Introduction in ecology science. Population dynamics.

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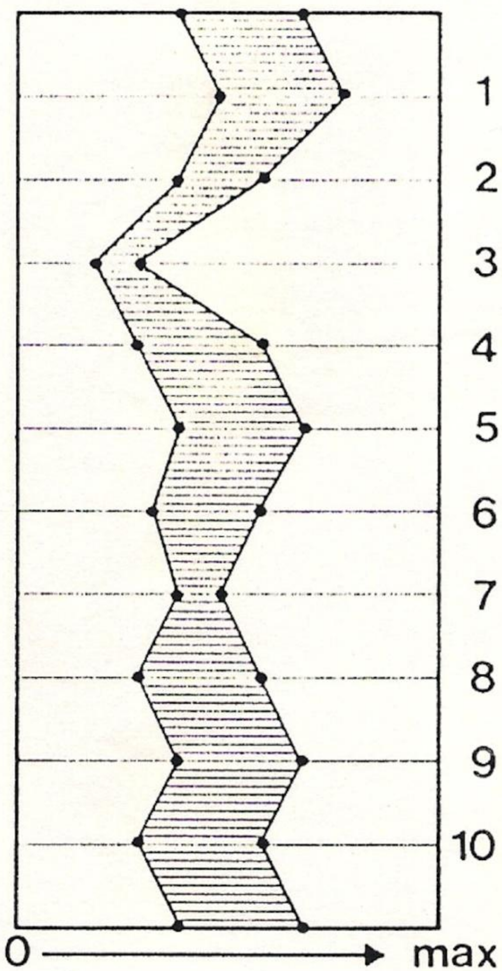
International Master in Architecture. Theme 3

Course Environmental Sustainability.

Population dynamics. The environment of a species.



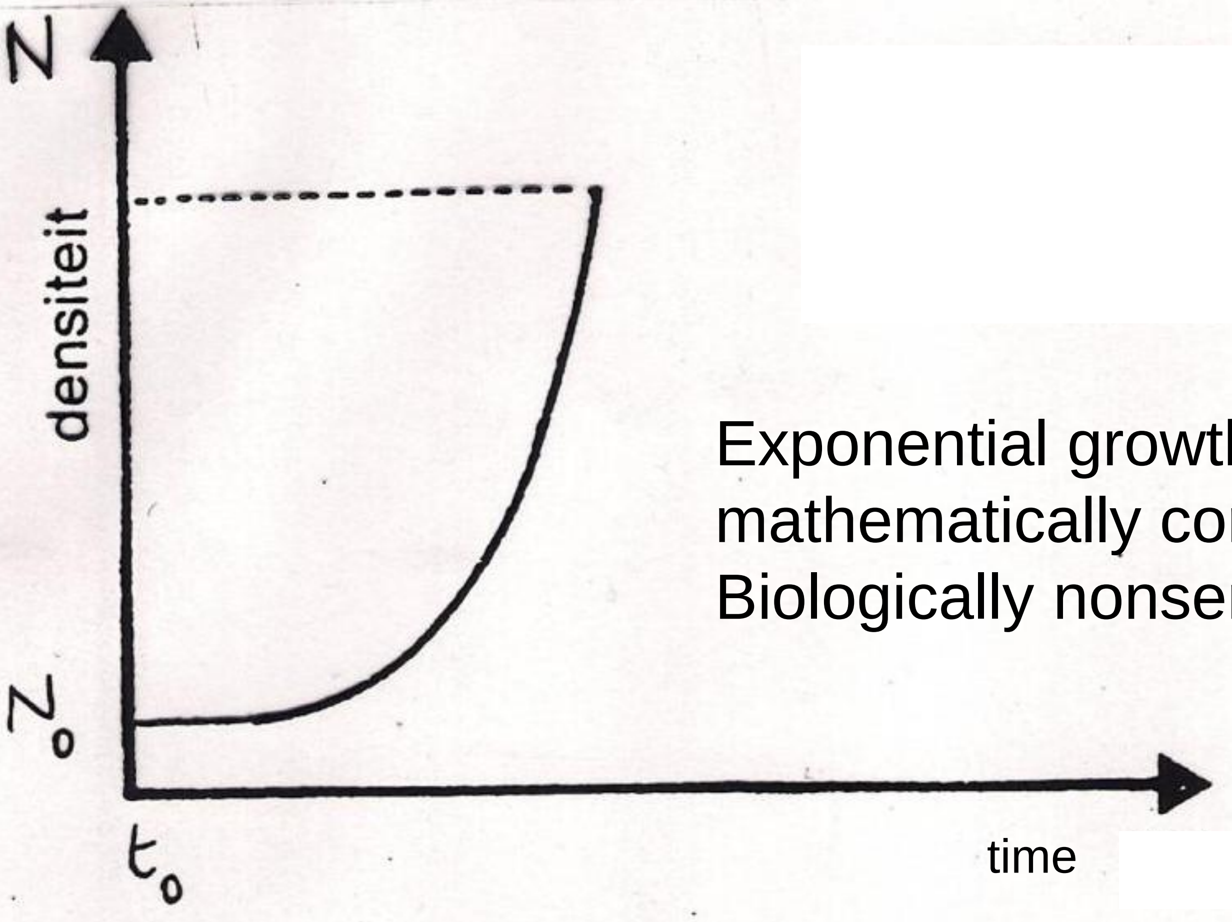
Amount of lime
pH
wind
Amount of loam
Grazing pressure
mowing frequency
Etc.…

Suppose, the environment of a species is favorable, all environmental conditions (both abiotic and biotic) are in order, that means within the tolerance width of the species.
That means within the shaded area of the diagram, left.

How large the species population can then be ? That is the subject of **"population dynamics"**

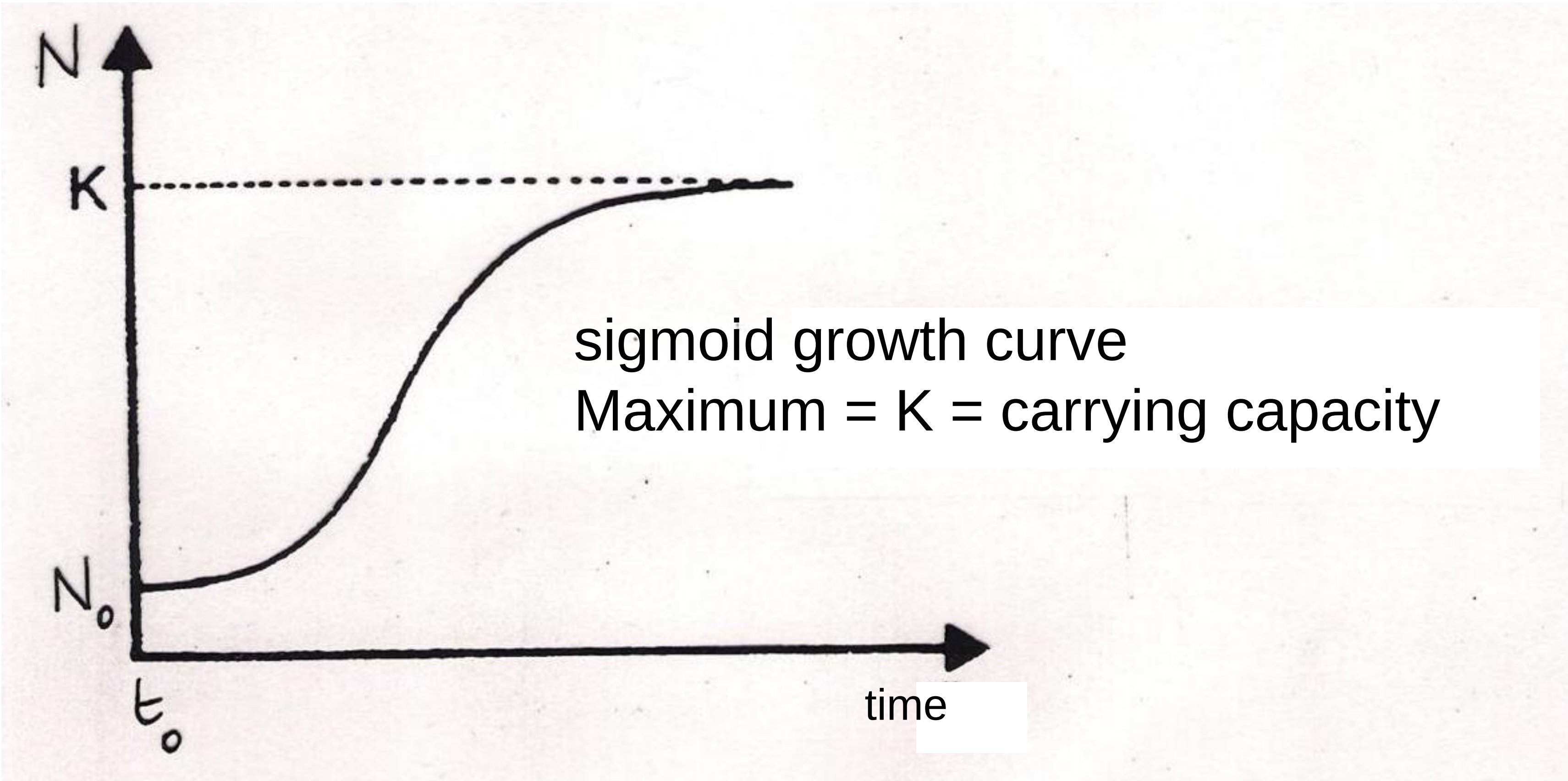
From SCHROEVERS, 1982

Theoretical exponential population growth curve with unlimited resources in an 'infinite' area.



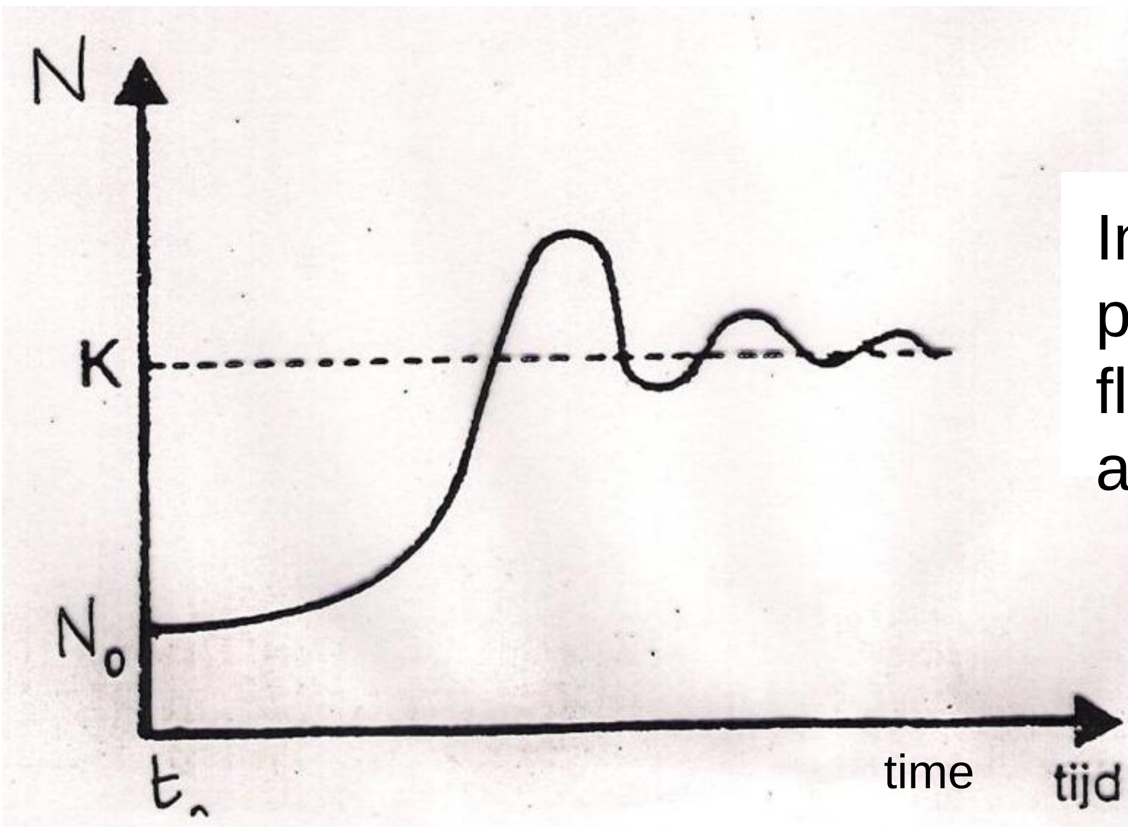
Exponential growth
mathematically correct
Biologically nonsense

In practice, the environment always has limits and limitations (space, food, ...), resulting in a maximum population size K.



Also this curve is biologically impossible, because this would mean that a species is aware in advance of the maximum number K, and takes into account this number while reproducing.

In reality, a growing population exceeds the carrying capacity, competition occurs and individuals die. As a consequence, population size will fluctuate around the carrying capacity.



In reality, the population size fluctuates around K

There is only one species that might escape from this scenario, because it is aware of the finiteness of resources. Man. Unfortunately ....

Population dynamics: mathematical approach.

Population growth is the result of natality (B) and mortality (D). Suppose the starting size N_0 beginning at time t_0 and size N at time t

Population growth is then: $dN / dt = B - D$ (1)

B and D of course depend on the size of the population: $B \sim N$ en $D \sim N$

$B = bN$ en $D = dN$ (2)

Maths: Replacement of a proportionality by an equality, introducing a species specific constant

Population dynamics: mathematical approach(2).

(2) in (1):

$dN/dt = bN – dN = (b – d) N$

r = intrinsic growth parameter of Malthus (= b – d)

r is species specific

r is high in many insects, rodents.

r is low in mammals and birds (Dajoz, 1975)

$$dN/dt = rN$$

r-value of some animal species (Dajoz, 1975)

Tableau XIV. — *Valeur du coefficient d'accroissement r pour quelques populations animales.*

Espèces et conditions de milieu	*Valeur de r par femelle et par an*	*Augmentation de la population par an* = e^r
Insectes :		
Sitophilus oryzae à 29 °C ...	39,6	$1,58 \cdot 10^{16}$
— à 23 °C ...	22,4	$5,34 \cdot 10^{8}$
— à 33,5 °C .	6,2	493
Tribolium castaneum à 28,5 °C et 65 % d'humidité relative	36,8	$1,06 \cdot 10^{16}$
Mammifères :		
Microtus agrestis	4,5	90
Rattus norvegicus...........	5,4	221
Homme.	0,005 5	1,0055

Population dynamics: mathematical approach(3).

solution of the equation: $dN / dt = rN$

$$\int dN / dt = \int rN$$

$$\ln N = rt + cte$$ (als $t = 0$ is $N = N_0$, dan is $\ln N_0$ een constante)

$$\ln N = rt + \ln N_0$$

$$\ln N - \ln N_0 = rt$$

$$\ln (N / N_0) = rt$$

$$N / N_0 = e^{rt}$$

$$N = N_0 . e^{rt}$$

This is an exponential function, depending on r.
Mathematically o.k., biologically nonsense.

Population dynamics: mathematical approach(4).

In reality, there is a biological maximum in any ecosystem. The mathematical representation must be given a maximum K:

dN / dt = r . N (K-N / N) , which means that if N = K then dN / dt = 0

At that moment, population growth stops, the curve gets a maximum

$N_{max} = K$

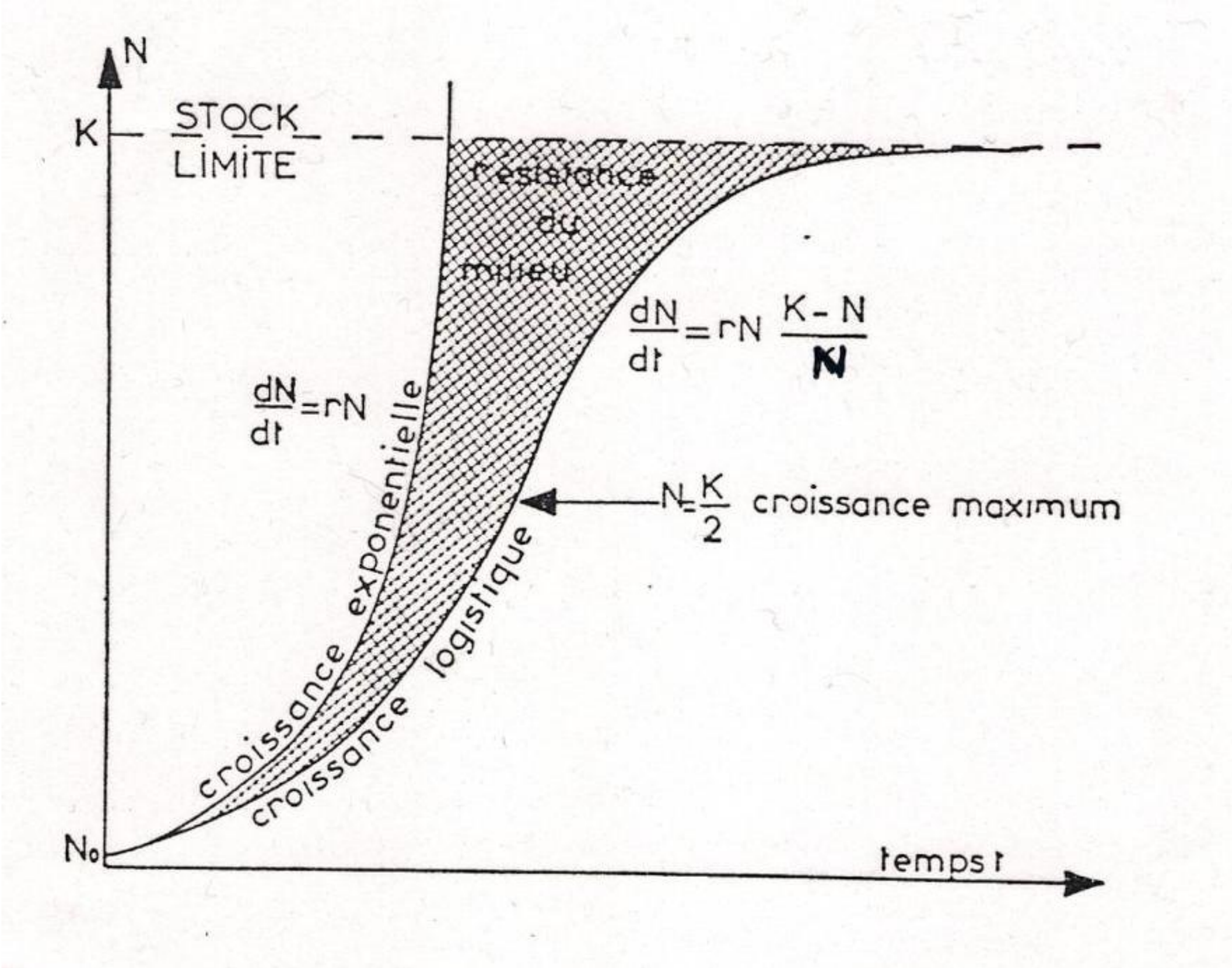
Remark that the speed of growth is maximal when N = K / 2

Because then: $$dN / dt = r\,N \frac{(K - K / 2)}{K / 2}$$

And dN / dt = r N

(thus exponential)

Graphic representation of the population growth curve (Dajoz 1975).



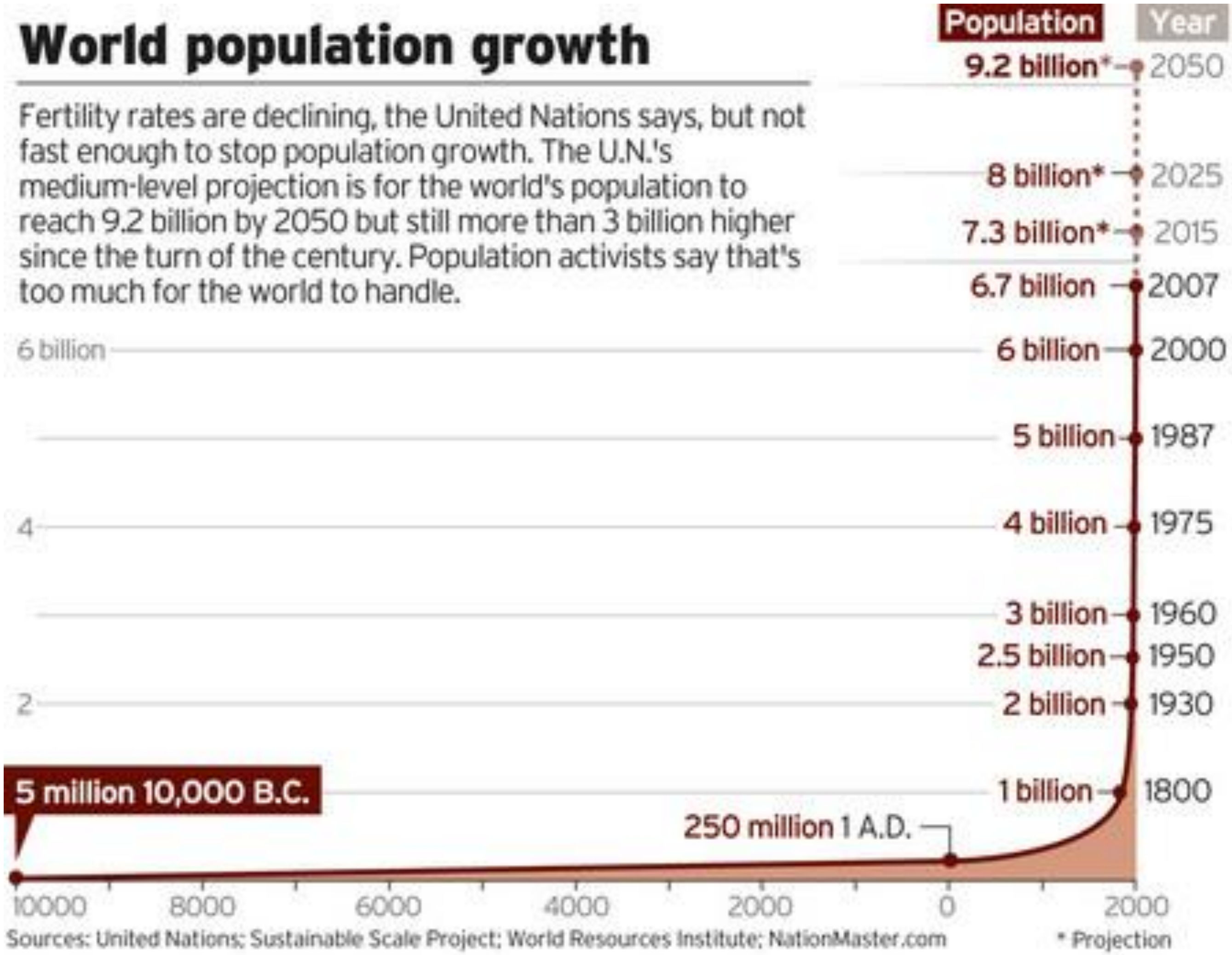
The shaded area is the inhibition, due to the limits of the environment (résistance du milieu) .

Relationship between growth rate and population doubling (for the human population)

Menselijke populatiegroei (OWEN, 1977)

groeisnelheid in % per jaar	verdubbelingtijd populatie in jaren
0.1 %	700 jaar
0.5 %	140 jaar
1.0 %	70 jaar
2.0 %	35 jaar
3.0 %	24 jaar
7.0 %	10 jaar
10.0 %	7 jaar

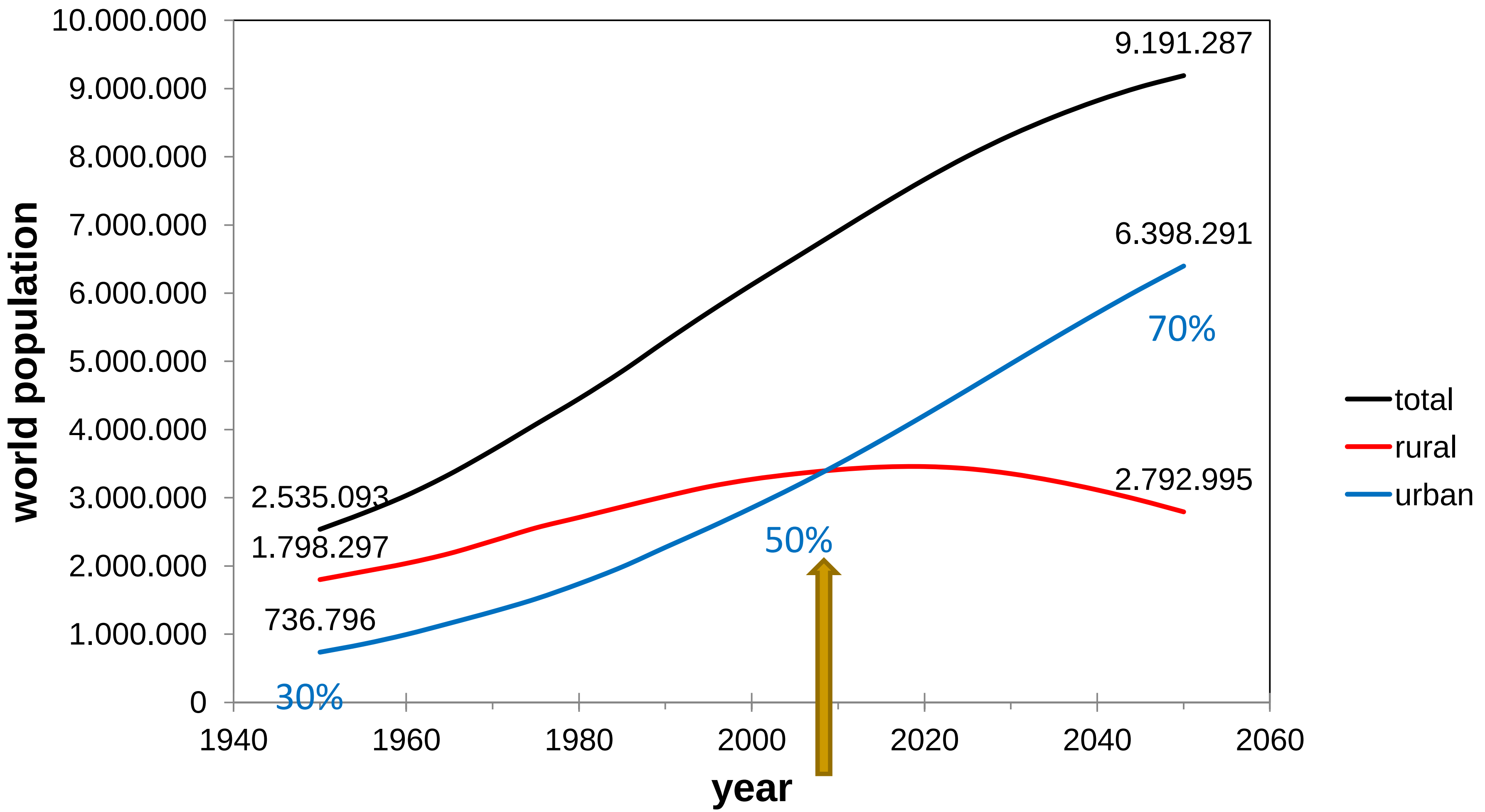
(Disturbing) human population growth curve.



http://albertideation.com/2009/12/21/world-population-growth-chart

World population: urban and rural.

http://esa.un.org/unup

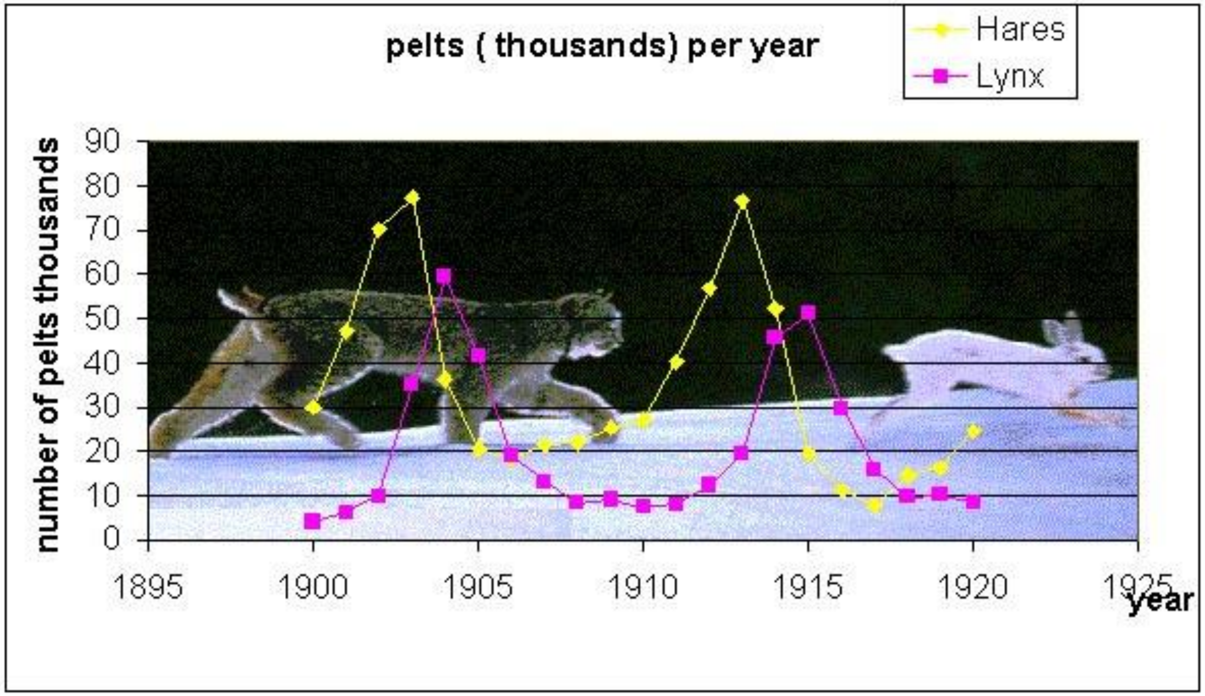


More than 50 % of the world population is living within urban areas, since 2008. This is more than ever before. So solutions for ecological and sociological problems must be found within urban areas.

An example: population size of a predator (**canadian lynx, Canadese lynx** (*Lynx canadensis*) and prey (**snowshoe hare, sneeuwschoenhaas** (*Lepus americanus*)

Hare in summer coat. Source: www.sanmarco.nl

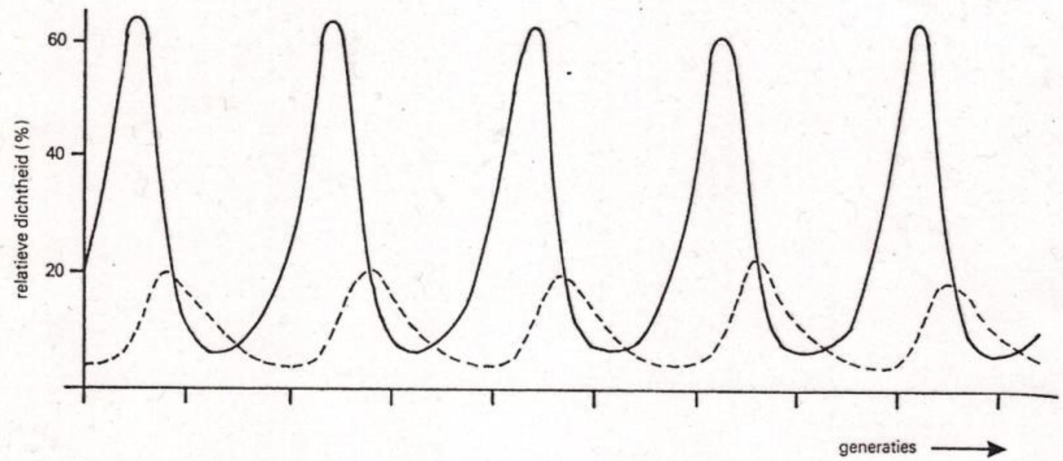
Source : SDSU & Joseph M. Mahaffy
San Diego State University



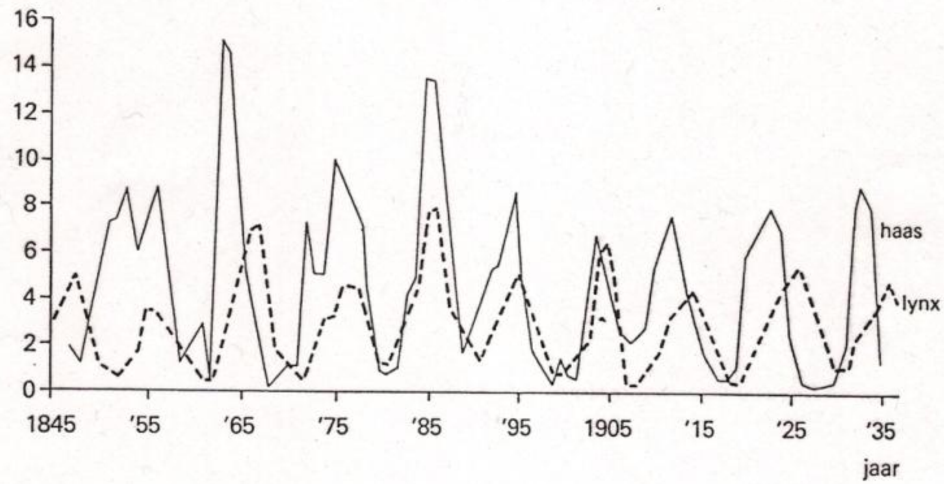
http://wwwrohan.sdsu.edu/~jmahaffy/courses/f00/math122/lectures/qual_de2/qualde2.html

Calculated and measured fluctuations in population size in [the predator-prey](#) relationship (Bakker et al. 1985).

Link: http://www.youtube.com/watch?v=xWm6037urxs



Afbeelding 5-29
Oscillaties van de aantallen in een prooi-predatormodelsysteem volgens de mathematische formulering van Volter:

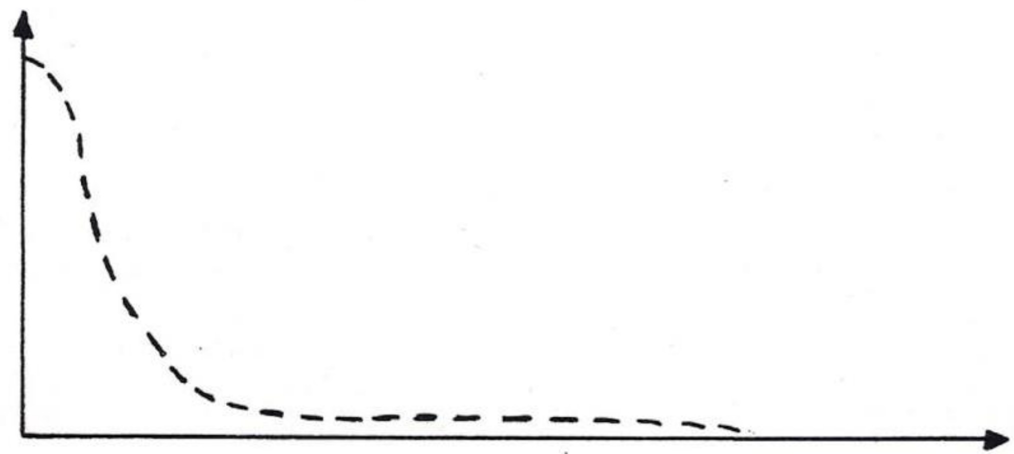


beelding 5-30
pulatieschommelingen van de Sneeuwschoenhaas en de Canadese Lynx. De aantallen berusten op de door de Hudson y Company verhandelde huiden. (Naar: MacLulich, 1937, *Univ. Toronto Stud. Biol. Ser. 43*.)

Population dynamics: survival strategies.
r-strategy.

r-strategie:

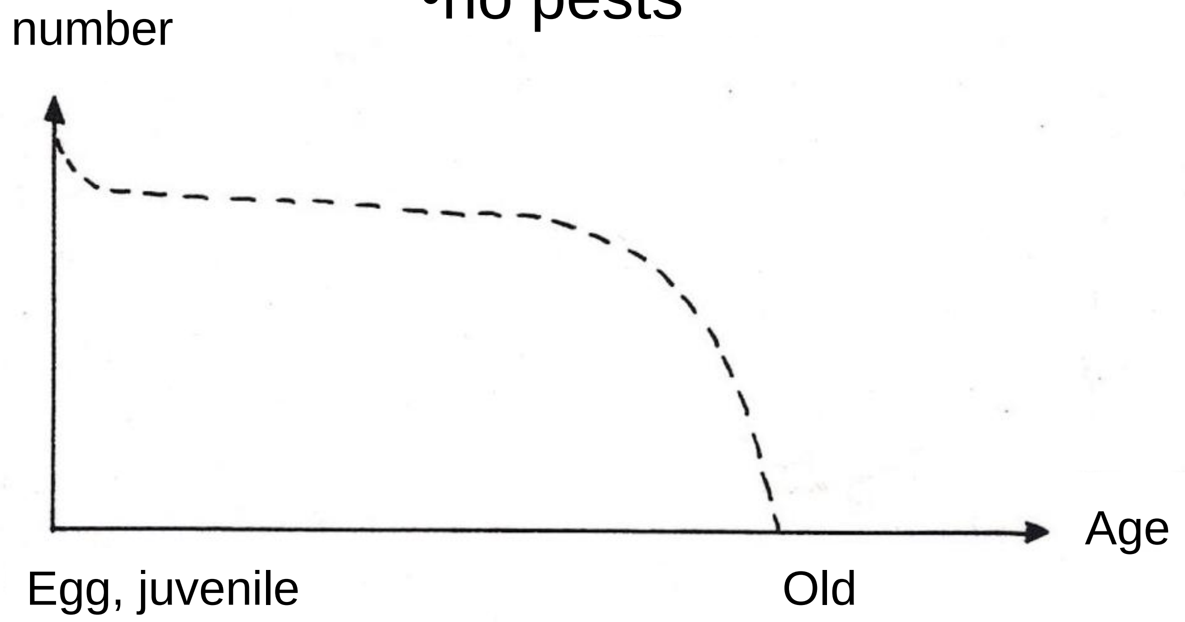
- a lot of eggs
- no brooding
- huge fluctuations in population size
- pests



Population dynamics: survival strategies.(2) K-strategy.

K-strategie:

- •few eggs and juveniles
- •brooding
- •little fluctuations in population size
- •no pests



Different survival curves (Dajoz, 1975).

Il existe trois types de courbes de survie (fig 96).

1) Dans le cas de la drosophile, de l'homme et de nombreux Mammifères beaucoup d'individus ont la même durée de vie et meurent pendant un intervalle de temps très court. Les courbes sont très convexes.

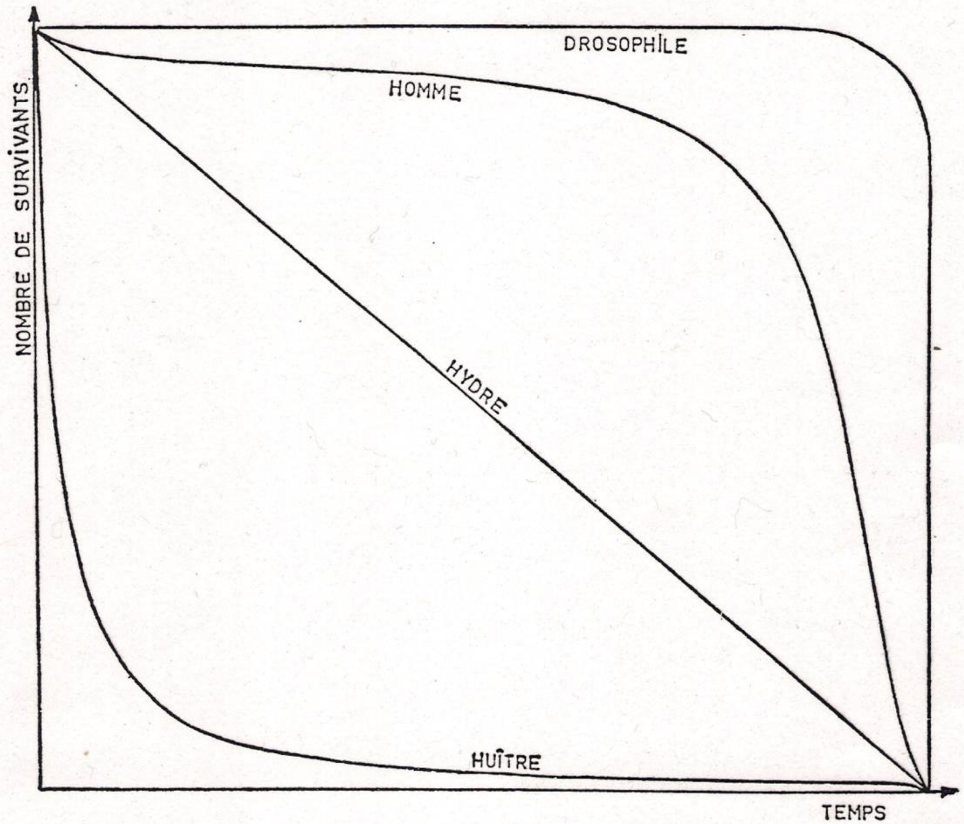
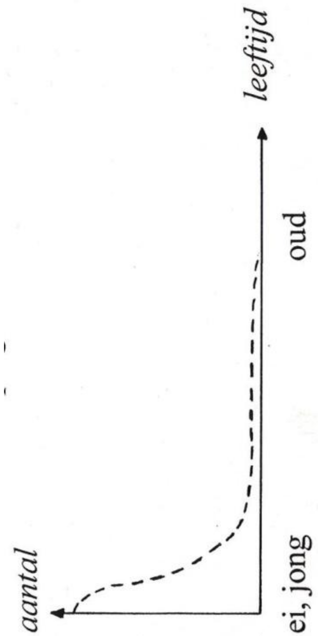


FIG. 96. — Les divers types de courbes de survie (DEEVEY, 1950).

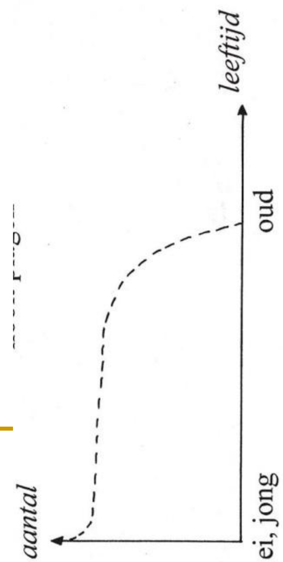
2) Dans le cas de l'hydre d'eau douce le coefficient de mortalité reste constant pendant toute la durée de la vie et la courbe est une droite.

3) Dans le cas de l'huître et de divers oiseaux, de poissons et de beaucoup d'Invertébrés, la courbe, très concave, correspond à une mortalité élevée aux stades jeunes.

From survival curve to population pyramid



r-strateeg



K-strateeg

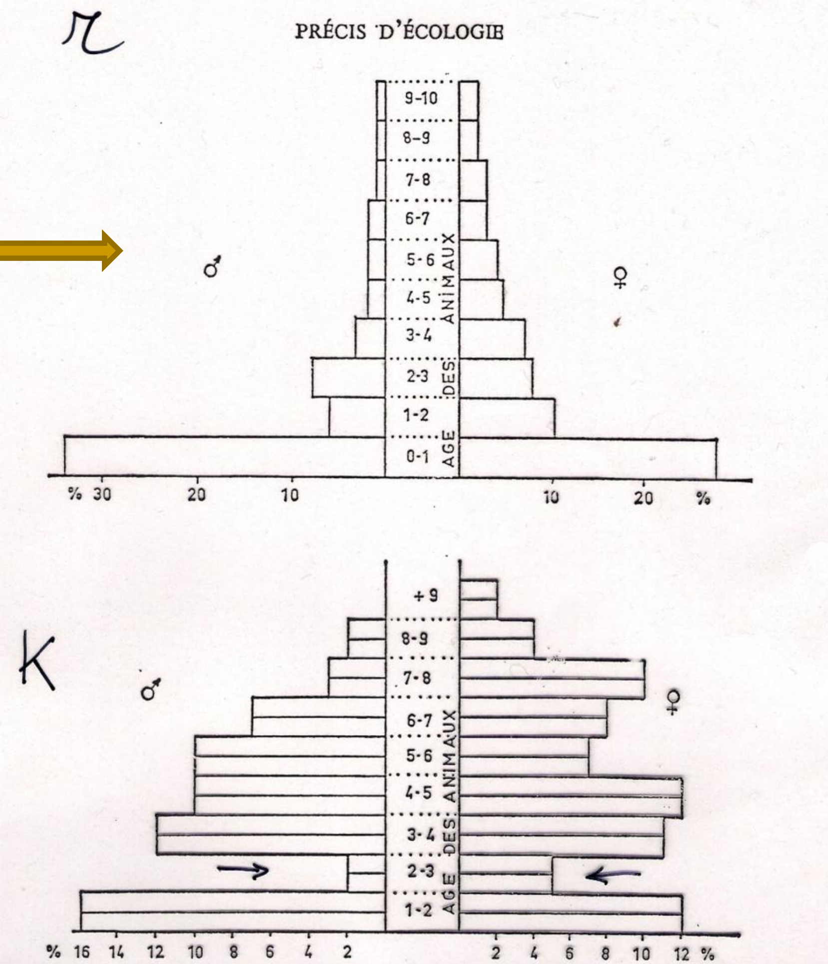
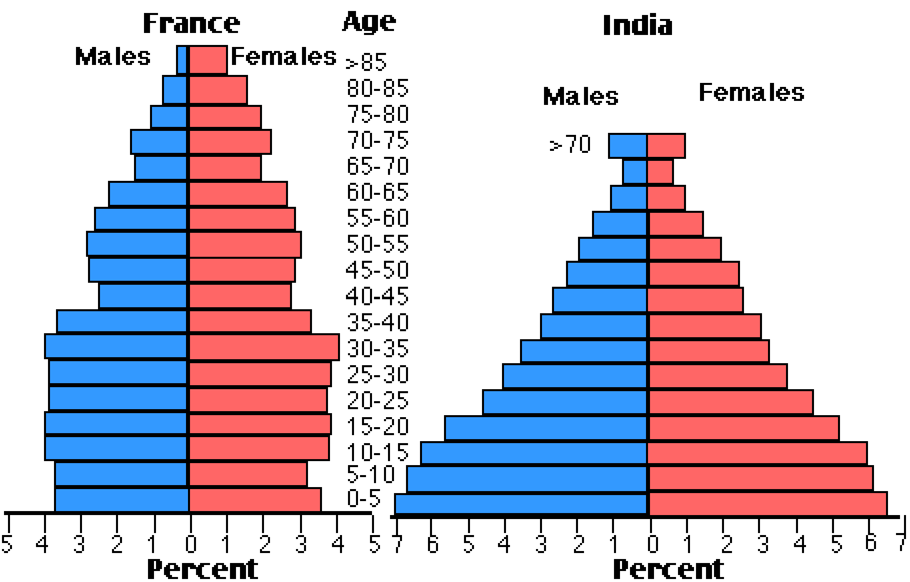
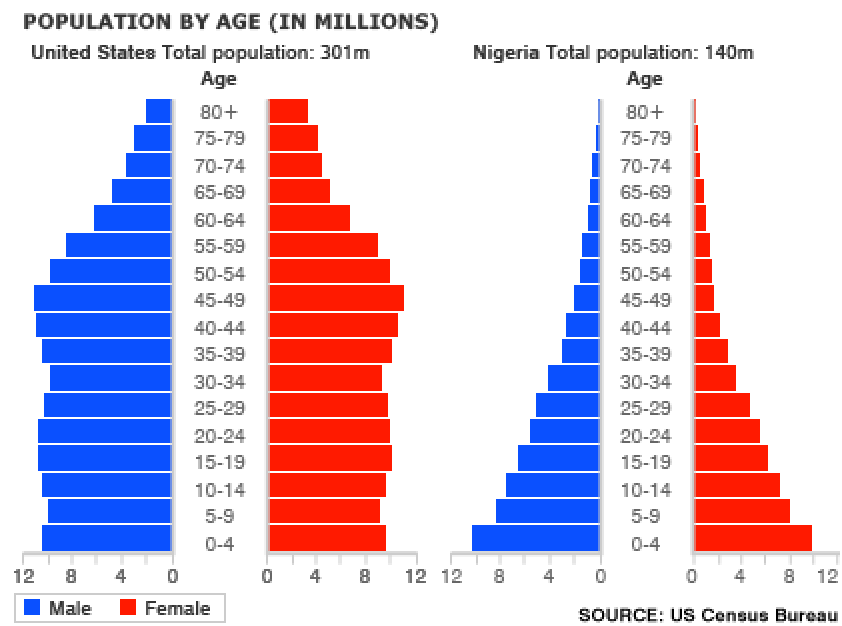


FIG. 100. — En haut, pyramide des âges pour une population du Cervidé *Odocoile hemionus* dans le chaparral de Californie. La pyramide a été dressée pour chaqu sexe séparément (TABER & DASMANN, 1958). En bas, pyramide des âges de la pop lation de mouflons de la réserve de Bavella en Corse. La rareté des animaux de à 3 ans correspond à l'incendie de la forêt qui entraîna la mort de nombreux ar maux (PFEFFER, 1967).

Human population pyramids: some examples.
France – India - USA - Nigeria





http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/P/Populations.html

http://geofreekz1.wordpress.com

Belgium 2050….a prognosis.