Can ecology and economics marry?

A theoretical ecologist's standpoint

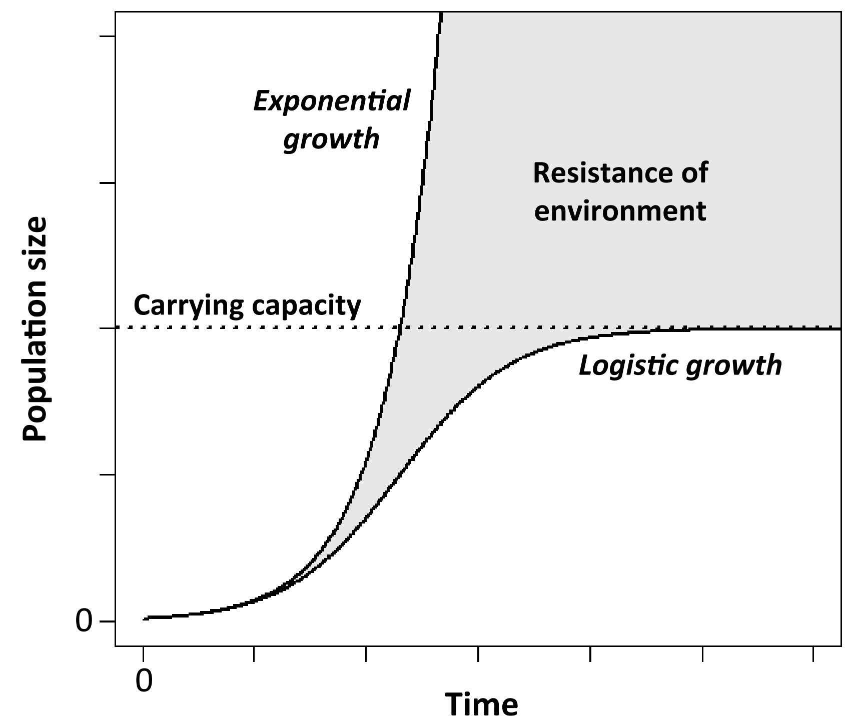
Michel Loreau

Centre for Biodiversity Theory and Modelling
Station d'Ecologie Expérimentale du CNRS
09200 Moulis, France
E-mail: michel.loreau@ecoex-moulis.cnrs.fr

Models in ecology
1. Exponential growth

$$N_{t+1} = N_t + bN_t - dN_t = / N_t$$

$$\Rightarrow \quad N_t = N_0 /^{\,t}$$



$$\frac{dN}{dt} = bN - dN = rN$$

$$\Rightarrow \quad N(t) = N_0 e^{rt}$$

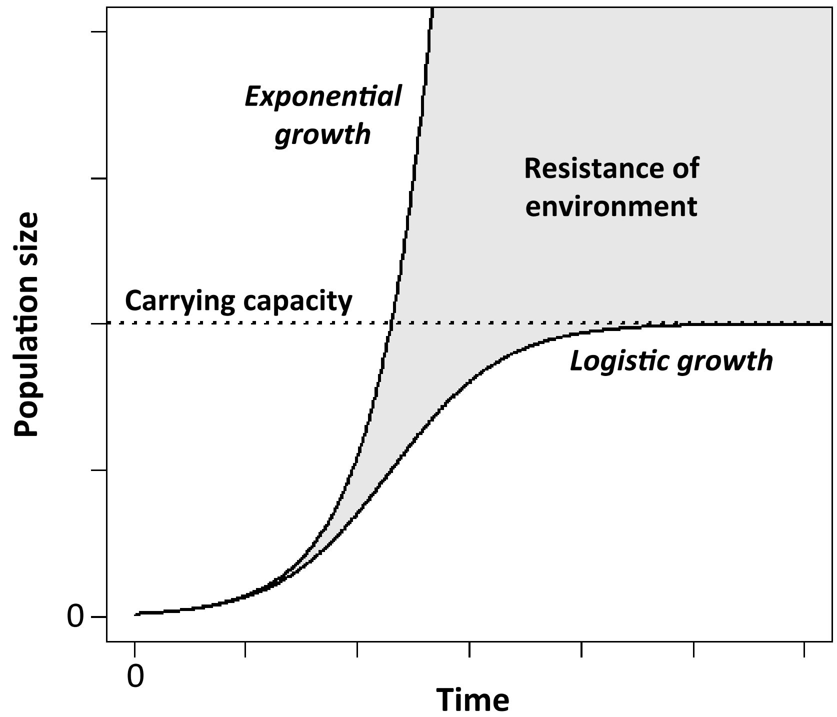
Lesson: Life has a propensity to grow without bounds

Models in ecology
2. Logistic growth

$$\frac{dN}{Ndt} = f(N)$$

$$f'(N) \le 0$$

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

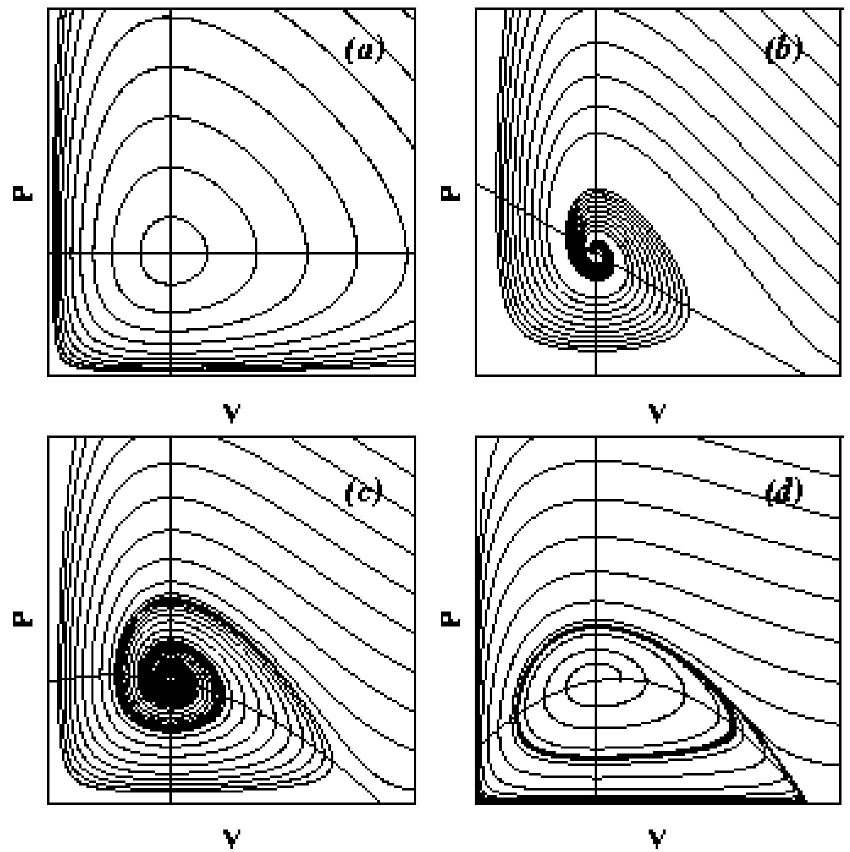


Lesson: Environmental constraints limit growth and thereby (often) stabilize populations and ecosystems

Models in ecology
3. Predator–prey models

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right) - \frac{cNP}{H+N}$$

$$\frac{dP}{dt} = \frac{ecNP}{H+N} - mP$$



Lesson: Species interactions yield all kinds of dynamics

Models in ecology
4. Models of evolutionary suicide

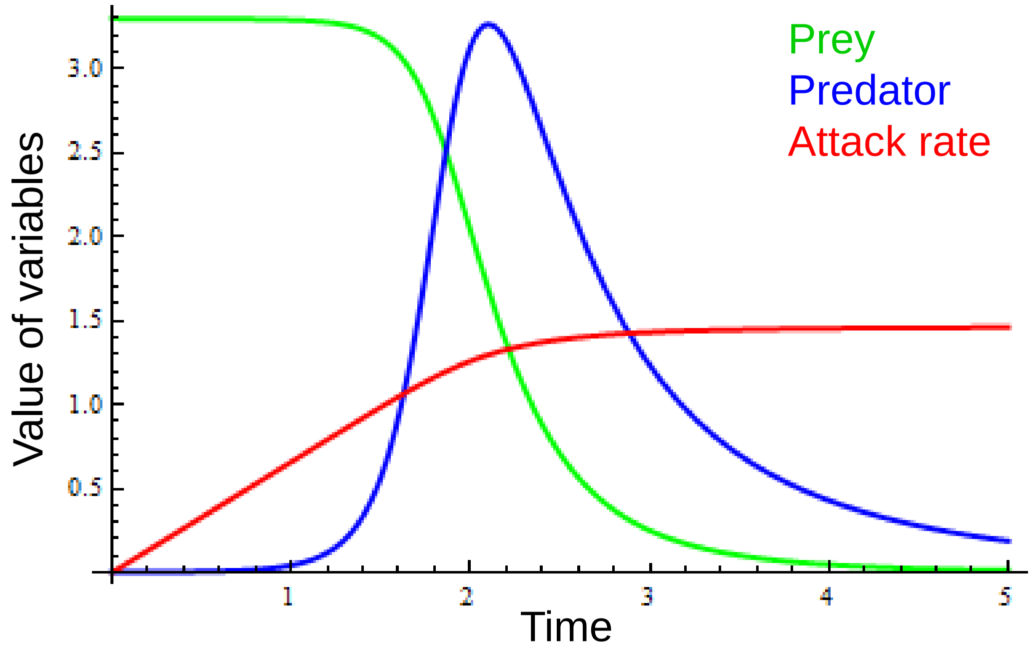
Lotka−Volterra predator−prey model with Allee effect in prey, intraspecific competition in predators, and evolution of predator attack rate:

$$\frac{dx}{dt} = x(-1 + rx - x^2 - \alpha y),$$

$$\frac{dy}{dt} = y[-d - y + (\alpha + 1)x],$$

$$\frac{d\alpha}{dt} = \epsilon x.$$

Webb, *Am. Nat.* 161: 181–205 (2003)



Lesson: Individual selection for increased resource consumption easily leads to population extinction

How do models in ecology compare with models in economics?

A typical bioeconomic model might work as follows:

- Use an ecological model to describe the dynamics of an exploited population
- Add a harvest function
- Maximise the expected net value of harvest
- This defines the optimal management strategy

How do models in ecology compare with models in economics?

Main differences with ecological models:

- Humans are not part of the ecological system
- Humans behave rationally toward this external system
- The human population is independent of ecological dynamics
- All these assumptions make sense only if human population dynamics takes place at much larger spatial and temporal scales

Economics = Ecology: Dynamics of human−nature interactions

Approach pioneered by Brander & Taylor's (1998) paper, "The simple economics of Easter Island", which assumes:

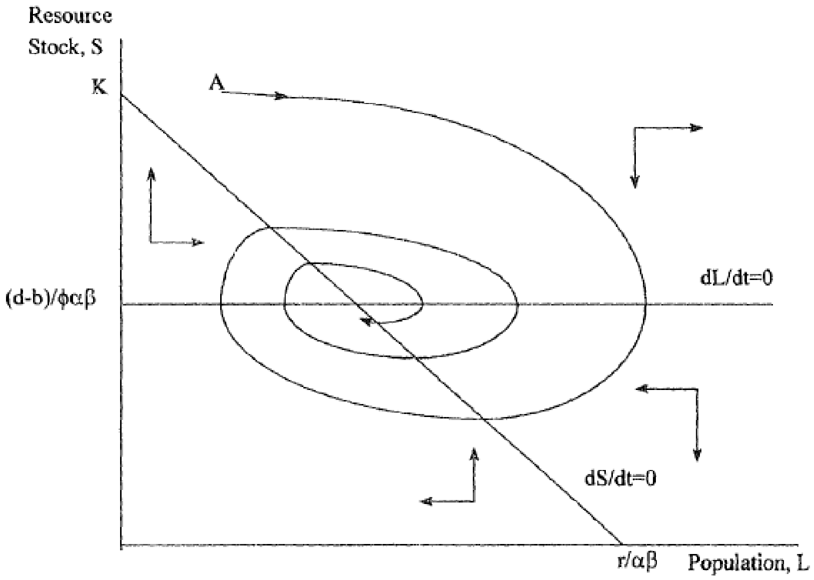
- A harvested natural stock, *S*, with logistic growth
- Maximization of utility, fixed resource stock and human population, and full employment at any point in time
- Labour (human population), *L*, grows with harvest

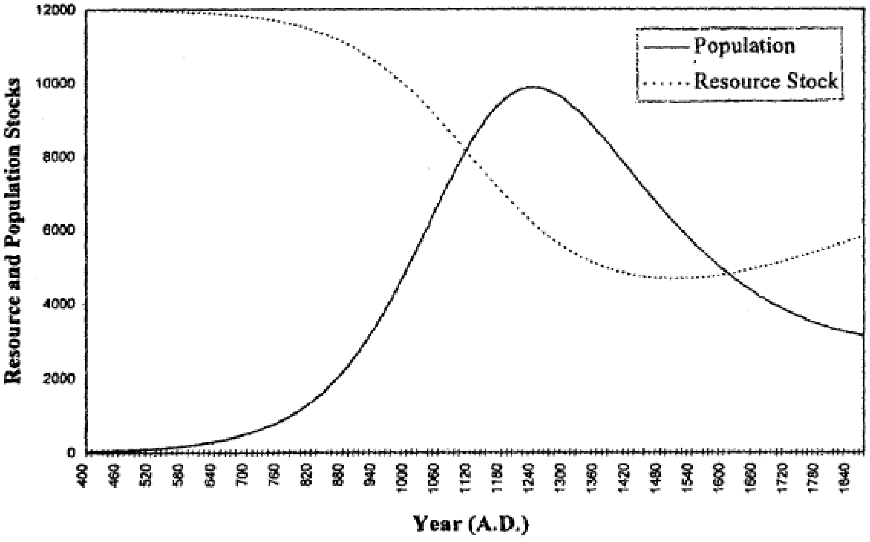
This yields a Lotka−Volterra predator−prey model:

$$dS/dt = rS(1 - S/K) - \alpha\beta LS$$
$$dL/dt = L(b - d + \phi\alpha\beta S)$$

Brander & Taylor, *Am. Econ. Rev.* 88: 119–138 (1998)

Economics = Ecology:
Dynamics of human–nature interactions





Brander & Taylor, *Am. Econ. Rev.* 88: 119–138 (1998)

Dynamics of human−nature interactions: An evolutionary suicide?

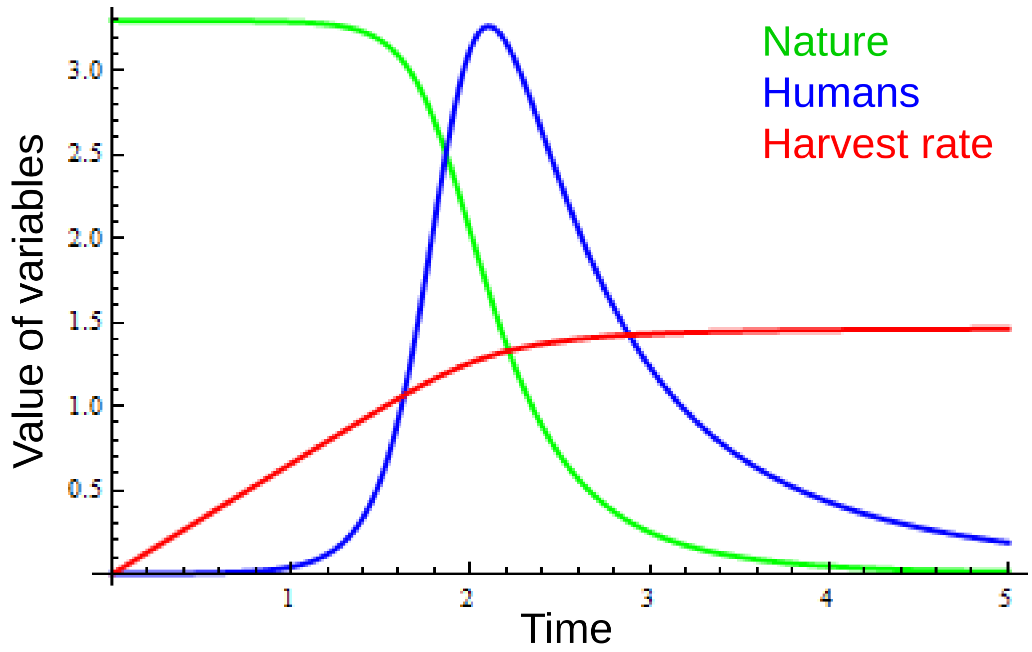
Lotka−Volterra predator−prey model with Allee effect in prey, intraspecific competition in predators, and evolution of predator attack rate:

$$\frac{dx}{dt} = x(-1 + rx - x^2 - \alpha y),$$

$$\frac{dy}{dt} = y[-d - y + (\alpha + 1)x],$$

$$\frac{d\alpha}{dt} = \epsilon x.$$

Webb, *Am. Nat.* 161: 181–205 (2003)



Dynamics of human–nature interactions: Conditions for collapse

Generalisation of Brander & Taylor's (1998) model:

$$\frac{dS}{dt} = N(S) - H(S, L) \qquad \textit{Natural stock}$$

$$\frac{dL}{dt} = r(S)L \qquad \textit{Labour (human population)}$$

Three conditions for "environmental crisis" (complete collapse):

- Weak governance
- Positive feedback from stock reduction to harvesting
- Tipping point = Allee effect in $N(S)$

Taylor, *Can. J. Econ.* 42: 1240–1275 (2009)

Conclusions

- Ecological and economic models differ in their basic assumptions: ecology views organisms as blind agents embedded in ecological systems they do not control; economics views humans as rational agents that control ecological systems from outside
- These differences reflect implicit differences in the spatial and temporal scales considered
- These differences tend to vanish in models of long-term dynamics of human–nature interactions, in which economics reveals itself as human ecology
- Both ecology and economics would gain from taking the perspective of the other discipline into account

Conclusions

- Population fluctuations, collapses, and extinctions are common in ecological systems, and there is growing evidence that they are also common in human societies
- The question, “Can a collapse of global civilization be avoided?” (Ehrlich & Ehrlich 2013), is a very serious and reasonable one
- Ecological theory could pay more attention to features such as foresight, behavioural changes, and innovations; although these features are particularly developed in humans, they also exist in other organisms