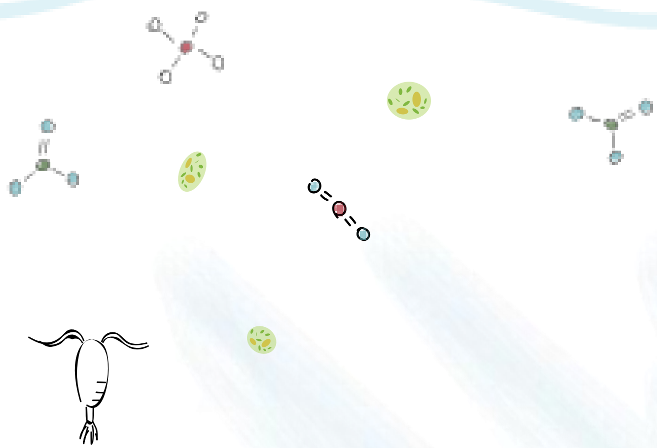

Reactive Transport in the Hydrosphere

Department of Earth Sciences, Faculty of Geosciences, Utrecht University

Lecturers: Lubos Polerecky and Karline Soetaert

Illustrations, narration and video editing: Renee Hageman
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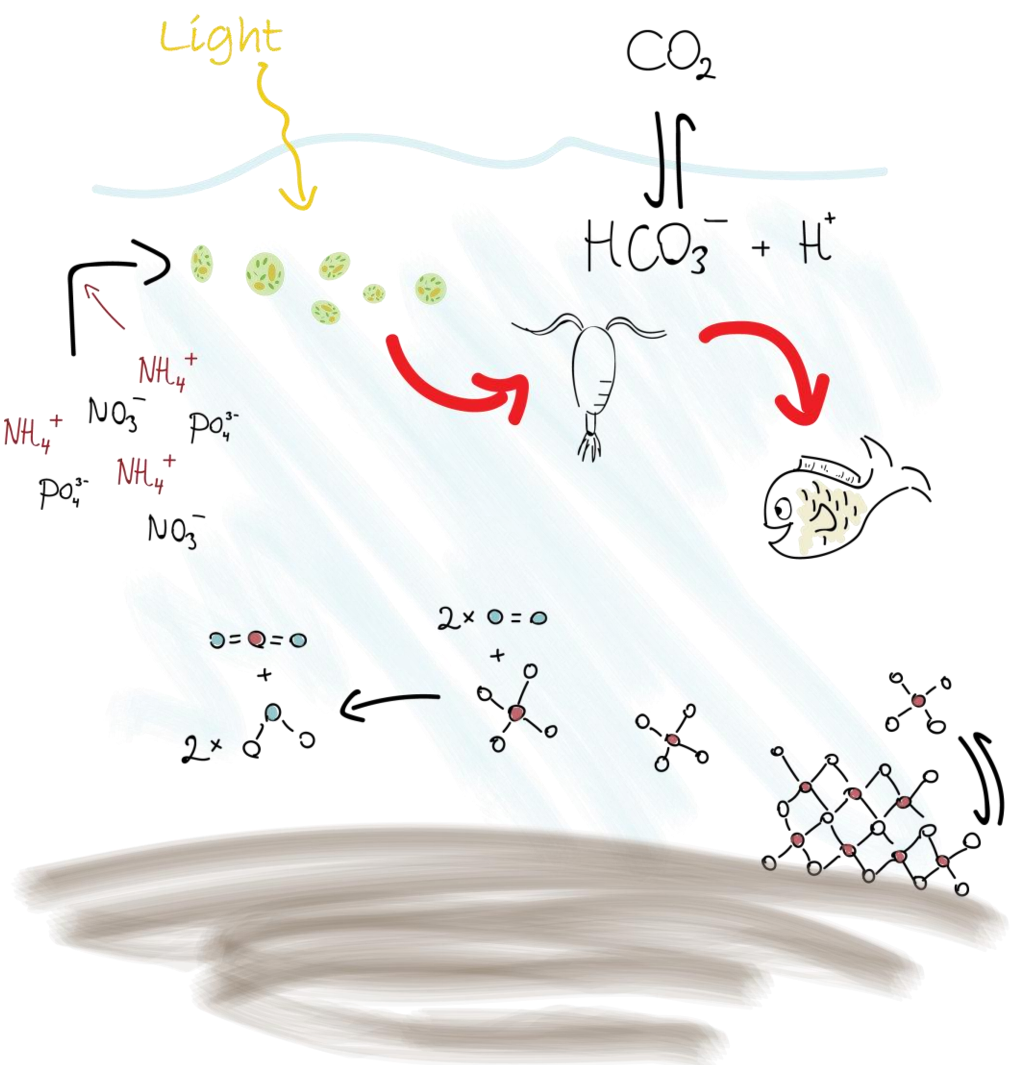
Rate laws for . . .



Chemical reactions

- Irreversible
- Reversible
- Enzyme-catalyzed (metabolic)
- Substrate limitation
- Substrate inhibition
- Rate saturation

Large-scale models

Partitioning between phases

- Mineral dissolution / precipitation
- Gas exchange

Ecological interactions

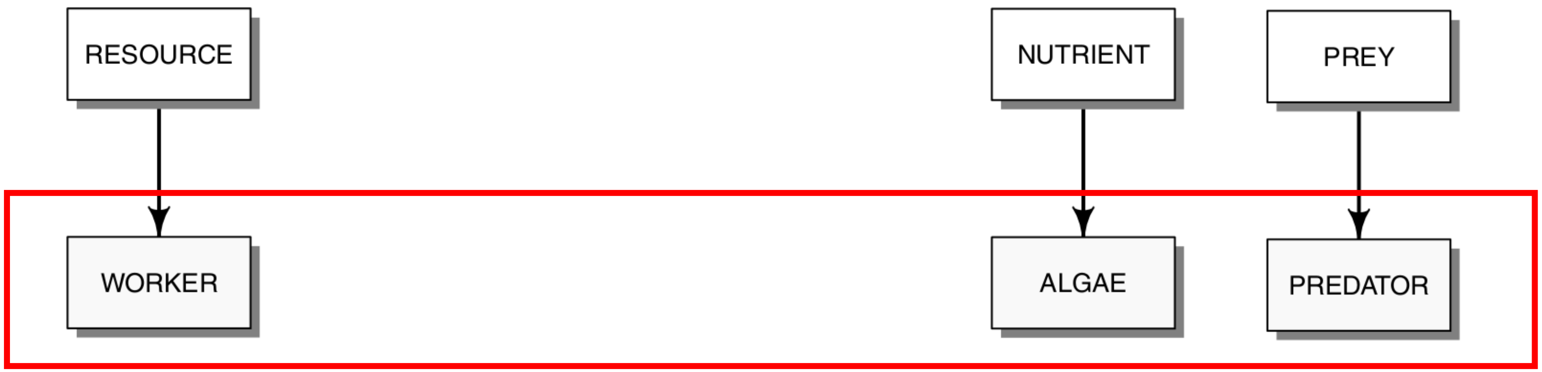
- Grazing, predator-prey type

Transport

Rate laws for ecological interactions

General form

Examples



$$\text{Interaction} = maxRate \cdot \boxed{\text{WORKER}} \cdot \text{RateLimitation} \cdot \text{RateInhibition}$$

- Workers do not interact with each other
- More workers = more work

$$NutrientUptakeRate = r \cdot ALGAE \cdot RateLimitingTerm$$

$$PredationRate = r \cdot PREDATOR \cdot RateLimitingTerm$$

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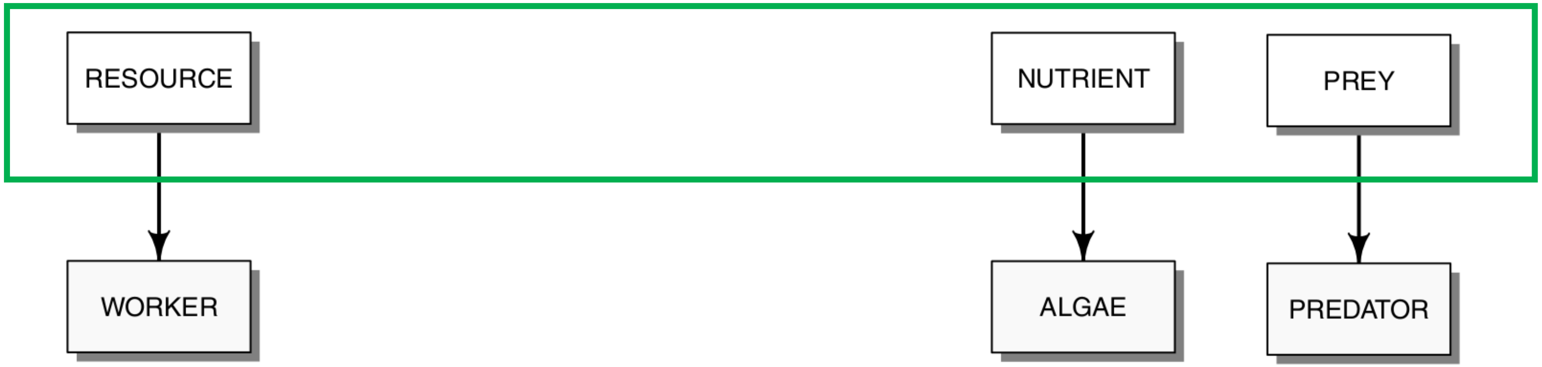
Ecological interactions

General form | **Examples**



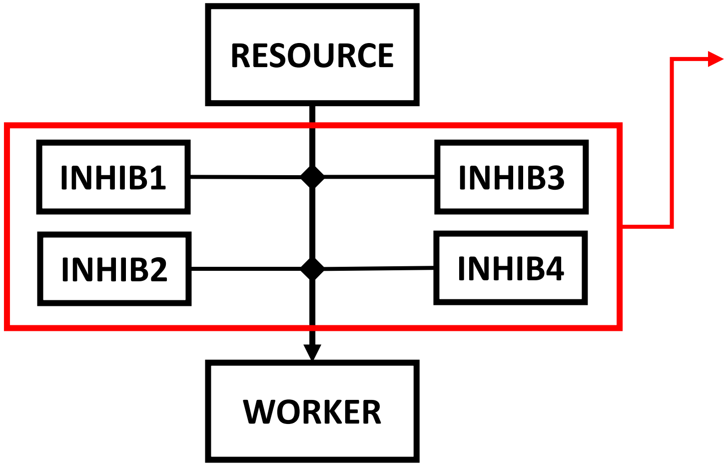
$$\text{Interaction} = maxRate \cdot \text{WORKER} \cdot \boxed{\text{RateLimitation}} \cdot \boxed{\text{RateInhibition}}$$

- Limitation by the resource
- Etc.

- Presence of competitors
- Inhibitor, Pollution, Etc.

$$NitrateUptake = r \cdot \boxed{\frac{[NO3]}{[NO3] + K_{NO3}}} \cdot \boxed{\frac{K_{NH3}}{[NH3] + K_{NH3}}} \cdot ALGAE$$

Lumping of multiple growth-inhibiting factors



Impact of the effects is lumped:

K = ecosystem carrying capacity (maximum size that the population can reach given abundant resources)

Logistic growth model:

$$\frac{dN}{dt} = r \cdot N \cdot \overbrace{\left(1 - \frac{N}{\boldsymbol{K}}\right)}^{\text{Inhibition term}}$$

Population size of the worker

Logistic growth model

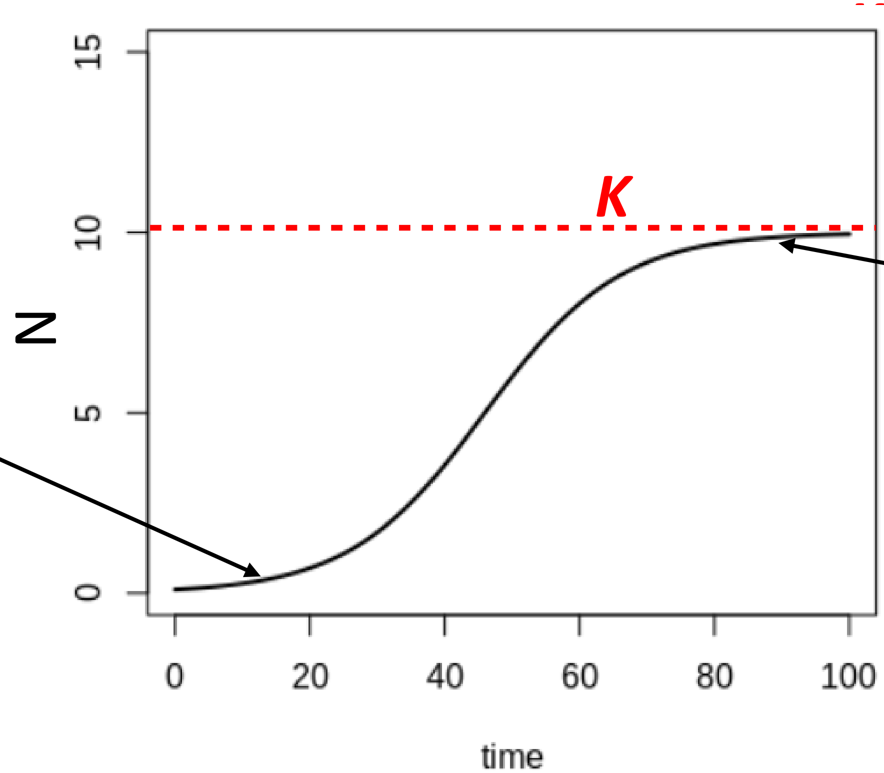
$$\frac{dN}{dt} = r \cdot N \cdot \left(1 - \frac{N}{\boldsymbol{K}}\right)$$

Optimal growth

$$N \ll \boldsymbol{K}$$

$$\left(1 - \frac{N}{\boldsymbol{K}}\right) \approx 1$$

$$N = N_0 \cdot \exp(rt)$$



Growth stops

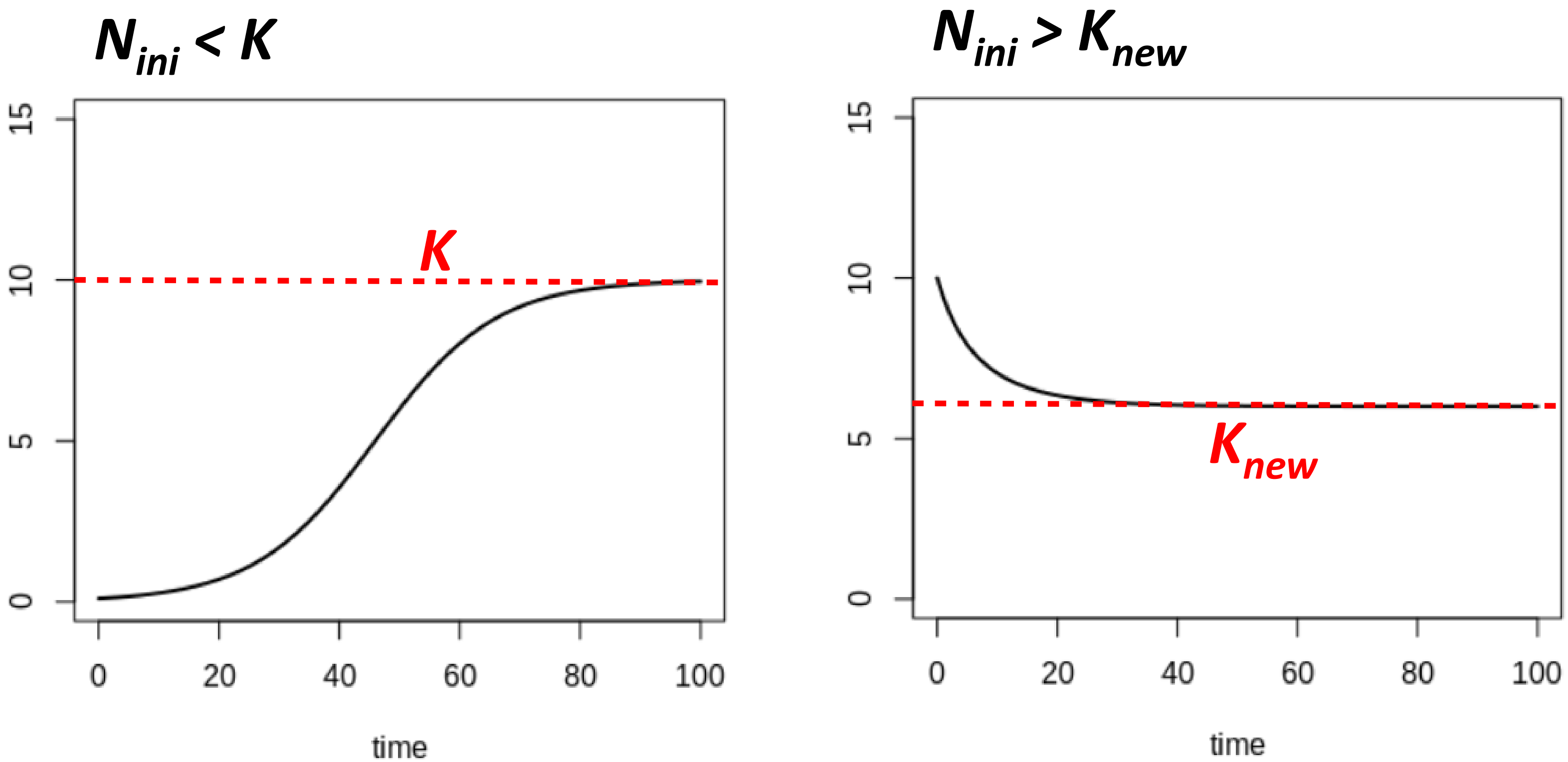
$$N \approx \boldsymbol{K}$$

$$\left(1 - \frac{N}{\boldsymbol{K}}\right) \approx 0$$

$$\frac{dN}{dt} \approx 0$$

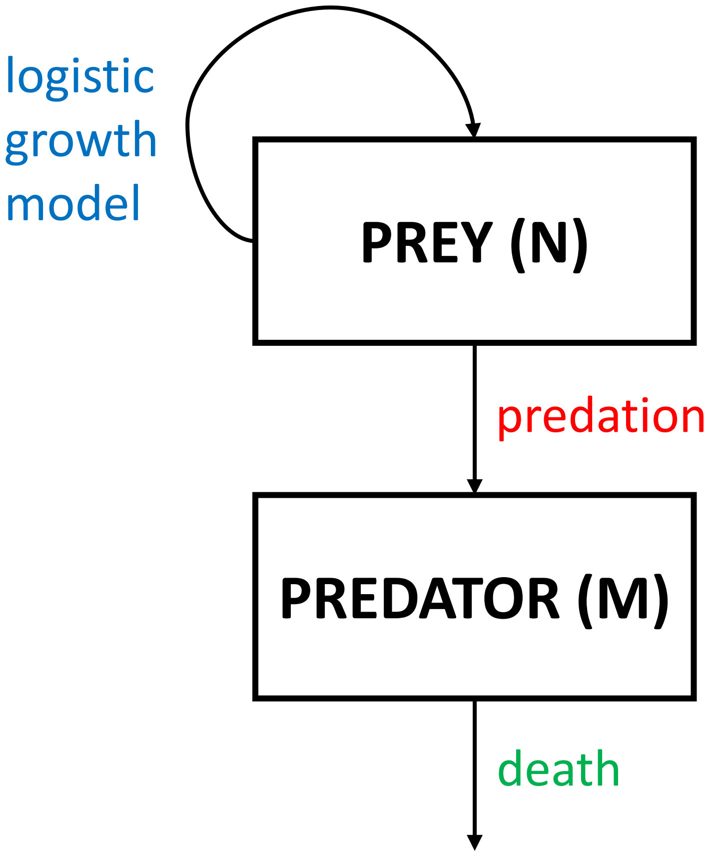
Logistic growth model

$$\frac{dN}{dt} = r \cdot N \cdot \left(1 - \frac{N}{K}\right)$$



K -> K_{new} due to, e.g., habitat destruction

Predator-prey interactions – Lotka-Volterra model



Predation intensity

$$\frac{dN}{dt} = r_i \cdot N \cdot \left(1 - \frac{N}{\boldsymbol{K}}\right) - \alpha \cdot N \cdot M$$

$$\frac{dM}{dt} = \gamma \cdot \alpha \cdot N \cdot M - m \cdot M$$

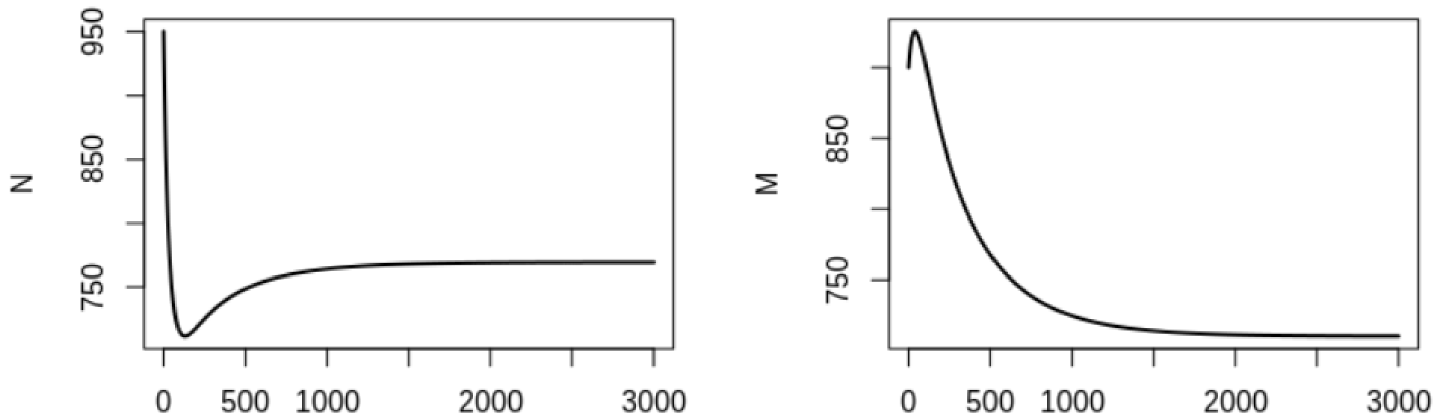
Efficiency of biomass assimilation by predators (γ<1)

Predator mortality rate constant

Predator-prey interactions – Lotka-Volterra model

$$\frac{dN}{dt} = r_i \cdot N \cdot \left(1 - \frac{N}{K}\right) - \alpha \cdot N \cdot M \qquad \frac{dM}{dt} = \gamma \cdot \alpha \cdot N \cdot M - m \cdot M$$

K=1000
r_i=0.04
α=1.3e-5
γ=0.8
m=0.2*r_i



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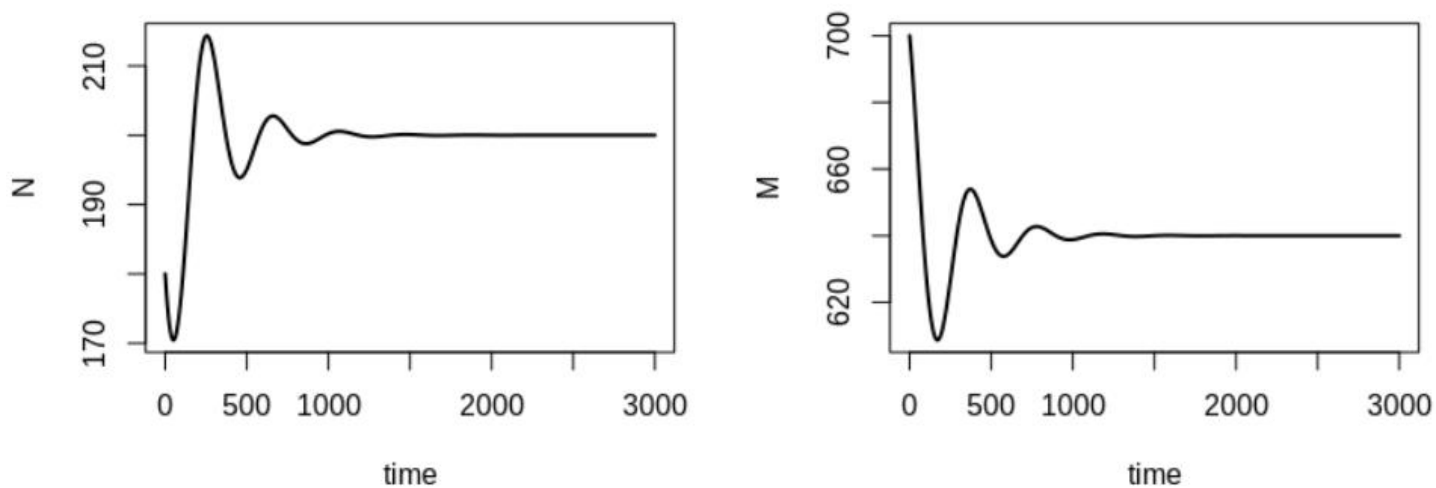

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