, prey numbers grow infinitely i.e. no food limit. **2.** Predator numbers grow depending on the availability of prey. **3.** Predators are solely reliant on a single prey for food. **4.** Predators are never 'full' and have an unlimited appetite.

Below are the Lotka-Volterra equations which describe the rate of change of the red deer (d_r) and wolf (w) populations.

$$\frac{dd_r}{dt} = \alpha d_r - \beta d_r w \tag{1}$$

Where α is the deer birth rate, β is the predation death rate due to the wolves and w is the population of wolves.

$$\frac{dw}{dt} = \delta d_r w - \gamma w \tag{2}$$

Where δ is the birth rate of wolves dependent on available food, and γ is the death rate of wolves in the absence of deer.

Red deer are known to produce one offspring per year [3], so we set α to 1.0. We assumed that the predation rate of deer from the wolves is approximately 10%, which means $\beta = 0.1$ and the death rate of wolves without food we set to $\gamma = 0.5$. Finally, we set the birth rate of the wolves to $\delta = 0.005$ which corresponds to 200 deer eaten to 1 wolf being born in the pack.

Without external measures, the wolf population would grow very large due to the infinite appetite assumption. In reality for a small-scale test, humans may cull the wolves to keep them stable. We have modelled this by increasing their death rate if the population exceed 15 animals.

To integrate this model over 100 years, we used 2nd order Runge-Kutta integration as this is much more accurate than Euler integration. This uses an intermediate time step to calculate trial values which are then used to calculate at the full time step. The two derivatives are calculated at each half time step, and then the new population is found using the equation below, with the same equation for the deer population.

$$w_{new} = w_{old} + \frac{dw}{dt} \times \Delta t \tag{3}$$

Where Δt is the time step, which we set to 0.01 for our model. We also set the initial number of wolves to 10, and the deer to 200.

Results and Discussion

The graph in Figure 1 shows the results of our model for a 100-year time period. There is a very rapid decrease in the deer population with the introduction of wolves. The wolf population also increases to the culling limit at which it oscillates for ~3 years. After this, the populations settle into a stable cycle with the wolves varying between 6 and 15 animals, and the deer varying between 4 and 60.

This type of cycle is extremely common with the Lotka-Volterra method: as the deer increase, there is more food for the wolves so their population increases. This increases the number of deer being eaten so their numbers drop and the wolf numbers drop off after due to the lack of food, and then the cycle repeats.

In a real system, there will be far more factors that affect the population. In reality, more deer may move into the territory of the wolves, or the wolves may move to find more deer. In this situation, the populations may reach a clearer equilibrium with even mixing of prey and culling of wolf numbers.

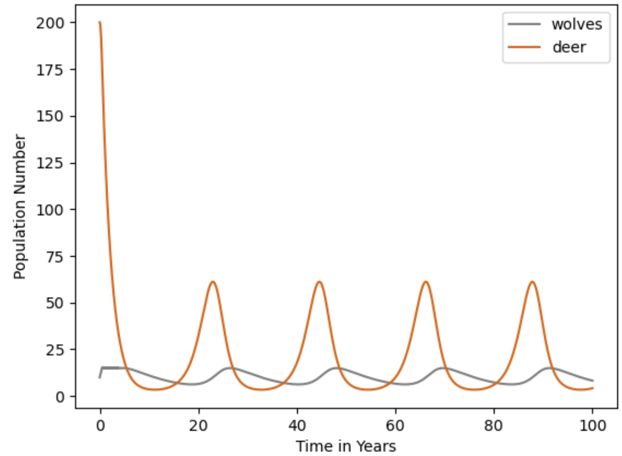

Figure 1: Graph showing the oscillatory variation in population levels of deer and wolves.

What our results do show is that the introduction of wolves to a small area of Scotland would reduce deer numbers and create a stable cycle of populations in a ~10 year period. The initial values we set for the birth and death rates have a large impact on the final results and since these are poorly known, the results should be used while taking this into account.

This work could be extended by using a more accurate model that fixes some of the assumptions necessary for the Lotka-Volterra method such as the infinite feeding rate of the wolves.

References

[1] URL: https://alladale.com/the-wolf-man/.

[2] URL: http://www.scholarpedia.org/article/Predator-prey_model.

[3] URL: https://ypte.org.uk/factsheets/deer-red/breeding.

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