Ecosystems

Models of interacting population dynamics

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Modelling interactions between species

Populations do not exist in isolation.

The dynamics of one population will influence the dynamics of other populations

For example as a result of …..

Predation
Competition
Parasitism
Epidemics

Modelling competition

Many complex models representing competition between organisms

Key question … what enables competing organisms to coexist?

Many explanations involve differential resource use

Simple models imply that competition for a single resource leads to one “winner”

Lotka Volterra competition model

- Involves multiple logistic equations
- The "N/K" negative feedback involves the sum of the individuals in all species

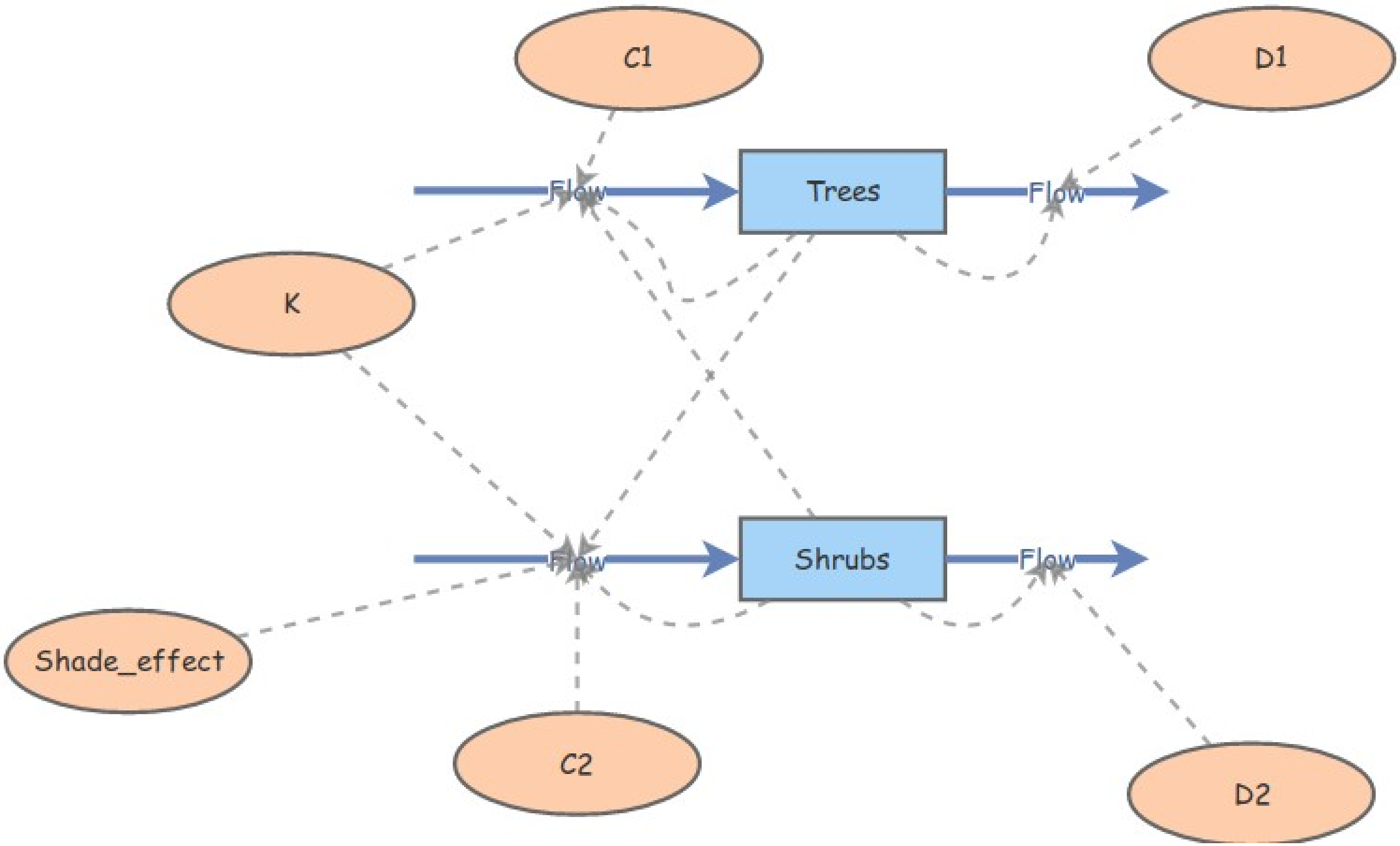
$$\frac{dN_1}{dt} = r_1 N_1 \frac{(K_1 - N_1 - \alpha_{12} N_2)}{K_1}$$

$$\frac{dN_2}{dt} = r_2 N_2 \frac{(K_2 - N_2 - \alpha_{21} N_1)}{K_2}$$

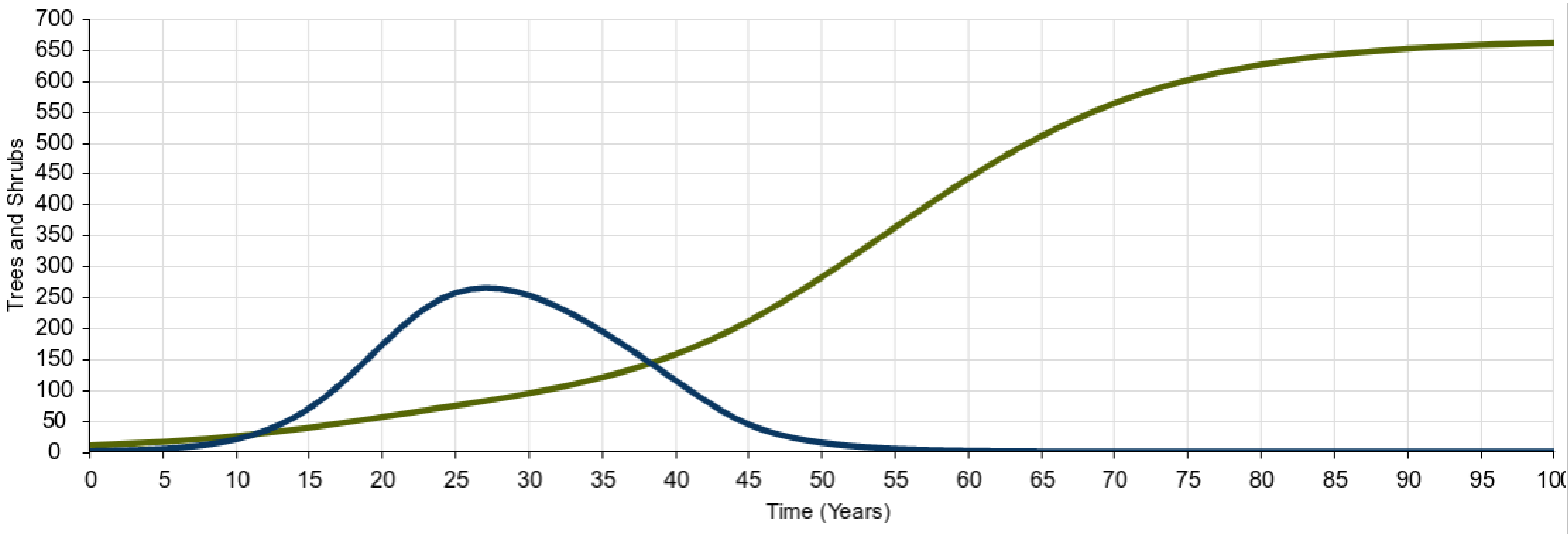
Example

- Think of plants competing for light, water and nutrients
- Longer lived plants are more effective at competing
- Shorter lived plants are more effective at dispersing seed, establishing and growing quickly

Example



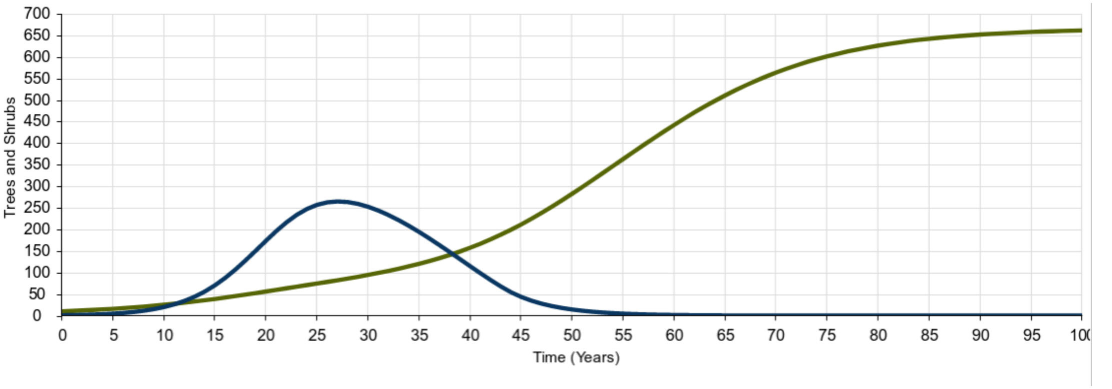
Example



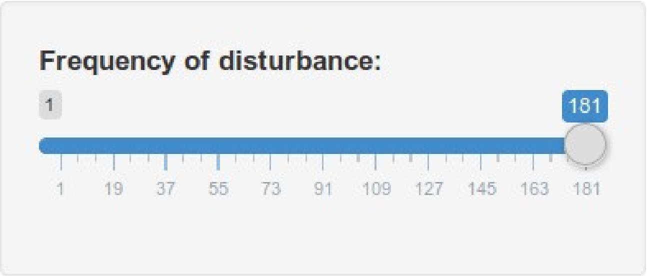
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Trees and Shrubs
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Time (Years)

Species diversity

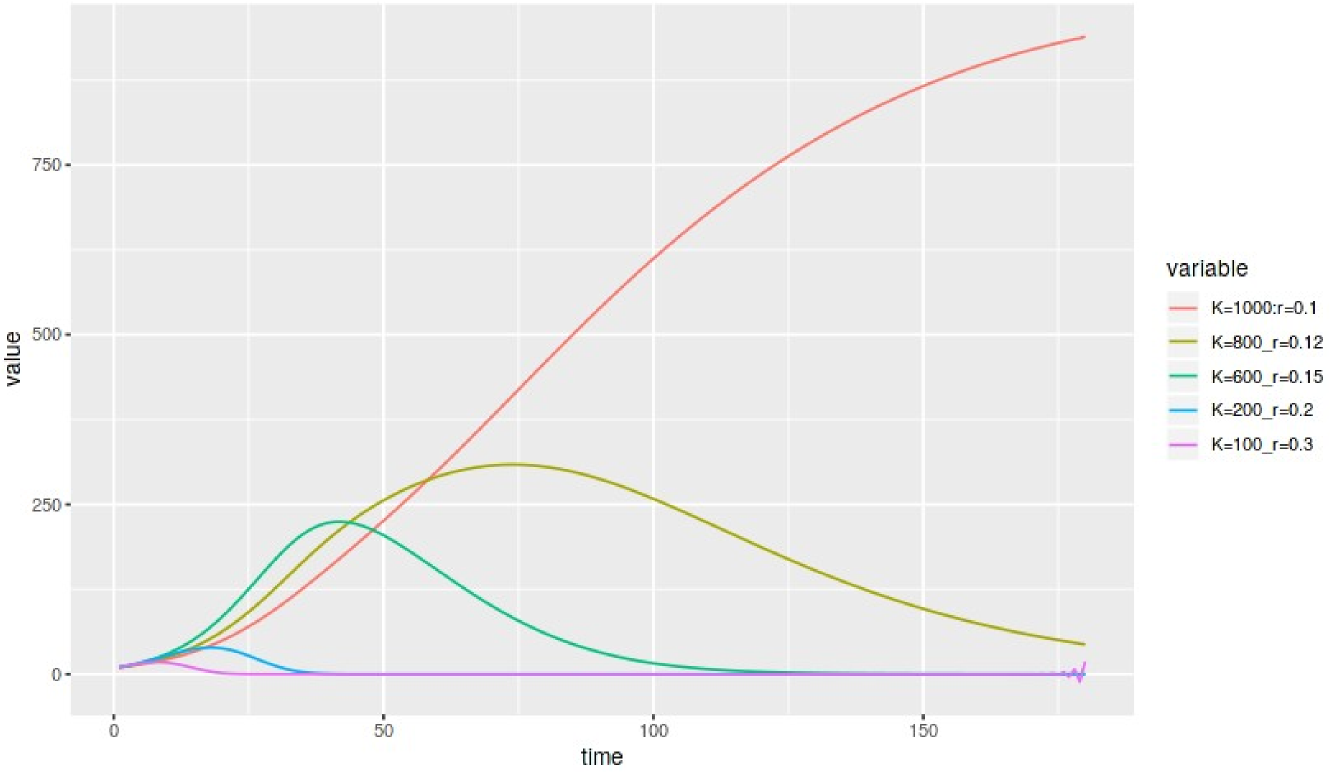
- Models of competition may suggest the existence of “winners” and “losers”
- Competition between species could reduce biodiversity
- However … look at the dynamics of the model



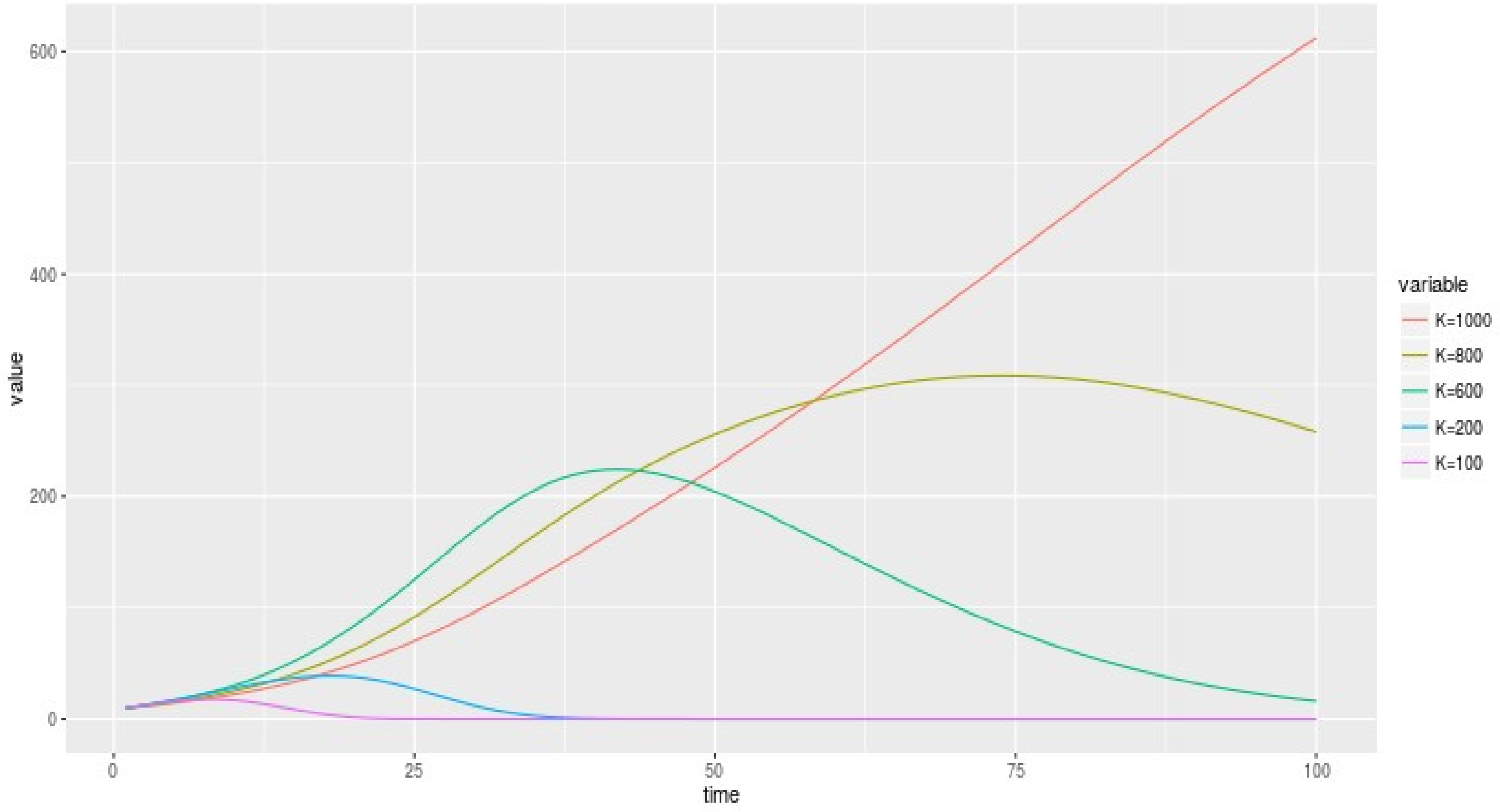
Multispecies model including disturbance



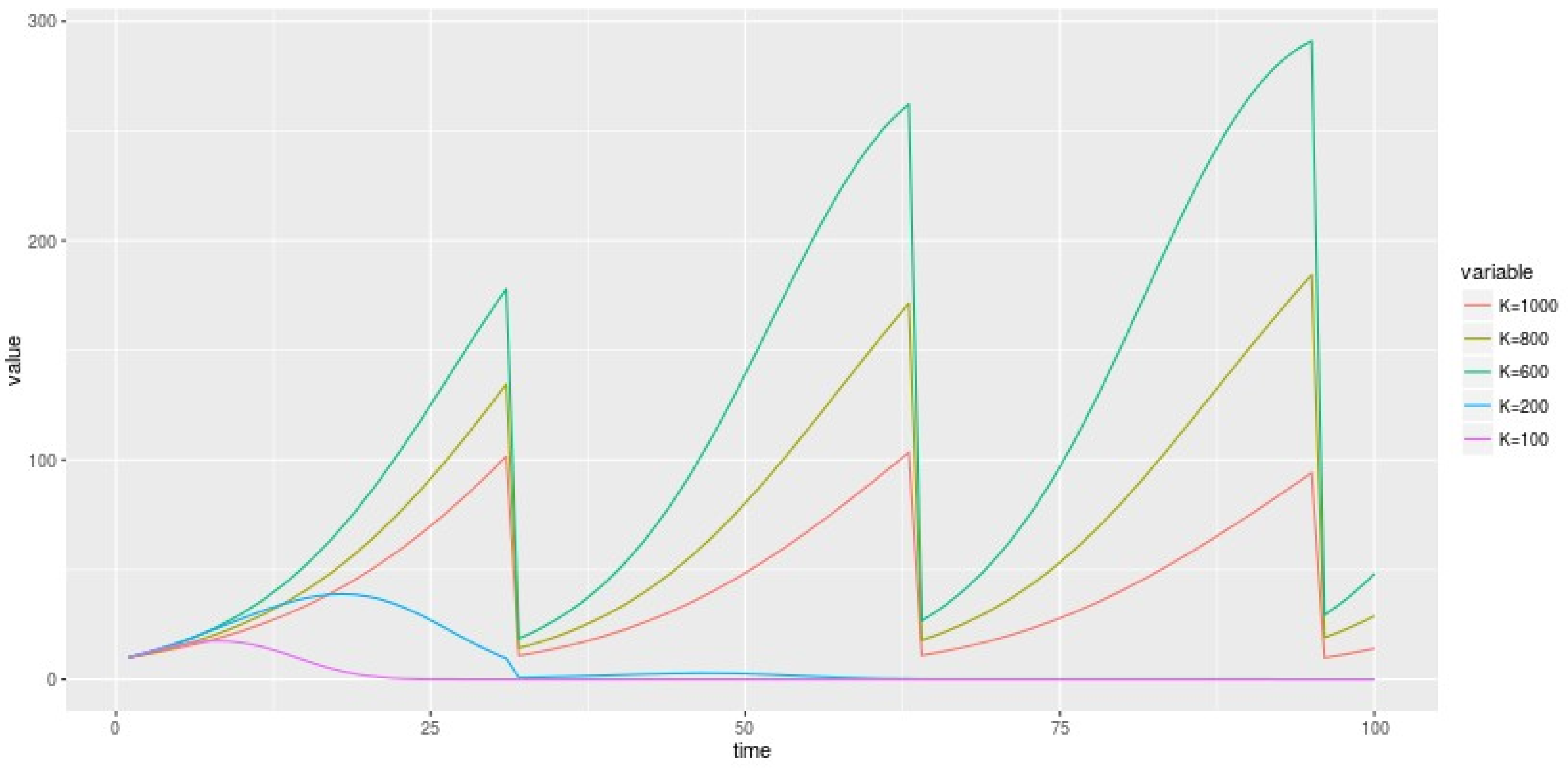
Alter the frequency of disturbance to run a series of experiments.



Without disturbance



With disturbance



Predator prey models

Predators obtain food through the mortality of prey species

Predator populations will increase when prey is abundant and decrease when prey is scarce

Prey populations may increase when predation pressure is reduced

Lotka Volterra model

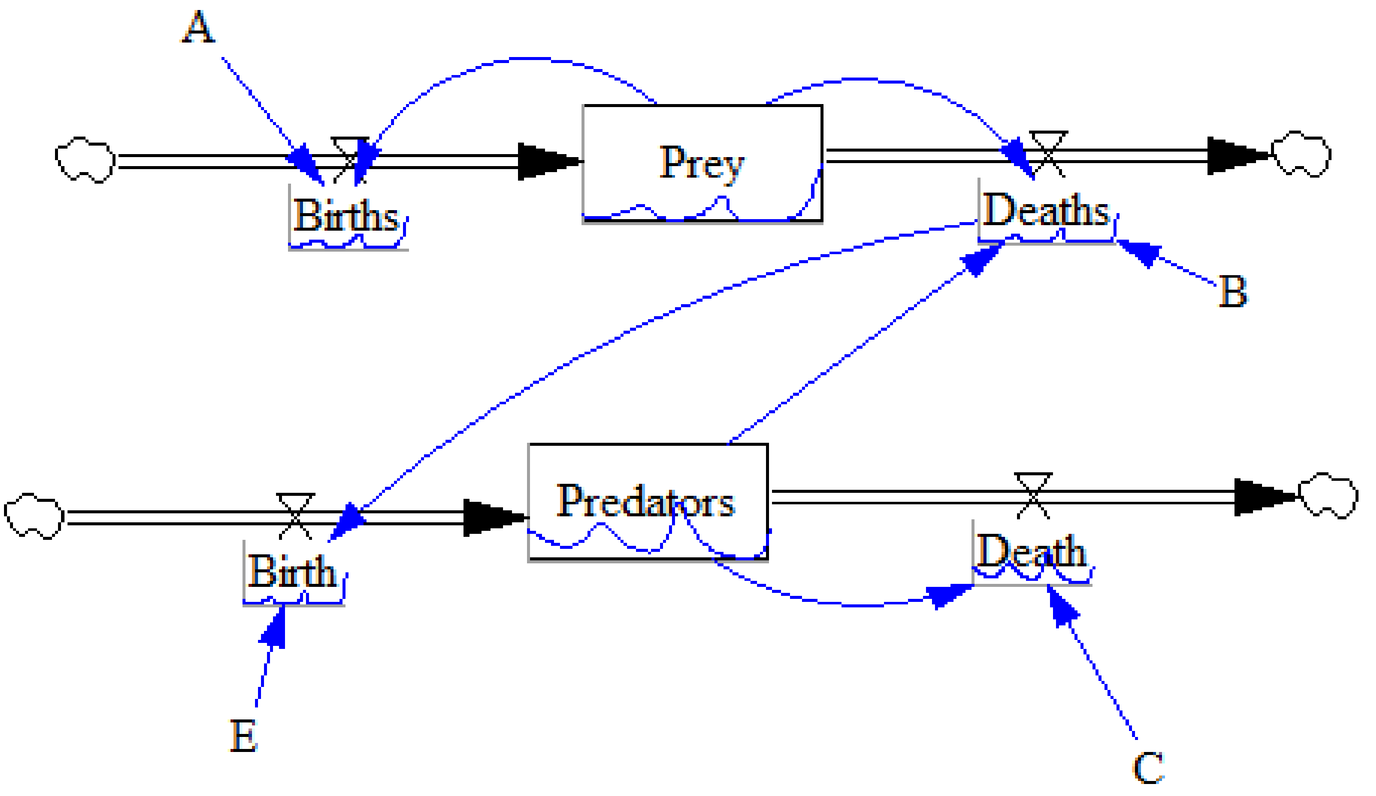
A = the natural growth rate of prey in the absence of predation,

B = the natural death rate of predators in the absence of food

C = the death rate per encounter of prey due to predation,

E = the efficiency of turning prey into predators.

Lotka Volterra model



$$\frac{dN}{dt} = AN - BNP$$

$$\frac{dP}{dt} = EBNP - CP$$

What does this imply?

- If BNP (predator induced mortality) is greater than AN (prey birth rate) the prey population will fall
- Predator induced mortality is a function of the number of predators.

$$\frac{dN}{dt} = AN - BNP$$

$$\frac{dP}{dt} = EBNP - CP$$

What does this imply?

- If EBNP (predator birth rate) is greater than CP (predator death rate) the predator population will increase
- Predator birth rate is a function of the number of prey.

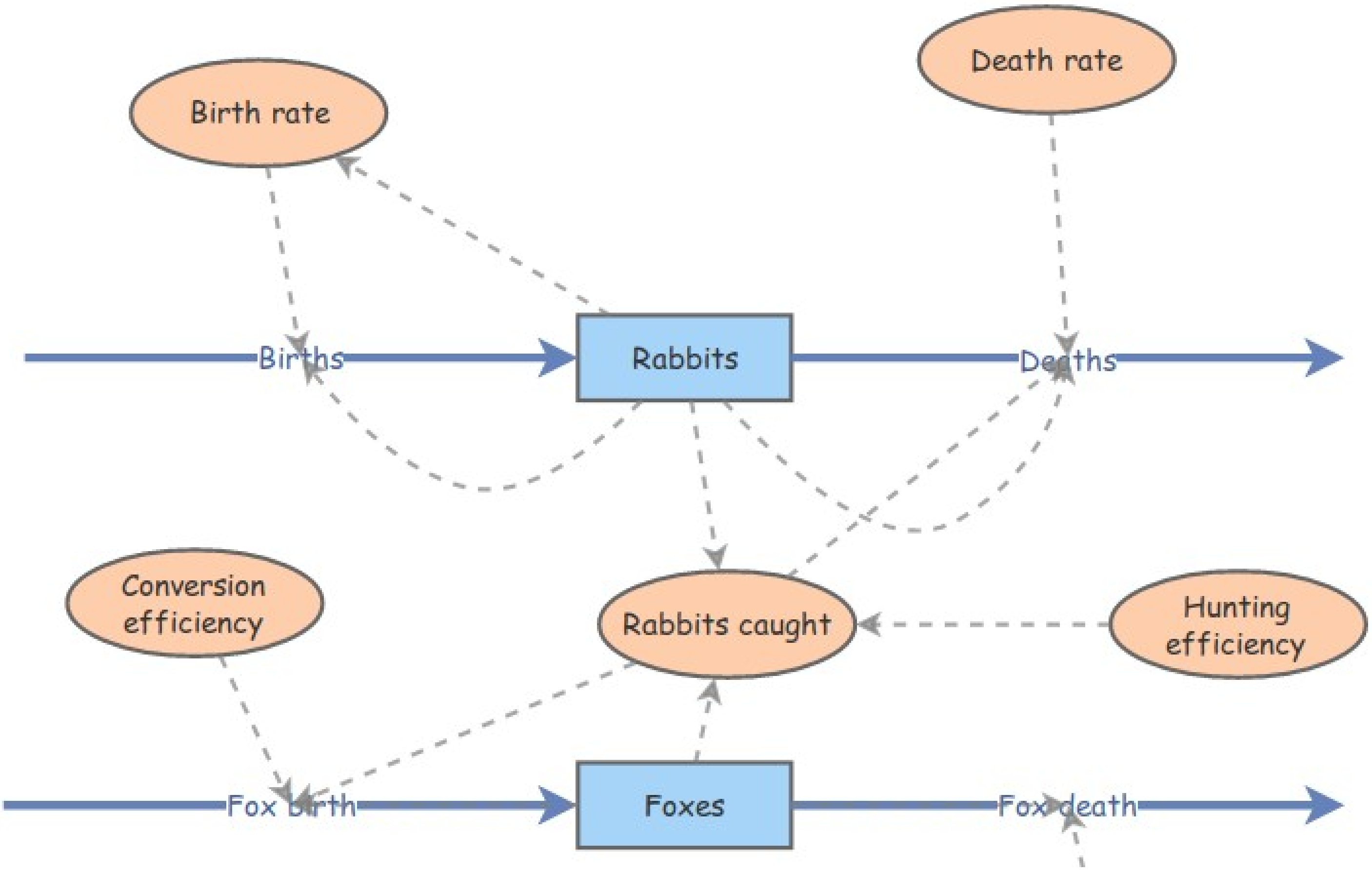
$$\frac{dN}{dt} = AN - BNP$$

$$\frac{dP}{dt} = EBNP - CP$$

Model assumptions

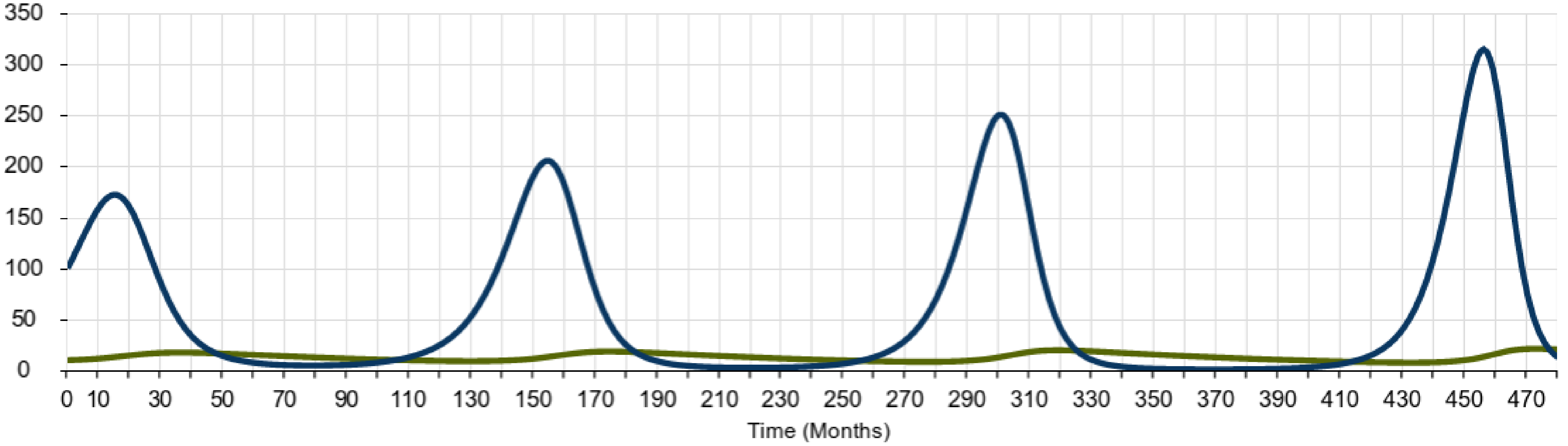
- All prey mortality is due to predation
- Predators only eat one form of prey
- Predator mortality rate is a constant
- Lack of prey leads to reduced reproduction of predators but not reduced mortality (directly)

Lotka volterra predator prey model

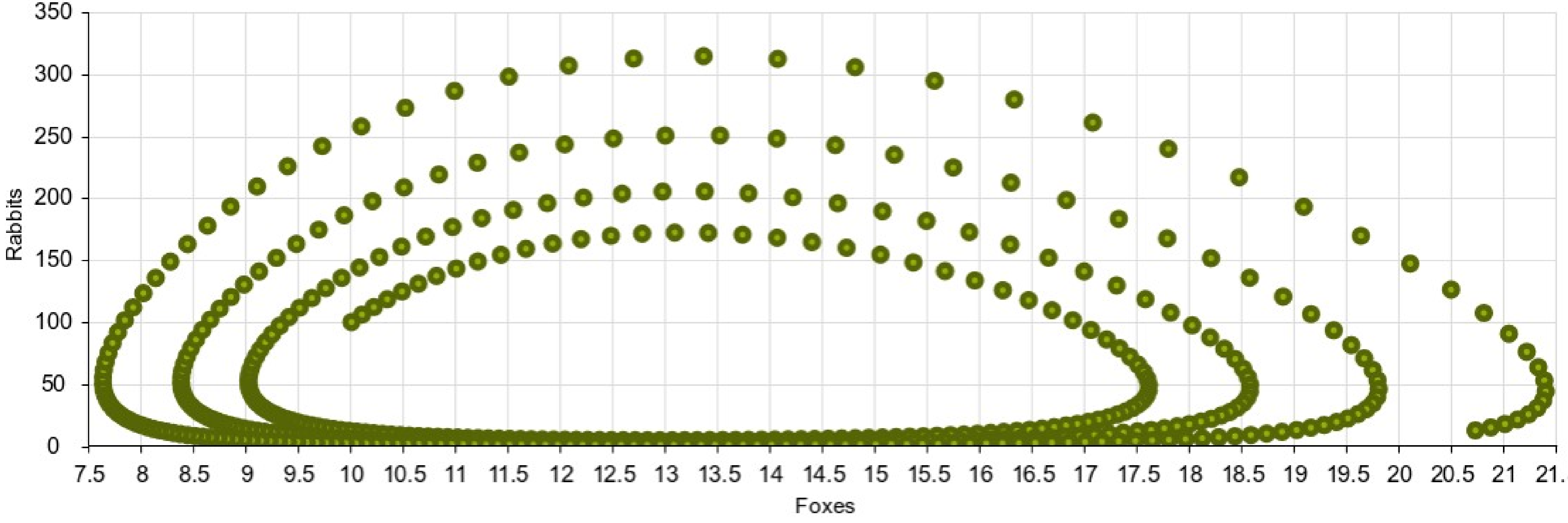


Results

Classic model produces cycles



Phase plane diagram



Classic textbook data: Snowshoe hare and Lynx

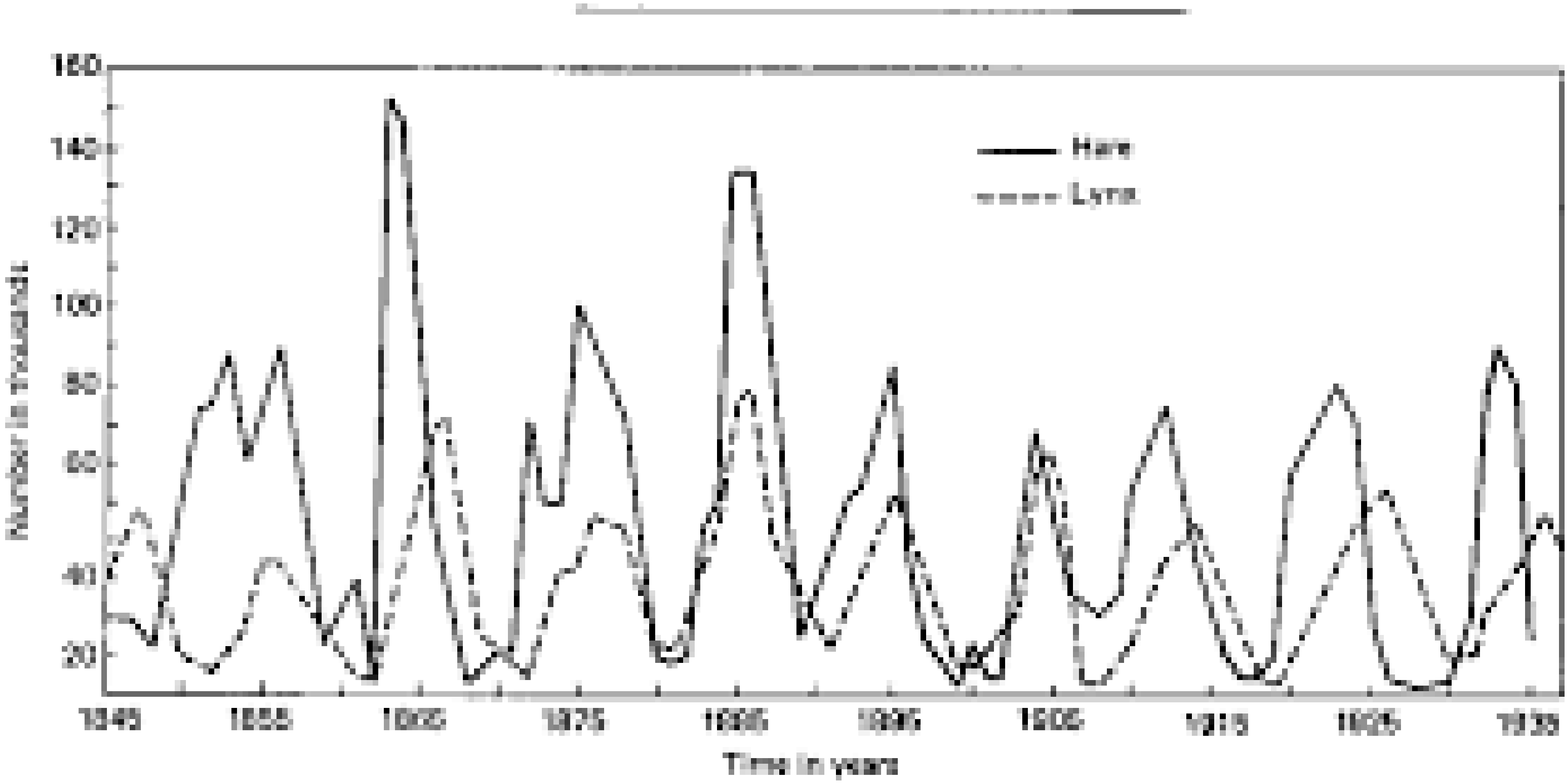
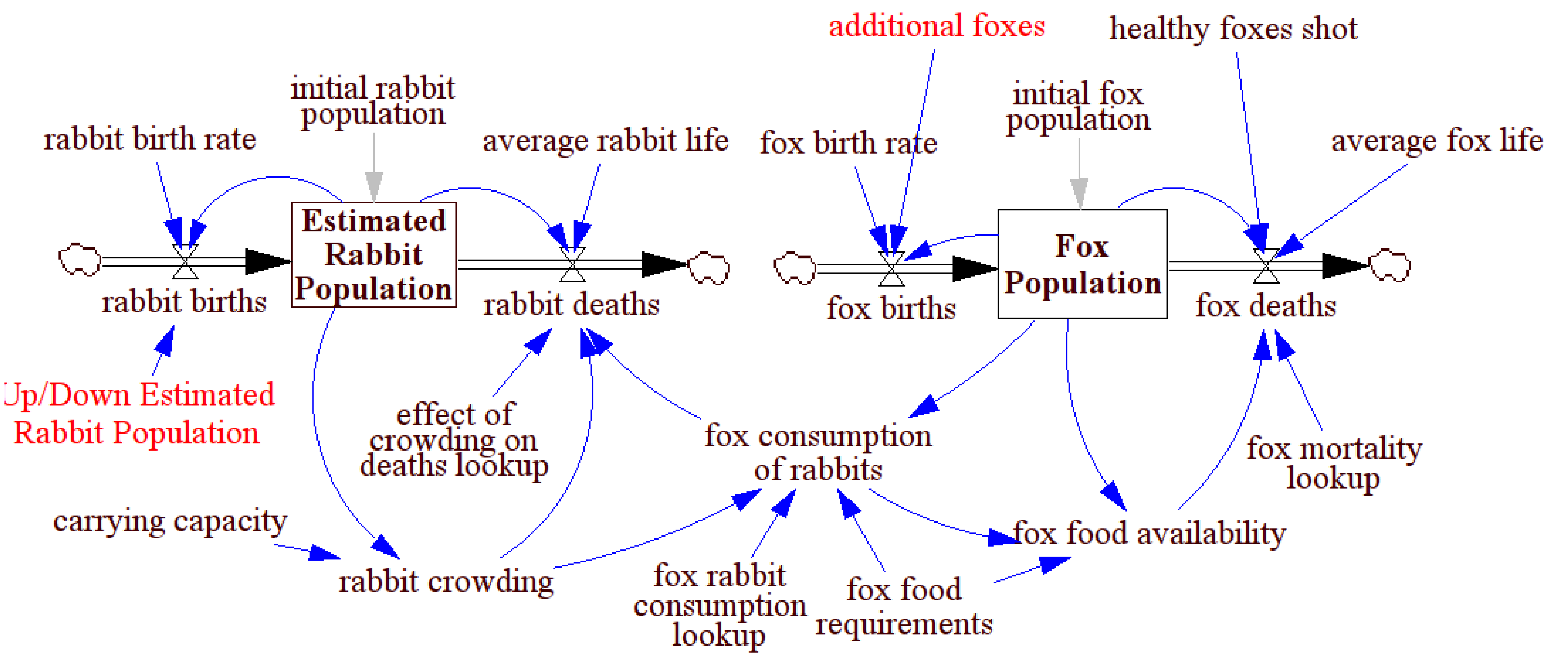


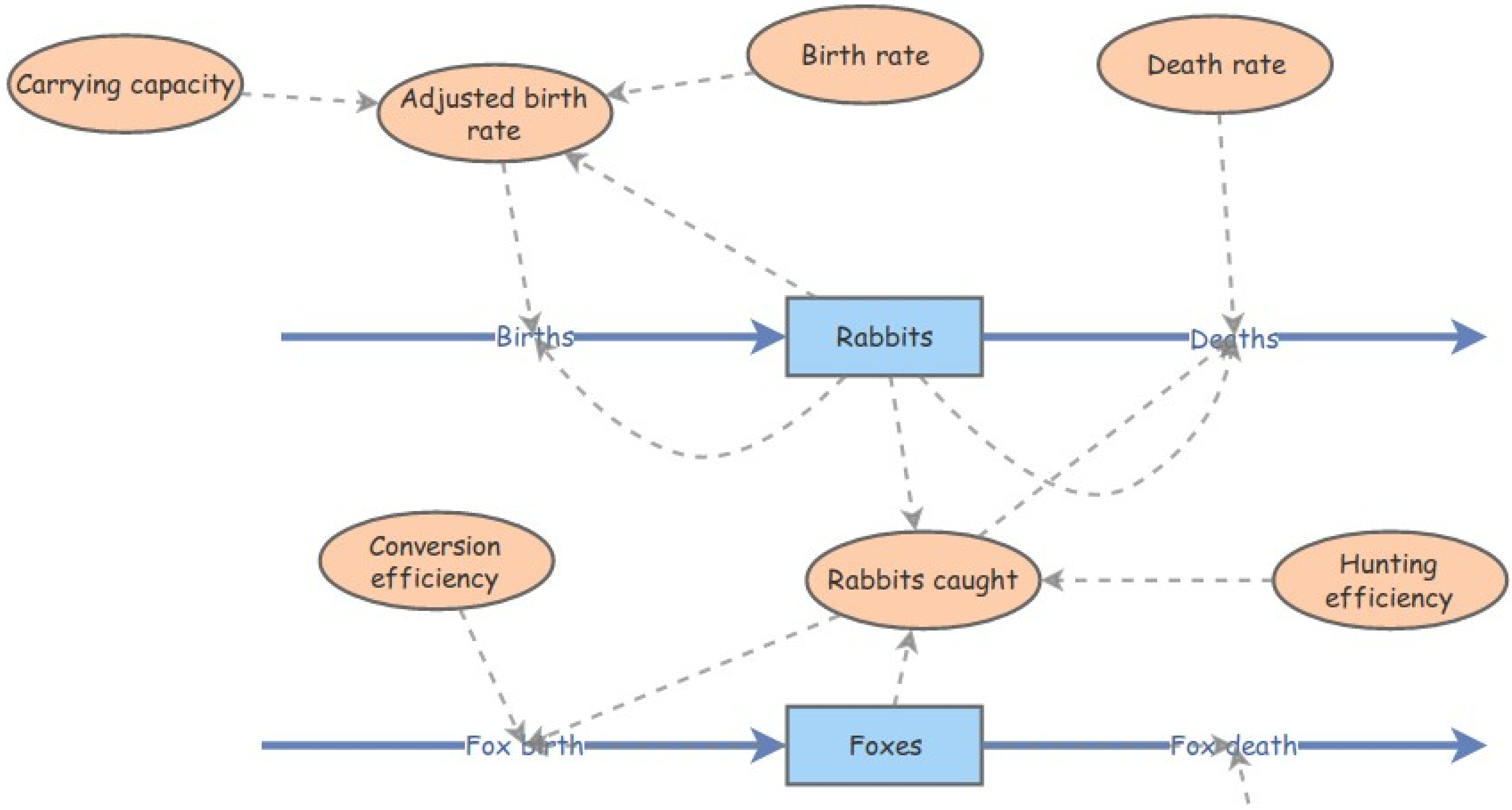
Figure 9-3. Changes in the abundance of the lynx and the snowshoe hare, as indicated by the number of pelts received by the Hudson's Bay Company. This is a classic case of cyclic oscillation in population density. (Redrawn from MacLulich 1937.)

What does the model not include?

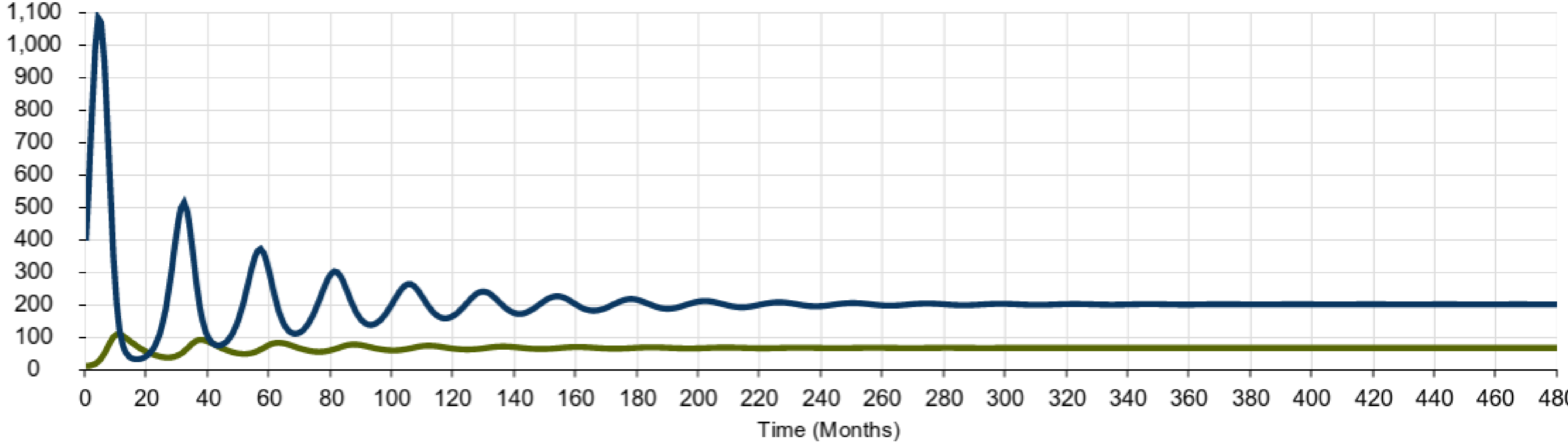
More complexity can be built into models



Lotka volterra with carrying capacity



Lotka volterra with carrying capacity



Further reading

Details of all these models are included in all introductory Ecology textbooks

Some treatments are mathematically complex

Look into criticisms of simple models and extensions to include more realistic assumptions linked to concepts taught on this course