UE Introduction à l'écologie du développement durable

2: une histoire de l'écologie

Enseignant : David Claessen

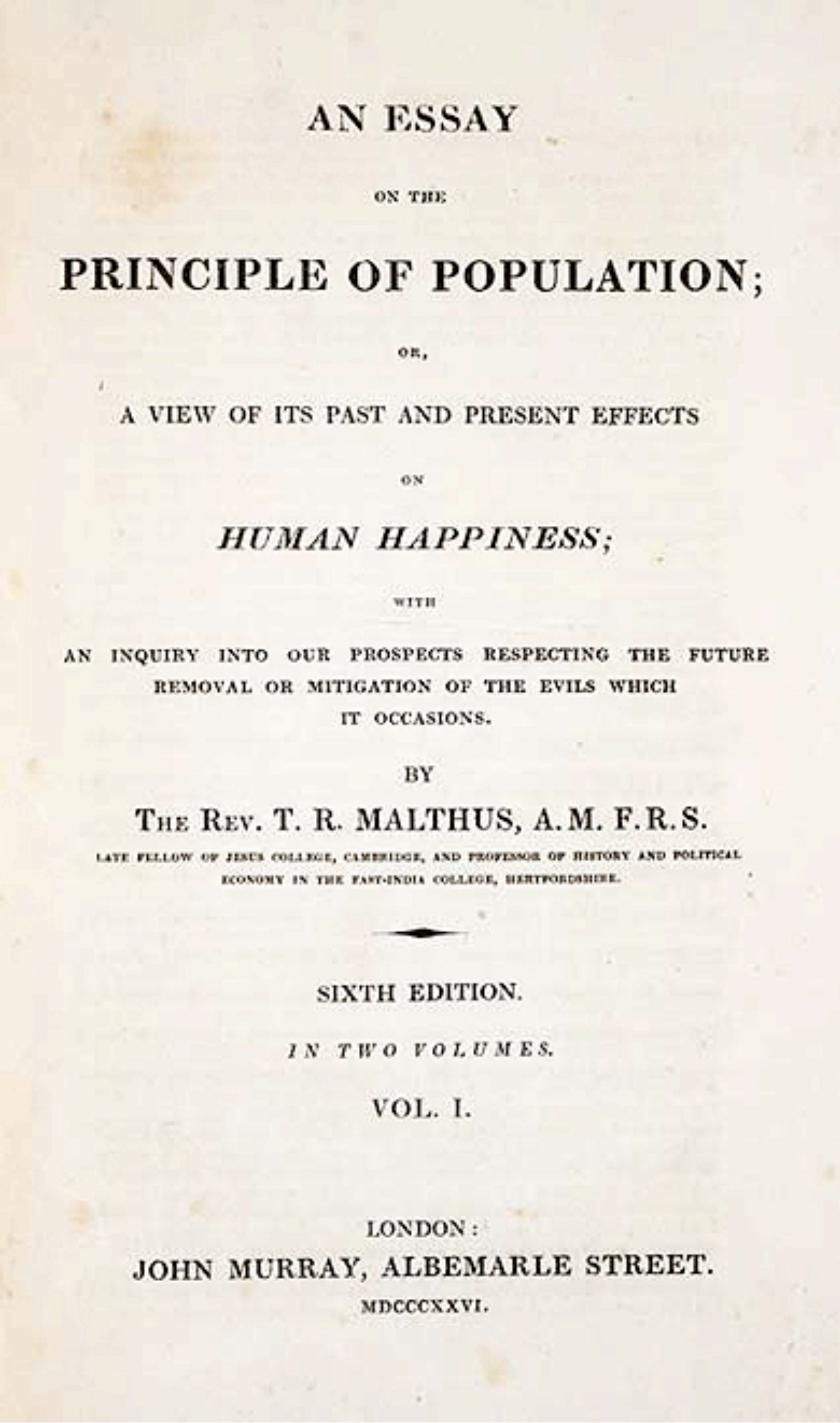
Centre de formation s sur l'environnement et la société (CERES)
et Institut de Biologie de l'ENS (IBENS)
École normale supérieure, 24 rue Lhomond, 75005 Paris

Histoire des idées

- 1798 **Malthus** « ***population****, croissance exponentielle, limitation* »
- 1805 **Von Humboldt** « *géographie des plantes* »
- 1809 **Lamarck** « *individu,* ***évolution****, transmutation* »
- 1838 **Verhulst** « *fonction logistique* »
- 1859 **Darwin**, **Wallace** « *biocénose,* ***lutte pour la vie, sélection naturelle, fitness*** »
- 1866 **Haeckel** « ***écologie*** »
- 1875 **Suess, Vernadsky** « *biosphère* »
- 1910 **Lotka, Volterra** « *écologie mathématique, cycles prédateur-proie* »
- 1911 **Cowles, Clements** « *succession écologique* »
- 1927 **Charles Elton** « *niche écologique, chaine trophique, écologie animale* »
- 1932 **Gause** « *principe d'exclusion compétitive* »
- 1935 **Tansley, Lindeman, Odum** « ***écosystème*** »
- 1947 **Lack** « *écologie évolutive* »
- 1957 **Hutchinson** « ***niche écologique*** »
- 1962 **Rachel Carso**n « *environnement, environmentalism, écologisme* »
- 1963 **Holling, McArthur**, **Rosenzweig** « *réponse fonctionnelle, paradox of enrichment* »
- 1973 **Maynard-Smith** « *théorie des jeux, stratégie évolutivement stable (ESS)* »
- 1976 **McArthur, Wilson** « *la biogéographie insulaire* »
- 1969 **Levins** « *métapopulations* »
- 1976 **May** « *chaos* »
- 1988 **Wilson** « ***biodiversité*** »
- 1990 **Anonymous** « ***services écosystémiques*** »
- 1998 **Levin** « *système complexe adaptatif* »

« écologie »

- 1866, le biologiste Ernst Haeckel
- « (...) la science des relations des organismes avec le monde environnant, c'est-à-dire, dans un sens large, la science des conditions d'existence. »
- « écologie », « ***oekologie*** »
  - Grec *oikos* (« maison », « habitat ») et *logos* (« science », « connaissance »)
  - « la science de l'habitat »


AN ESSAY

ON THE

PRINCIPLE OF POPULATION;

OR,

A VIEW OF ITS PAST AND PRESENT EFFECTS

ON

HUMAN HAPPINESS;

WITH

AN INQUIRY INTO OUR PROSPECTS RESPECTING THE FUTURE REMOVAL OR MITIGATION OF THE EVILS WHICH IT OCCASIONS.

BY

THE REV. T. R. MALTHUS, A.M. F.R.S.

LATE FELLOW OF JESUS COLLEGE, CAMBRIDGE, AND PROFESSOR OF HISTORY AND POLITICAL ECONOMY IN THE EAST-INDIA COLLEGE, HERTFORDSHIRE.

SIXTH EDITION.

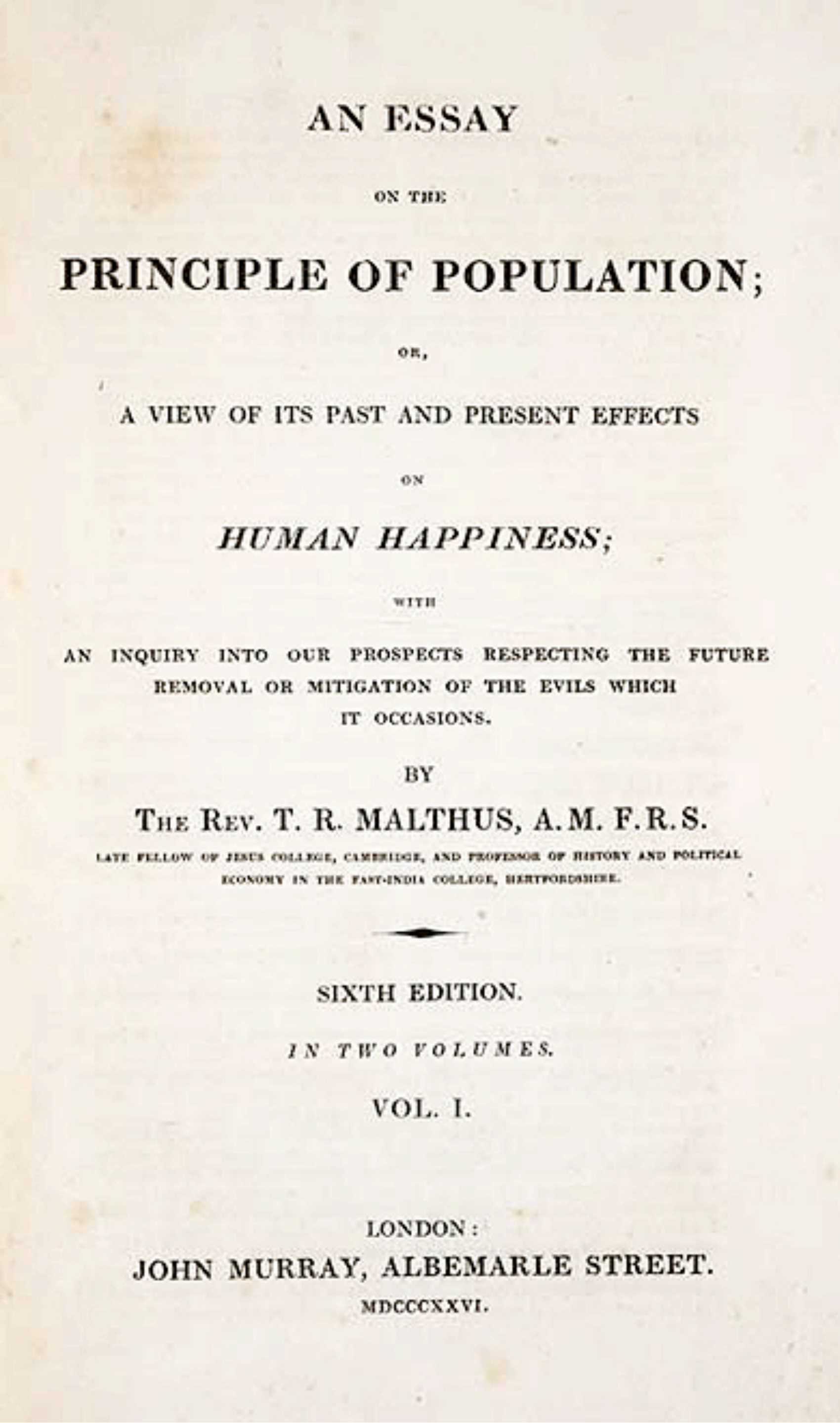
IN TWO VOLUMES.

VOL. I.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
MDCCCXXVI.

Thomas Robert Malthus

- The increase of population is necessarily limited by the means of subsistence;
- The population does invariably increase when the means of subsistence increase;
- The superior power of population is repressed, and the actual population kept equal to the means of subsistence, by misery and vice.


AN ESSAY

ON THE

PRINCIPLE OF POPULATION;

OR,

A VIEW OF ITS PAST AND PRESENT EFFECTS

ON

HUMAN HAPPINESS;

WITH

AN INQUIRY INTO OUR PROSPECTS RESPECTING THE FUTURE REMOVAL OR MITIGATION OF THE EVILS WHICH IT OCCASIONS.

BY

THE REV. T. R. MALTHUS, A.M. F.R.S.

LATE FELLOW OF JESUS COLLEGE, CAMBRIDGE, AND PROFESSOR OF HISTORY AND POLITICAL ECONOMY IN THE EAST-INDIA COLLEGE, HERTFORDSHIRE.

SIXTH EDITION.

IN TWO VOLUMES.

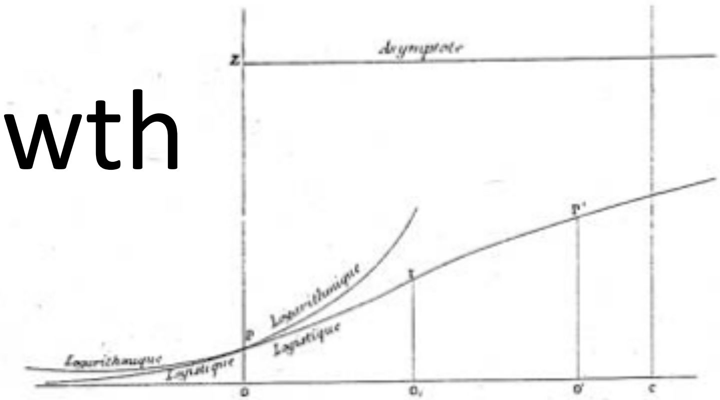
VOL. I.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
MDCCCXXVI.

Thomas Robert Malthus

- The increase of population is necessarily limited by the means of subsistence;
- The population does invariably increase when the means of subsistence increase;
- The superior power of population is repressed, and the actual population kept equal to the means of subsistence, by misery and vice.

Logistic growth



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

$$N(t) = \frac{K}{1 + CKe^{-rt}}$$

Mathématicien, inspiré par le « principe de population » de Malthus, il proposa en 1838 ce modèle pour la dynamique des populations animales grâce à un modèle qui ne soit pas exponentiel.

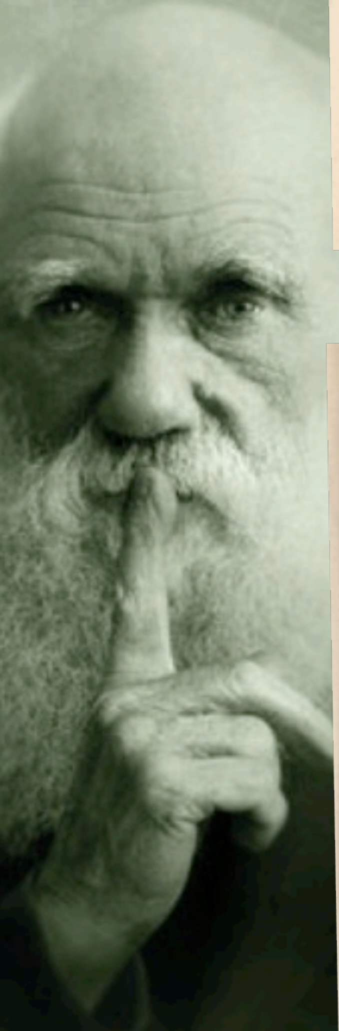
K = capacité de charge
r = taux intrinsèque de croissance

Redecouvert en 1920 par Raymond Pearl et Lowell Reed, depuis très répandu en écologie

Charles Darwin (1859) identified the « struggle for existence »,

in combination with heritable variation,

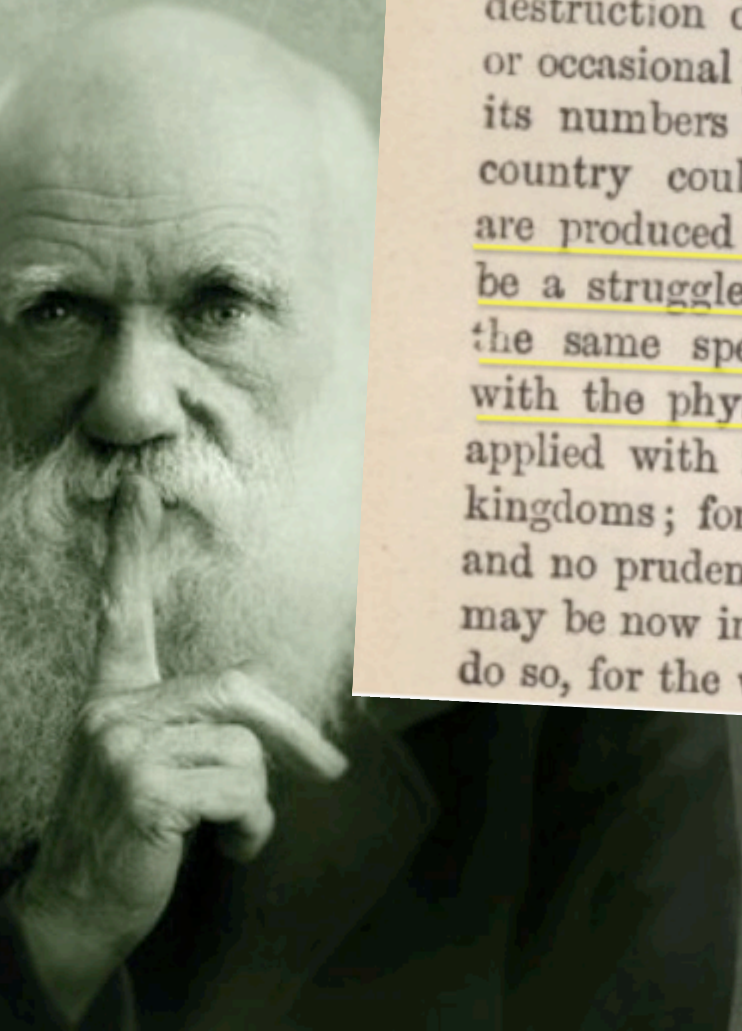
as the driving force of evolutionary change.



organic world.

Again, it may be asked, how is it that varieties, which I have called incipient species, become ultimately converted into good and distinct species, which in most cases obviously differ from each other far more than do the varieties of the same species? How do those groups of species, which constitute what are called distinct

genera, and which differ from each other more than do the species of the same genus, arise? All these results, as we shall more fully see in the next chapter, follow from the struggle for life. Owing to this struggle, variations, however slight, and from whatever cause proceeding, if they be in any degree profitable to the individuals of a species, in their infinitely complex relations to other organic beings and to their physical conditions of life, will tend to the preservation of such individuals, and will generally be inherited by the offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species



Geometrical Ratio of Increase.

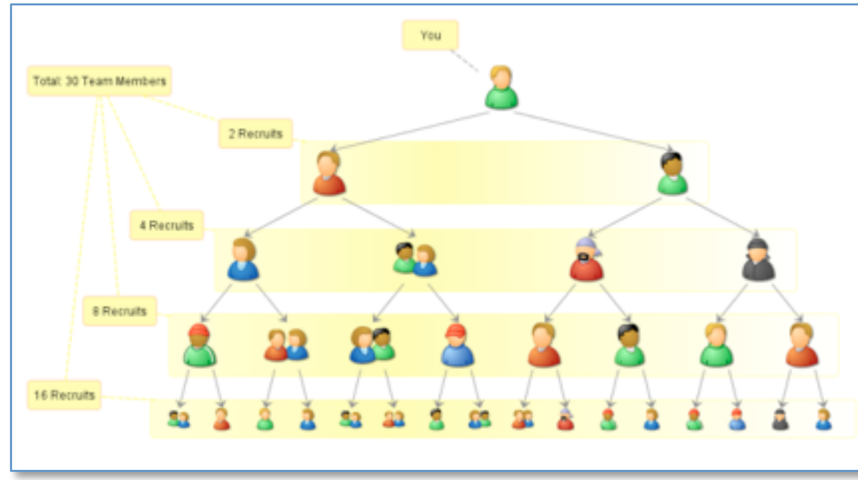
A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. Hence, as more individuals are produced than can possibly survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms; for in this case there can be no artificial increase of food, and no prudential restraint from marriage. Although some species may be now increasing, more or less rapidly, in numbers, all cannot do so, for the world would not hold them.

The Complete Work of Charles Darwin Online (http://darwin-online.org.uk/)

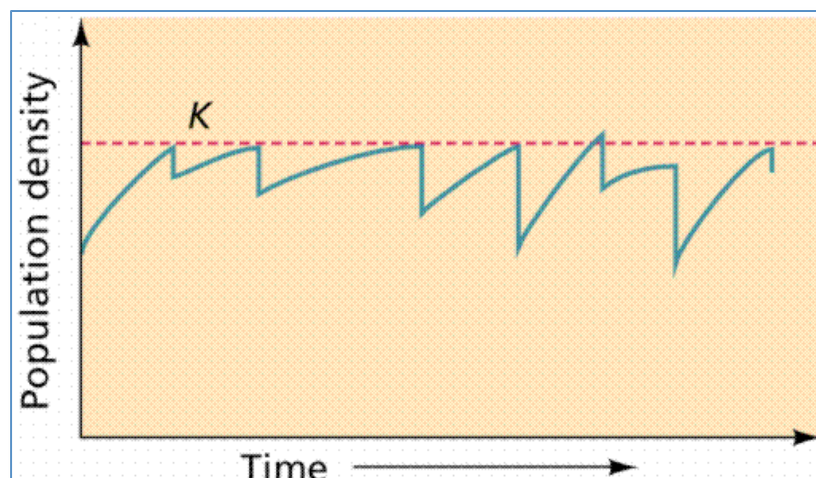
The origin of this struggle

« It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms »

Two basic observations:



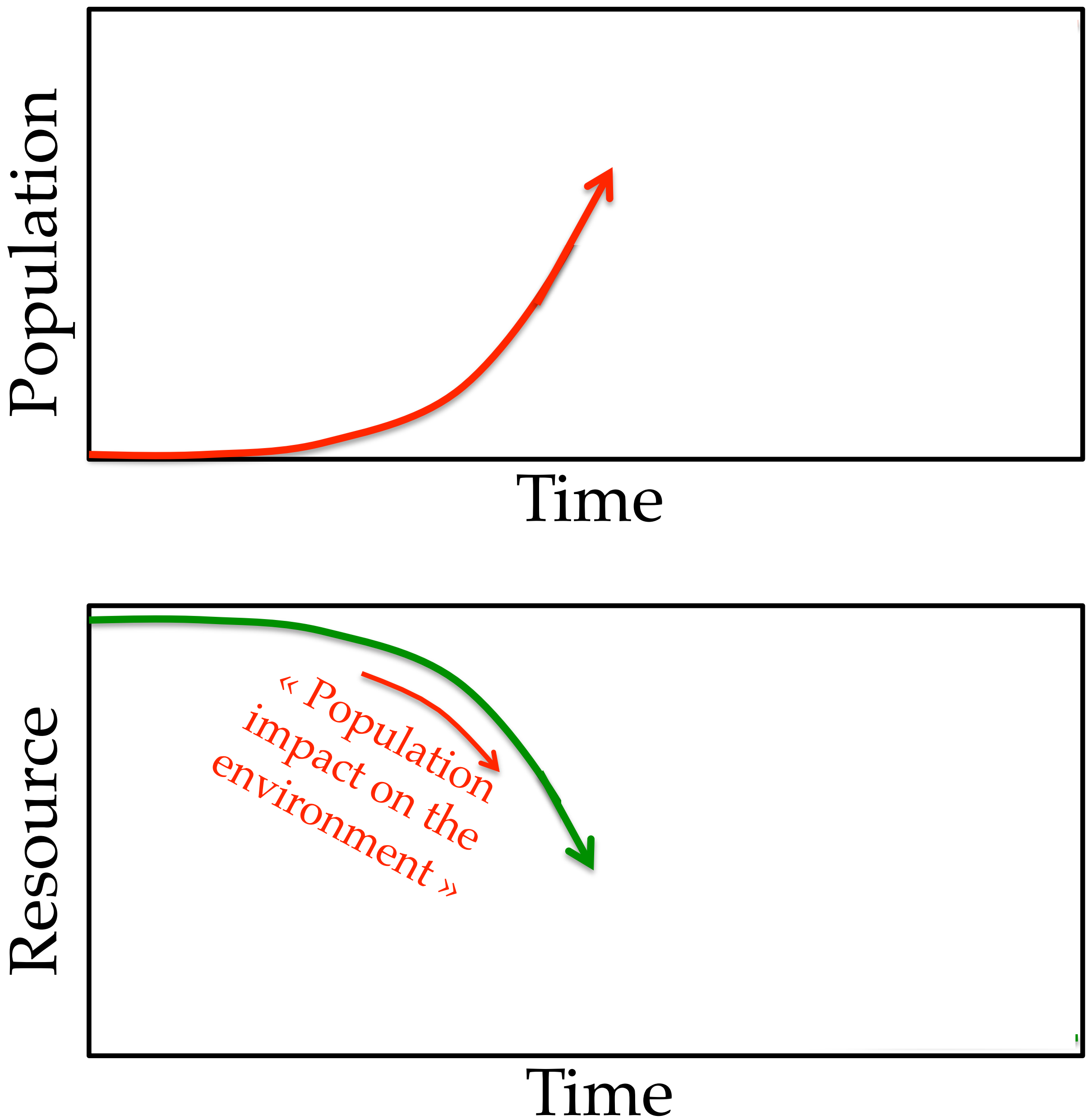
1. All populations tend to grow exponentially

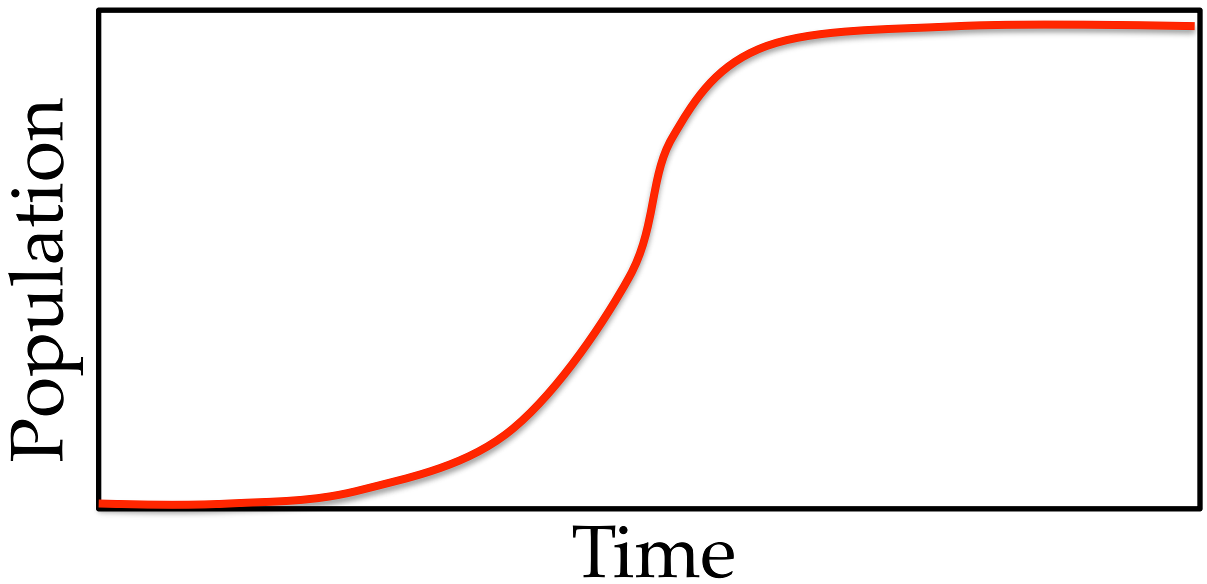


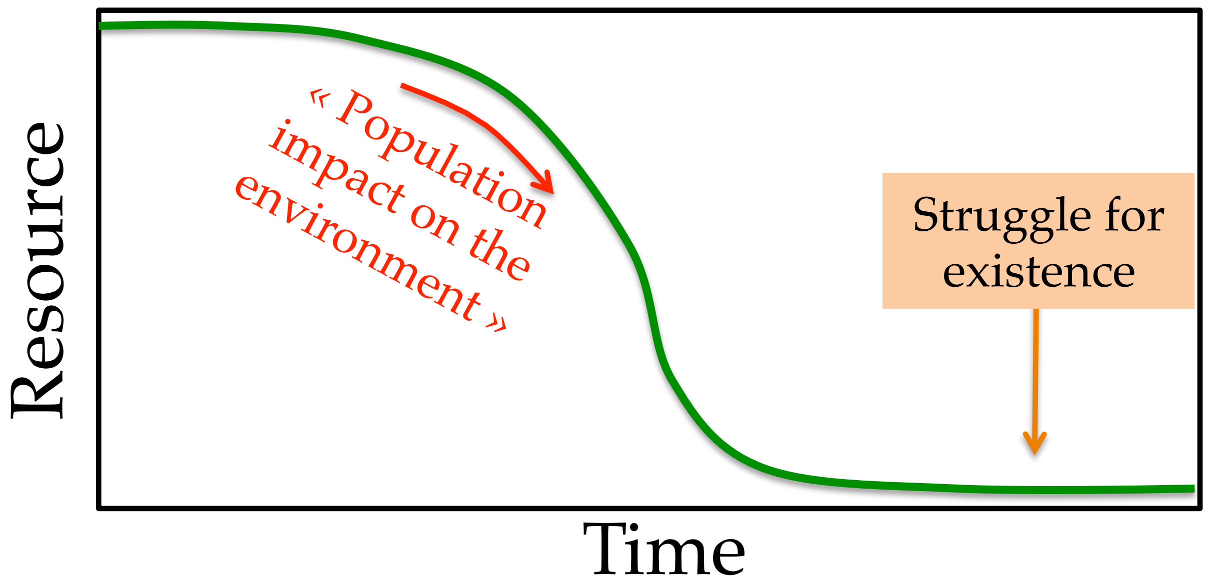
2. Exponentially growing populations are kept in check by regulatory mechanisms
   – *Food depletion, predation, disease, competition, etc*

Struggle for existence

- As a population grows exponentially, its impact on the environment is such that conditions get less favorable for population growth
- This results in population regulation
- In combination with heritable variation, this also results in natural selection (or: survival of the fittest)


Population
Time
Resource
« Population impact on the environment »
Time


Population
Time

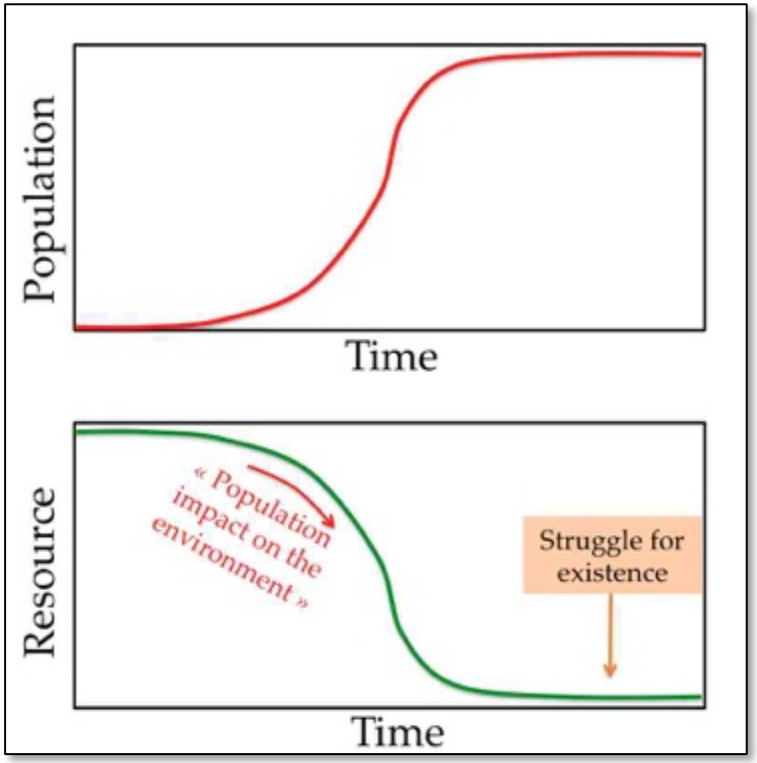

Resource
« Population impact on the environment »
Struggle for existence
Time

Feedback loop

- The struggle for existence corresponds to a feedback loop:
  - The environmental conditions determine the population growth rate

↓↑

  - The population size determines the environmental conditions



It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with Reproduction; Inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the external con-

490 CONCLUSION. CHAP. XIV.

ditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less-improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.

First global scientific explorations

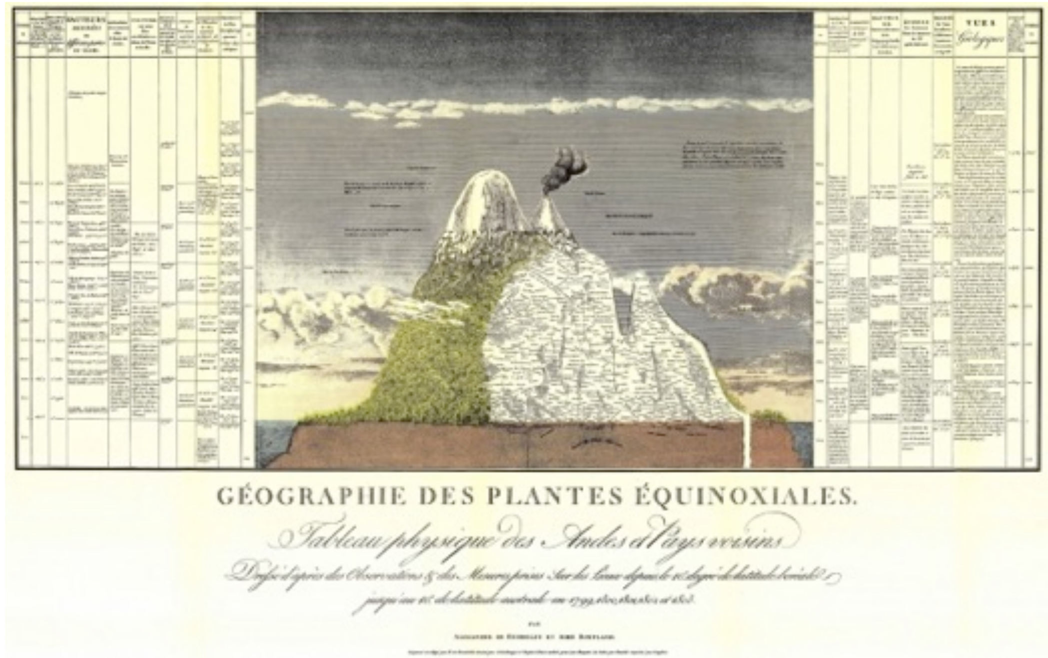
Alexander von Humboldt : *Essai sur la géographie des plantes* (1805).
Alphonse de Candolle : *Géographie botanique raisonnée* (1855).

On the slopes of the Chimborazo, a 6,310 m high volcanic peak in the Andes Mountains of Ecuador, Alexander von Humboldt and Aimé Bonpland recorded the altitudinal distribution of plants and multiple physical characteristics of the environment.

Alexander von Humboldt

Humboldt's Scientific Representation of the Chimborazo
Humboldt, Essai sur la géographie des plantes (1805–1807)

The image is flanked by extensive descriptions, his attempt to correlate vegetation to everything from altitude to zoological life to rainfall and temperature.



"In **these immense chains of cause and effect**, nothing can be regarded in isolation. The **overall equilibrium** which exists throughout major **perturbations** is the result of an **infinite range of mechanical forces and chemical reactions** all of which balance each other. While each series of facts needs to be **studied separately** in order to discover its own rules of order, the general study of nature demands that all knowledge about transformations of matter be then **combined**."

Géographie des plants

- Alexandre de Humboldt, « *Essai sur la géographie des plantes* », 1805 ;
- Alphonse de Candolle, « *Géographie botanique raisonnée* », 1855.

Eugen Warming, professeur de botanique à l'Université de Copenhague, qui publie en 1895 un traité de géobotanique végétale portant en titre le mot « écologie ». Il y est notamment écrit :

« *La géographie végétale traite de la distribution des plantes à la surface de la terre, et des principes qui la déterminent. Nous pouvons considérer cette distribution de deux points de vue différents, et, en conséquence, diviser cette science en deux branches, la géobotanique floristique et la géobotanique écologique* ».

Géographie des plants

- Alexandre de Humboldt, « *Essai sur la géographie des plantes* », 1805 ;
- Alphonse de Candolle, « *Géographie botanique raisonnée* », 1855.

Eugen Warming, professeur de botanique à l'Université de Copenhague, qui publie en 1895 un traité de géobotanique végétale portant en titre le mot « écologie ». Il y est notamment écrit :

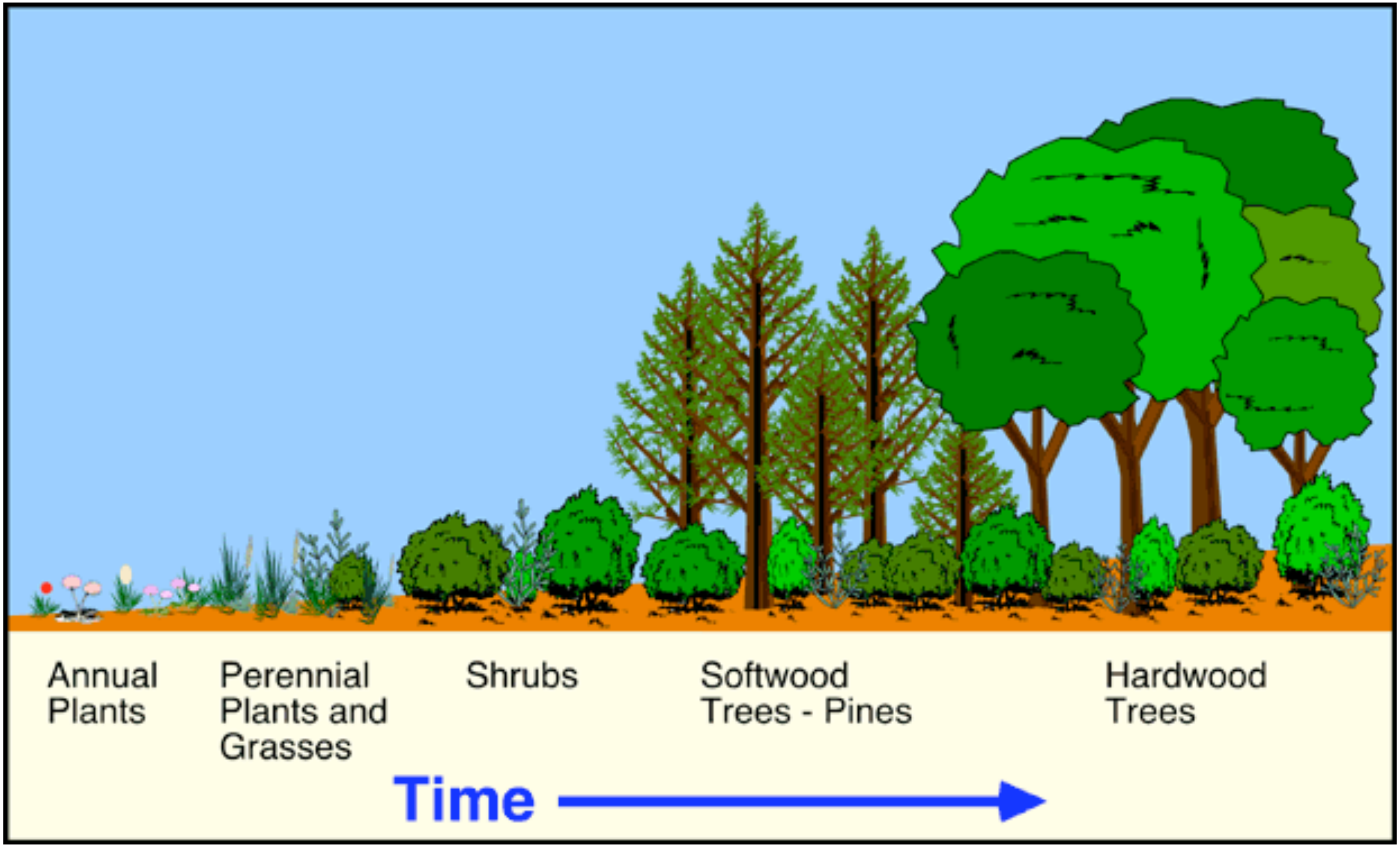
« *La géographie végétale traite de la distribution des plantes à la surface de la terre, et des principes qui la déterminent. Nous pouvons considérer cette distribution de deux points de vue différents, et, en conséquence, diviser cette science en deux branches, la géobotanique floristique et la géobotanique écologique* ».

Expansion aux USA

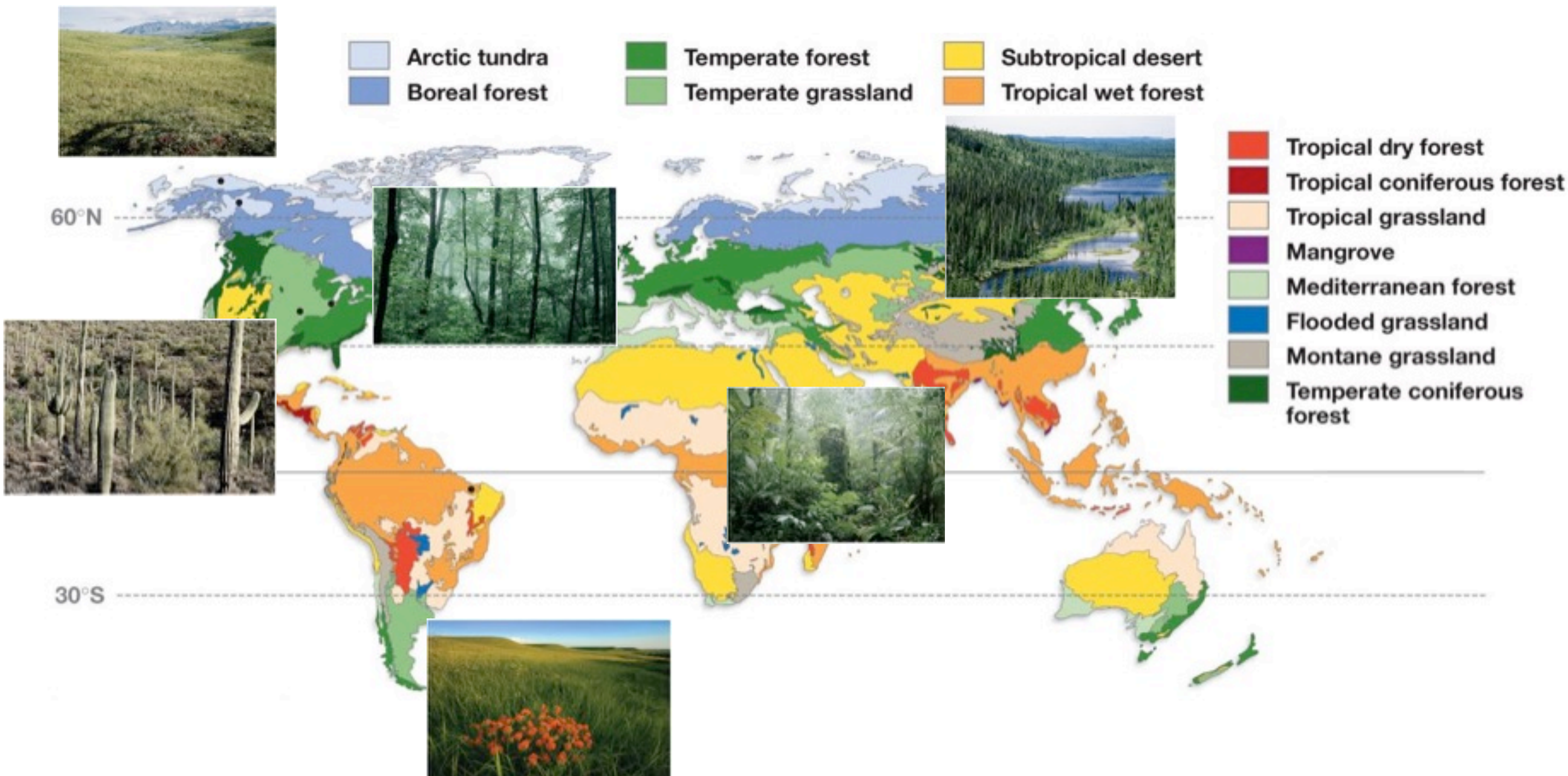
(besoin économique, vastes écosystèmes aux USA, inventorier les richesses)

- Henry Chandler Cowles, qui publie en 1899 sa thèse sur les successions végétales ;
- Frédéric Clements, qui publia en 1905 son « *Research methods in ecology* » puis en 1916, « *Plant succession* ». Influencé par Cowles, il y développe l'idée d'une homéostasie des formations végétales. Celles-ci sont assimilées à des superorganismes.

Succession écologique



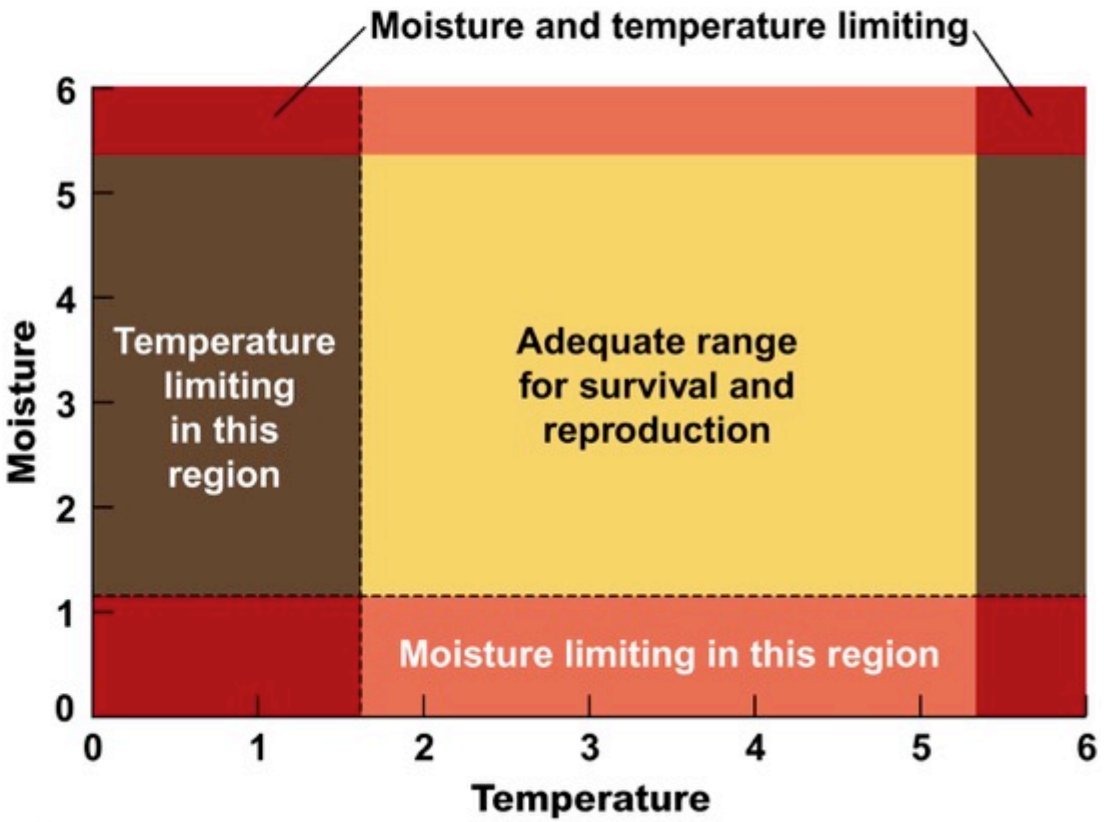
Frederic E. Clements (1916) identified major types of terrestrial **communities** based on **vegetation types.** Each vegetation type **develops** as a **succession** culminating in a **climax,** which Clements treat as a **'super-organism'.**



Clements' view was highly criticized by **Gleason (1926)**, who opposed an **individualistic (species-wise) approach** to communities. The concept of **ecological niche**, proposed by **Joseph Grinnell (1911)** and **Charles S. Elton (1927),** opened an alternate route to thinking about diversity.

Grinnellian niche = what the species ***needs***

Eltonian niche = what the species ***does***



Ecologie animale

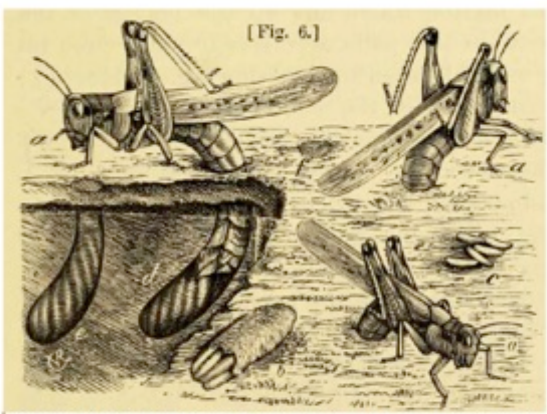
- 1907 Shelford, travaille avec Clements. Distribution d'insects en relation avec succession végétale
- « Equivalence ecologique »
  - Des espèces jouant le même rôle dans des communautés écologiques différentes
  - Ex Labbes et Frégates, se nourrissent par piratage des proies de sternes, en zone septentrionales ou tropicales
- 1927 Charles Elton **« niche écologique »**

Ces travaux conduiront ultérieurement Charles Elton (1927) à assigner au concept de niche écologique[2] un contenu strictement fonctionnel : « *Il est commode (…) de disposer d'un terme qui décrive le statut d'un animal dans sa communauté pour indiquer ce qu'il y fait et pas seulement à quoi il ressemble, et le terme utilisé est celui de niche* ».

Ecologie animale

- Lutte biologique
- Charles V Riley
  - Entomologiste amateur
- Lutte contre les ravageurs
- Jeunes USA, expansion vers ouest, monocultures de mais, blé, coton, tabac, vigne
- Conditions pour graves problèmes liés au pullulations de ravageurs importés ou indigènes
  - Phylloxera, parasite de la vigne.
  - Solution: greffe de plantes résistantes
  - Cochenille australienne, ravageur des plantations californiennes d'agrumes (depuis 1868)
  - 1889 : introduction de 10,000 coccinelles résulte en régulation

Icerya purchasi et *Rodolia cardinalis*, **larves et adultes** - *Cliché J. d'Aguilar*



Melanopus spretus, le "Rocky mountain locust", espèce aujourd'hui disparue. Différentes vues de la femelle oviposant, de l'oothèque et des œufs. *Dessin de Ch. V. Riley, in : The locust plague in the United States: being more particularly a treatise on the Rocky Mountain locust or so-called grass-hopper, as it occurs east of the Rocky Mountains, with practical recommendations for its destruction, 1877.*

Ecologie animale

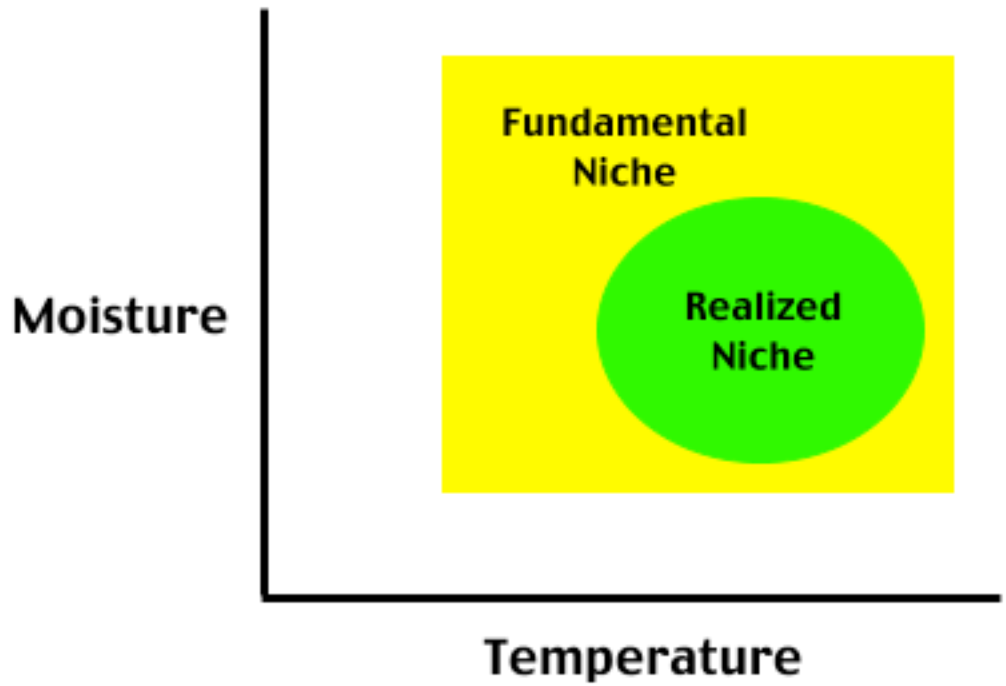
- Charles Elton 1927, *« Animal ecology »*
  - **Niche écologique**
  - **Structure pyramidale des populations d'une biocénose**
  - **Chaine alimentaire**
  - **Reseaux trophique**

- **Les bases de l'écologie des populations**
- (Sans évolution !)

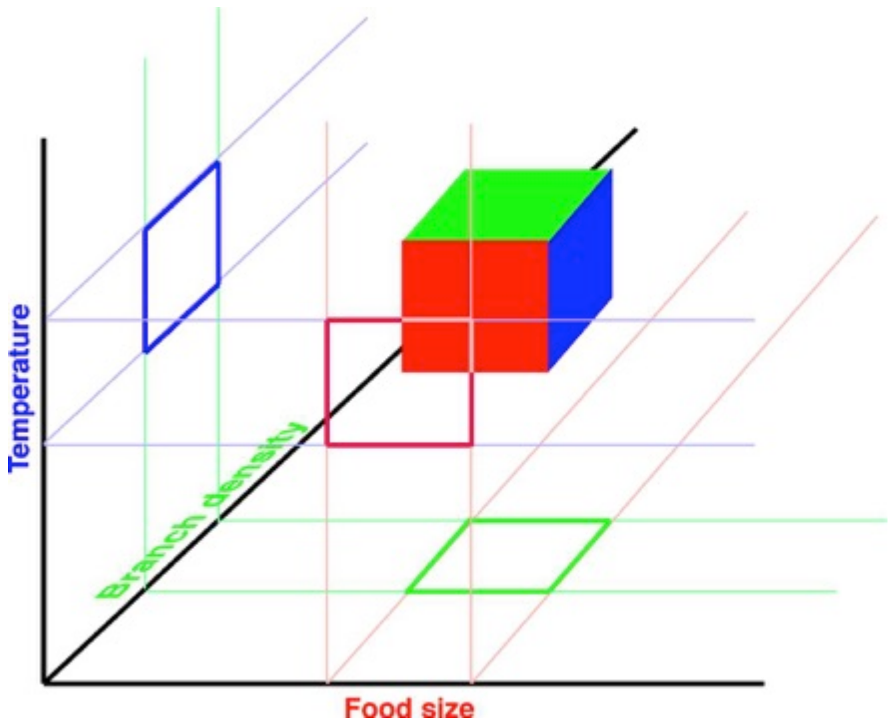
Charles Elton with a sack of mouse traps headed for a survey trip (from Chitty 1996, p. xvi)

L'écologie moderne 1950-70

- George Evelyne Hutchinson
  - Raymond Lindeman, Robert MacArthur, Eugene Odum, Howard Odum, Lawrence Slobodkin, Rachel Carson, …
- 1928 Yale
  - Cycles trophiques, biogeochimiques, écosysteme
- 1957 formalisation du concept du « **niche écologique** » : « hypervolume à n dimensions » dont chaque dimension, biologique ou physique, représenterait une ressource utilisable par les populations de la biocénose
- 1953: Odum & Odum « Fundamentals of ecology » « **ecosystem** »


Fundamental
Niche
Realized
Niche
Moisture
Temperature

G. Evelyn Hutchinson (1957) developed a quantitative model of the Grinnelian niche as a **multidimensional hypervolume** defined by axes of **resource** use and/or environmental **conditions,** within which populations of a species are able to maintain a **viable population**.



Fundamental niche = defined in the absence of competitors and natural enemies
Realized niche = observed in presence of all interactions

The concept of niche prompted fundamental questions about **populations**: when is a population viable? Can we predict **populations coexistence,** hence diversity, from the species' niche characteristics? The **Malthusian law** is the foundational principle: **Populations grow exponentially.**

Thomas Malthus (1798) *Essai sur le Principe de Population.*

$$\boxed{\frac{dn}{dt} = (b - d)\,n}$$

n = population density
b = birth rate
d = death rate
r = *b* – *d* = intrinsic per capita rate of increase

This principle will be generalized in 1945 by **P.H. Leslie** to **age-structured populations.**

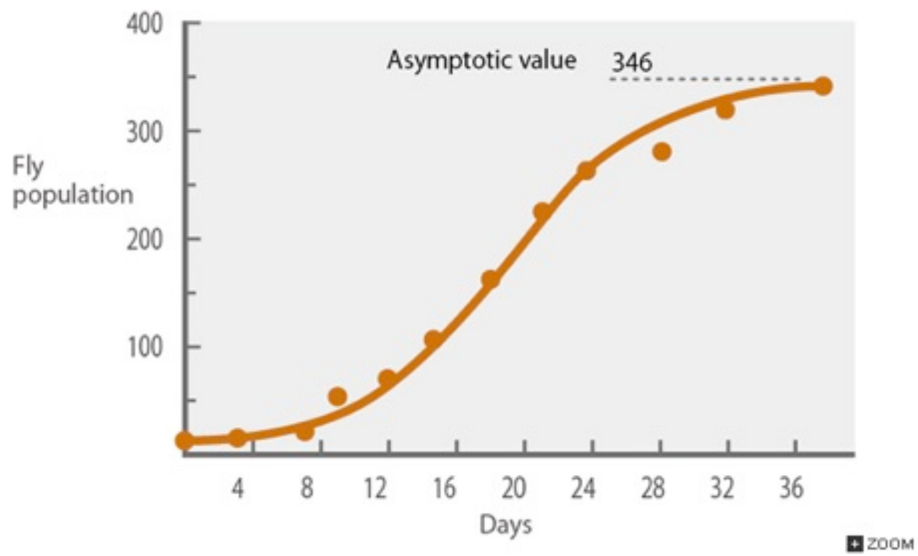
Populations are **regulated** by **negative density-dependence** due to **competition for limiting resources**

Pierre-François Verhulst (1838) *Notice sur la Loi que la Population Suit dans son Accroissement.*

"Logistic" model:

$$\boxed{\frac{dn}{dt} = r\left(1 - \frac{n}{K}\right)n}$$

r = intrinsic per capita growth rate
K = **carrying capacity**

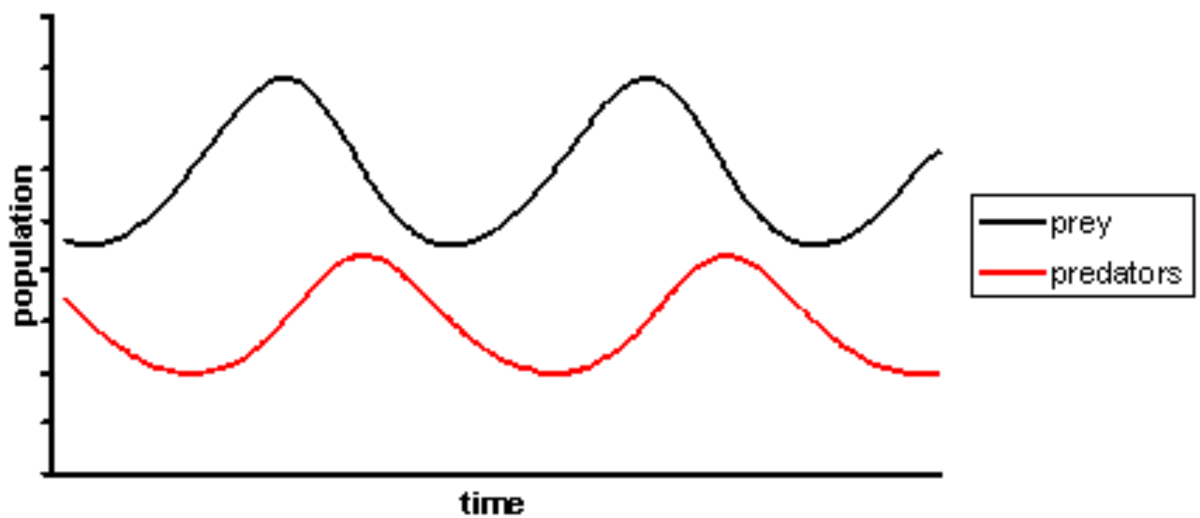


Populations can also be **regulated by enemies (predators). Prey-predator interaction** can cause populations to **oscillate** permanently

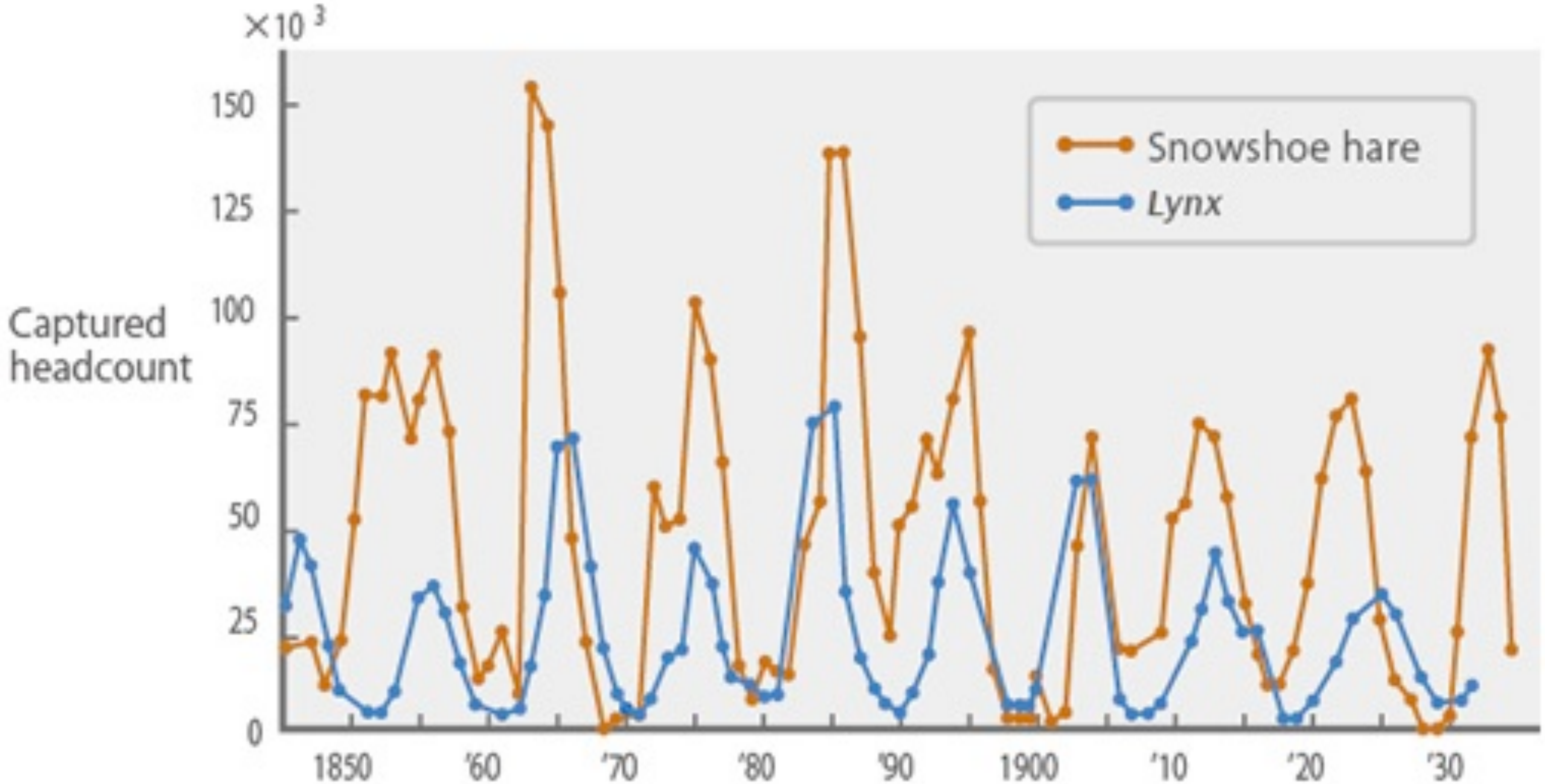
Lotka, A.J. (1910) Contribution to the Theory of Periodic Reaction. *J. Phys. Chem.* 14: 271–274 (1910).
Volterra, V. (1926) Fluctuctuations in the abundance of a species considered mathematically. *Nature* 118: 558-560.

x = prey density
y = predator density

$$dx/dt = (\alpha - \beta y)x$$
$$dy/dt = (-\gamma + \delta x)y$$



Prey-predator cycles may be apparent in **snowshoe hare – lynx** population time series from Canada



Data from McLulich (1937).