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Department of Ecology and Environment

Field: Marine and Continental Hydrobiology

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BIOLOGY AND POPULATION DYNAMICS

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Course intended for students of
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Biology and Population Dynamics

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BIOLOGY AND POPULATION DYNAMICS

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ABSTRACT

Population Biology and Dynamics focuses on biotic and abiotic interactions that govern population structure and organisation assembly.

The main objective of this module is to provide an overview of the biology and dynamics of populations, namely the structure and organization of individuals within a population, characterized by major shifts that depend on demographic processes controlling population size, whose variation contributes to population equilibrium.

It also aims to understand the relationships between a population and its environment, in their complexity, by analyzing the effects of environmental changes on demography and social systems, without neglecting the reverse effects.

The density of a population, its increase or decrease, depends on the number of individuals added to it (natality, immigration) and those that disappear (mortality, emigration). It is the interaction between intrinsic and extrinsic factors that ultimately determines densities and the stability of population sizes.

Finally, the trajectory of a population over time can be modeled mathematically using exponential and logistic models. The carrying capacity K of a habitat describes its maximum capacity to shelter and sustain organisms without causing environmental degradation. These factors limit the expansion of populations with particular life-history strategies (sets of traits that function and co-evolve together), enabling populations to acclimate to their environment.

PREFACE

In order for you to assimilate the course concepts and design a system that meets student requirements, the course proposes several methods, each with its own specific characteristics and advantages.

The targeted competencies are based on acquired knowledge, which requires specific methods to achieve and assessments to test your understanding and verify whether objectives have been met.

A transmissive method through the introduction of examples is employed, as it is the most effective approach for demonstrative support in memorizing concepts.

Knowledge of these alone is insufficient, understanding is deepened through theoretical questions and practical exercises, problem-solving, and comparison of results in order to benefit from exchanges between students.

All types of questioning allow testing of assimilation and comprehension in the mastery of concepts related to application, which facilitates the transition to a more advanced stage of learning.

Assessment is based on the results obtained and the acquisition of knowledge.

TABLE OF CONTENTS

1. INTRODUCTION

2. CHAPTER I. POPULATION–ENVIRONMENT SYSTEM

I. The Population and Dispersal Phenomena

I.1. Definition of Population

I.2. Concept of Population

I.3. Population Structure

I.4. Dispersal I.4.1. Definition

I.4.2. Measurement of Dispersal Distance

I.4.3. Types of Dispersal

I.4.4. Means of Dispersal

I.4.5. Causes of Dispersal

I.4.6. Consequences of Dispersal

II. The Metapopulation

II.1. Concept of Metapopulation and Dynamics

II.2. Metapopulation Model

III. Population–Environment System

3. CHAPTER II : EXPONENTIAL GROWTH AND POPULATION GROWTH RATES

I. Demographic Growth Rate

II. In an Environment with Unlimited Resources, the Temporal Evolution of

Population Size Can Be Calculated

II.1. Overview

II.2. Exponential Model : The Malthus Model

III. The Carrying Capacity of a Habitat Gives the Maximum Number of Individuals That Can Sustainably Develop Within It

III.1. Definition

III.2. The Logistic Model or Verhulst Model (1804–1849)

III.3. The Logistic Model Integrating the Carrying Capacity of the Habitat

III.3.1. Example A : Without Predation or Competition, Unicellular Populations

Follow the Logistic Model...

III.3.2. Example B : ...But the Adjustment Is Not Instantaneous

III.3.3. Example C : ...Provided the Biotope Remains Stable

4. CHAPTER III : DENSITY-DEPENDENT REGULATION OF POPULATIONS : ROLE OF ECOLOGICAL FACTORS

I. The Concept of Density Dependence

II. Density-Dependent and Density-Independent Factors

II.1. Density-Independent Factors = Abiotic Factors

II.1.1. Edaphic Factors (Soil)

II.1.2. Chemical Factors

II.1.3. Climatic Factors

II.1.4. Topographic Factors : Slope, Altitude, and Exposure

II.2. Density-Dependent Factors = Biotic Factors

II.2.1. Negative (–) Interactions Between Species

II.2.1.1. Predation

II.2.1.2. Parasitism

II.2.2. Positive (+) Interactions Between Species

II.2.2.1. Cooperation

II.2.2.2. Commensalism

II.2.2.3. Symbiosis or Mutualism

II.2.2.4. Amensalism

II.2.2.5. Competition

5. CHAPTER IV : BIODEMOGRAPHIC PARAMETERS

I. Overview

1. Natality and Mortality

1.1. The Natality Rate

1.2. The Mortality Rate

2. The Natural Growth Rate

3. Natural Increase

4. Demographic Growth

5. Fertility Rate

6. Sex Ratio

7. Age Pyramids

8. Density

6. CHAPTER V : EVOLUTIONARY BIOLOGY : EVOLUTIONARY ECOLOGY AND ADAPTIVE STRATEGIES

II. r-Strategy, Resulting from Density-Independent Selection

II.1. Characteristics of r-Strategy Species

III. K-Strategy, Resulting from Density-Dependent Selection

III.1. Characteristics of K-Strategy Species

7. CONCLUSION

8. PERSPECTIVES

9. BIBLIOGRAPHIC REFERENCES

COURSE STRUCTURE AND PLANNING



COURSE INFORMATION

Faculty : Natural and Life Sciences and Earth and Universe Sciences

Department : Ecologie and Environnement

Target Audience : L3, Specialty BEMA.

Course Title : Biology and Population Dynamics.

Credits : 05

Coefficient : 03

Semester : S6

Semester Contact Hours : 90H00min

Instructor : Dr. Samira Bouayad alam

Contact : by email at nizousam@gmail.com TARGET

AUDIENCE :



L3 BEMA



PREREQUISITES:

Before taking this course, you should know :

- Basic definitions regarding the living component (population) of an ecosystem.
- Populations naturally fit within an environment on which they depend.

A test is available to you on the distance learning platform.



THE COURSE OBJECTIVES :

- To know the structure and organization of individuals within a population, characterized by major variables that depend on demographic processes whose temporal variability confers a certain dynamic.
- Analysis of the effects of environmental changes on demography and social systems, with the aim of contributing to a better understanding of the relationships between populations and their environment.



COURSE SYLLABUS :

The course consists of five essential chapters which are :

- Introduction
- Chapter I : Population–Environment System
- Chapter II : Exponential Growth and Population Growth Rates
- Chapter III : Density-Dependent Regulation of Populations
- Chapter IV : Biodemographic Parameters
- Chapter V : Evolutionary Biology / Population Evolution

The training is composed of learning units ; each unit is addressed through pedagogical sequences, assimilated through planned concepts, and consolidated by learning activities — this is one of the strengths of this training.

The detailed course plan is available online :

- Introduction to the study of population and dispersal movements.
- Concept of metapopulation and model.
- Access to demographic parameters, structure by sex and age, life tables, and fecundity.
- Regulation of populations by density-dependent and density-independent factors.
- Population increase through an exponential growth and a logistic model.
- Evolution of populations through the concept of adaptive strategies in ecology.



LEARNING OBJECTIVES :

Overall, the targeted competency is the ability to analyze and coordinate the population–environment system, which is directly linked to existing biodemographic parameters, drawing on general ecology and evolutionary biology for the selection of methods and models used, while meeting the required demands.

This is a complex performance that progressively builds knowledge mastery, implements practical skills, and ultimately operates with professional conduct.

Biology and Population Dynamics aims to :

- + In terms of knowledge : learning the basic concepts, namely definition, concept, and structure of a population's relationship with its environment.
- + In terms of practical skills : practicing through exercises, using a basic CMR model (capture-mark-recapture), modeling the metapopulation, and constructing and interpreting a life table.
- + Orientation toward the design implementation phase to better identify and solve problems, as well as the ability to produce a report or presentation with a sound interpretation of results.



ASSESSMENT METHOD:

- Continuous and regular assessment accounting for the remaining 40%, enabling the accumulation of points throughout the semester ; this assessment is carried out in various forms.
- Final exam covering all course material.

INTRODUCTION

A population represents an ecological entity with its own characteristics. One of the most remarkable features of natural populations is their relative stability. A study conducted over a sufficient period of the main populations of a community shows that their numbers do not, as a rule, undergo significant variations. This relative stability is all the more remarkable given that each living species has a growth potential (**Grandi. M., 2020**).

The relationship between population and environment represents a particular challenge in the context of significant environmental changes taking place depending on the location and scale of observation in connection with climatic conditions and demographic growth.

It also addresses the phenomenon of migration and population dynamics, while considering the living environment, whether aquatic or terrestrial. Population dynamics is a branch of ecology concerned with temporal variations in the numbers of living organisms (**C. Lauzeral et al., 2004**).

Among the essential objectives of population dynamics is the study of mechanisms regulating the numbers of living organisms and controlling their distribution and abundance.

The dynamics of aquatic populations studies fluctuations in the size and structure of populations (births, deaths, migrations) under the influence of environmental and anthropogenic factors. These ecosystems, characterized by high productivity, are heavily impacted by pollution, climate change, and fishing, causing biodiversity loss and homogenization of species.

The course is structured as follows :

- An introduction to the study of populations and their movements.
- Metapopulation : concept and different models.
- Regulation with the importance of density.
- Access to the various biodemographic parameters with their main measurement indices and graphical representations.
- Evolution through the concept of adaptive strategies in ecology.
- Conclusion et perspectives.

CHAPTER I. POPULATION–ENVIRONMENT SYSTEM

I. The Population and Dispersal Phenomena

I.1. Definition of Population

An assemblage of animal or plant individuals belonging to the same species constitutes a population. These individuals interbreed and occupy a well-defined space and time.

Over time, the population undergoes changes : the appearance of new subjects (natality, immigration) or disappearance (mortality and emigration).

I.2. Concept of Population

Each population is characterized by state variables :

- Population density.
- Structure and distribution of individuals in the environment.
- Demographic structure (age-sex).
- Allelic or genetic frequency.
- Social organization.

These variables depend on temporal changes through demographic processes that confer a dynamic character to the population.

I.3. Structure of the population

Each population has a spatial and temporal constitution, and the relevant parameters are :

- Density
- Size and organization of habitat areas
- Proportion of individuals in each age category
- Genetic variability
- Movement of individuals.

The degree of interactions between organisms or conversely the level of mutual independence leads to the distribution and movement of organisms within a population.

These movements performed by individuals from their birthplace or from a densely populated area are called dispersal.

I.4. Dispersal

I.4.1. Definition

These are changes in the structure of a local population (sub-population) that can be attributed to the movement of individuals between populations. These movements are called : dispersal movements.

Long-distance dispersal is characterized by :

- Measurement that is difficult to calculate directly
- Detection of these movements requires capture-mark-recapture (CMR) methods. (Fig.1).

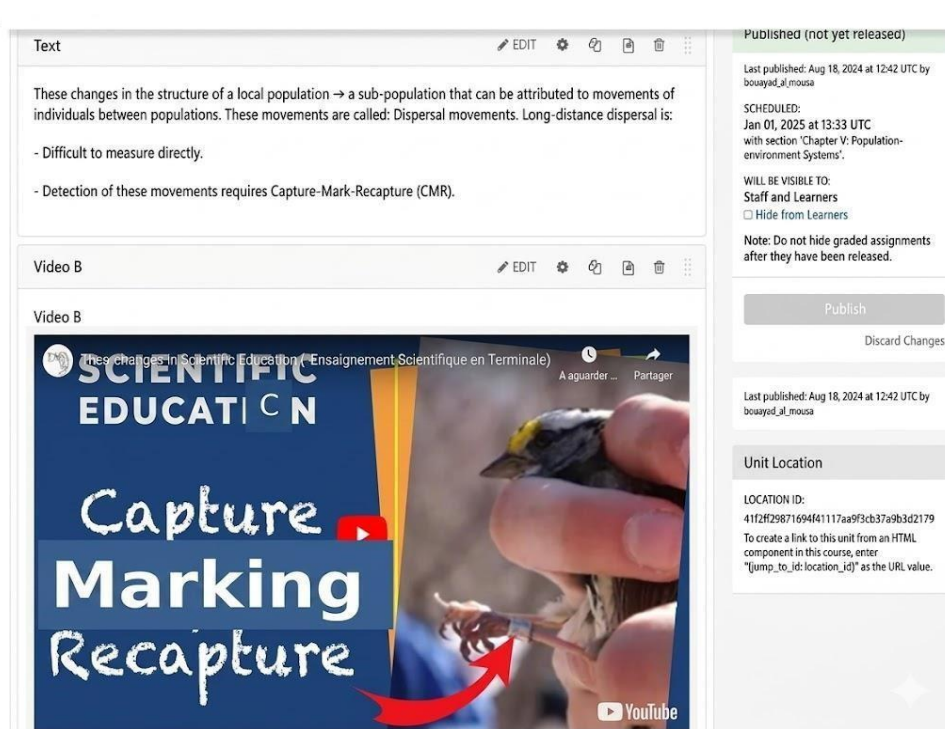


Figure 1 : Video illustrating the CMR method (Site)

EXERCISE :

In a small pond, 20 fish are captured and marked using colored tags. The pond actually contains a population of N fish we want to know (population size).

After releasing the 20 marked fish (M) and allowing a few days to pass, a second fishing event (recapture) is conducted, capturing 50 (n) fish, of which 6 (x) are already marked.

Thus :
$$N = (n \times M) / x$$

n = number of individuals in the second capture x = number of recaptured individuals already marked

Question : $N = ?$

This CMR method (**Jolly, 1965-1979**) represents the population size.

I.4.2. Measurement of Dispersal Distance

The first measurement of dispersal distance in a natural population was performed using measurements of movements made by *Drosophila* (*Drosophila pseudoobscura*) in the meadows of Colorado (from an identifiable ne release point).

EXERCISE :

Crumparker et Williams (1973) marked these flies using a fluorescent powder ; they were then released and subsequently recaptured in traps placed at regular intervals along 8 cardinal directions up to a distance of 351 m from the origin point.

Note : The quality of the dispersal index (S) as a measure lies in the fact that the variance $(S)^2$ de la distance augmente avec le temps.

Drosophila dispersal : $S_1 = 155$ m/day (mean between 139–171 m).

What is the dispersal distance and variance that the flies achieve over their lifetime ?

Therefore : After 2 days : $2(S_1)^2 = 2(155)^2 = ?$ et la variance = ? m ; After 4

days : $4(S_1)^2 = 4(155)^2 = ?$ et la variance = ? m.

Therefore, if flies have a mean lifespan = 23 days, what is the dispersal distance and variance they achieve over their lifetime ?

After 23 days : $23(S_1)^2 = 23(155)^2 = ?$ et la variance = ? m.

I.4.3. Type of dispersion

In aquatic environments, different fish species are not distributed uniformly along the river. Specific fish characterize each zone ; the first zone of the watercourse is called the trout zone, as it is not found in other river environments (**Fig. 2**).

Trout have significant oxygen requirements ; if the oxygen concentration in the water falls below 9 mg/L, trout show signs of asphyxiation which may lead to death.

The same applies to other river fish such as barbel and bream.

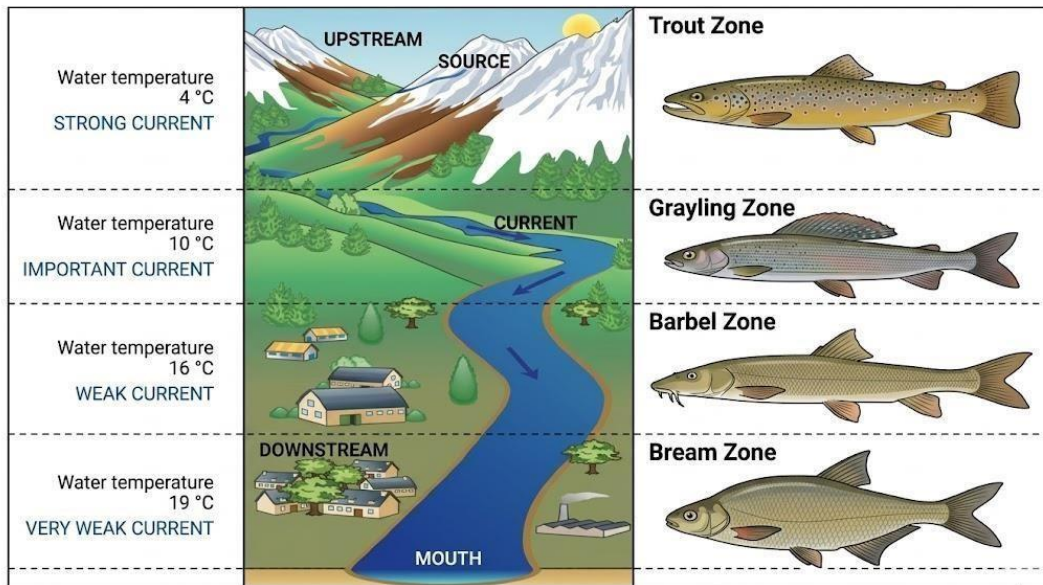


Figure 2 : The different zones of a river

In terrestrial environments, there are two types of dispersal : active and passive, and the distribution of organisms takes all sorts of forms. **(Figure 3) :**

- Aggregated dispersal (hunting efficiency, offspring care, exclusion of undesirable individuals) ;
- Uniform dispersion (aggressive interaction between neighbors) ; — Random dispersal.

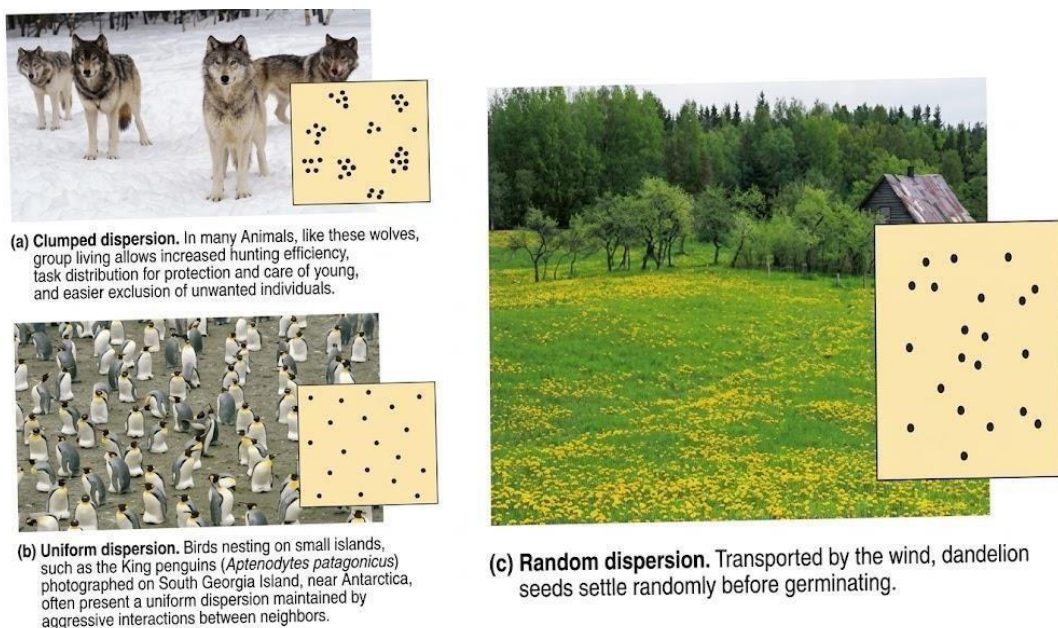


Figure 3 : Types and different forms of dispersal

I.4.4. Means of Dispersal

The following table and figure present the different means of population dispersal.

Table 1 : The different means of dispersal

Natural factors	Artificial
Wind forces.	Human activities that impact the population through habitat loss and fragmentation.
Running water (upstream-downstream).	
Other mobile animals	

The following figure presents the different means of dispersal in aquatic and terrestrial environments



Figure 4 : means of dispersion (natural and artificial)

I.4.5. Causes of Dispersal

We find several causes according to biotics et abiotics factors (**Tab. 2**).

Table 2 : Different causes of dispersal

Abiotic factors	Biotic factors
Temporal and spatial variations → major cause of dispersal.	Density effect: High density → competition → decreased survival and reproduction rate → essential force of dispersal.
Environmental conditions (temperature, humidity, resource availability, etc.).	Relatedness effect: A determining factor in triggering dispersal. It is selected to avoid inbreeding (individuals clustered at their site of origin are more likely to mate with each other → reducing their reproductive success).
High population density.	This relatedness has negative effects on individuals (direct) and on the related (indirect).
The quality and size of potential habitat for an individual.	
The degree of isolation of a patch (a habitat unit constituting a functional ecological unit) in relation to its distance from others.	

I.4.6. Consequences of Dispersal

For a long time, we have witnessed :

- The number of invasive species is exploding, as they possess a high dispersal capacity (**Fig. 5**).
- Certain societies enable some species to increase their capacities, allowing them to spread very far.

- The opposite also occurs, making the environment impassable.
- Mortality during transport.
- Genes influence the development of adaptations in certain species.
- The arrival of new predators for these individuals is a negative effect.



Figure 5 : Invasive species — consequences of dispersal

II. Metapopulation

Areas that meet the conditions and resources necessary for life are called habitat patches.

Individuals of a species living in habitat patches are called a local population. This population interacts through the processes of immigration and emigration.

The set of local populations occupying a network of habitat patches connected to one another by individual movements is called a metapopulation, or population of populations.

II.1. Concept of Metapopulation and Dynamics

The conceptual foundation of the theory of dynamic equilibria related to the concept of metapopulation dates back to **Levin Richard (1969-1970)**.

A metapopulation is therefore a composite population or an assembly of several populations. This can also correspond to what is called a population of populations.

At any time, certain habitat patches may be unoccupied by individuals of the species, and are thus susceptible to colonization by individuals from occupied patches.

- If a local population is small and experiences local catastrophes or random fluctuations in numbers, there is an important effect on dynamics, and it may undergo extinction over time.

II.2. Metapopulation Models

- **Spatially implicit metapopulation model** : all local populations are equally connected, **Levin (1970)** see that all populations are accessible to individual who disperse (**Fig. 6**).
- **Spatially explicit metapopulation model** : certain models link the degree of connectivity between different local populations to the level of dispersal that unites them and the distance separating the habitat patches.

Remarque : the degree of dispersal increases when the distance is small.

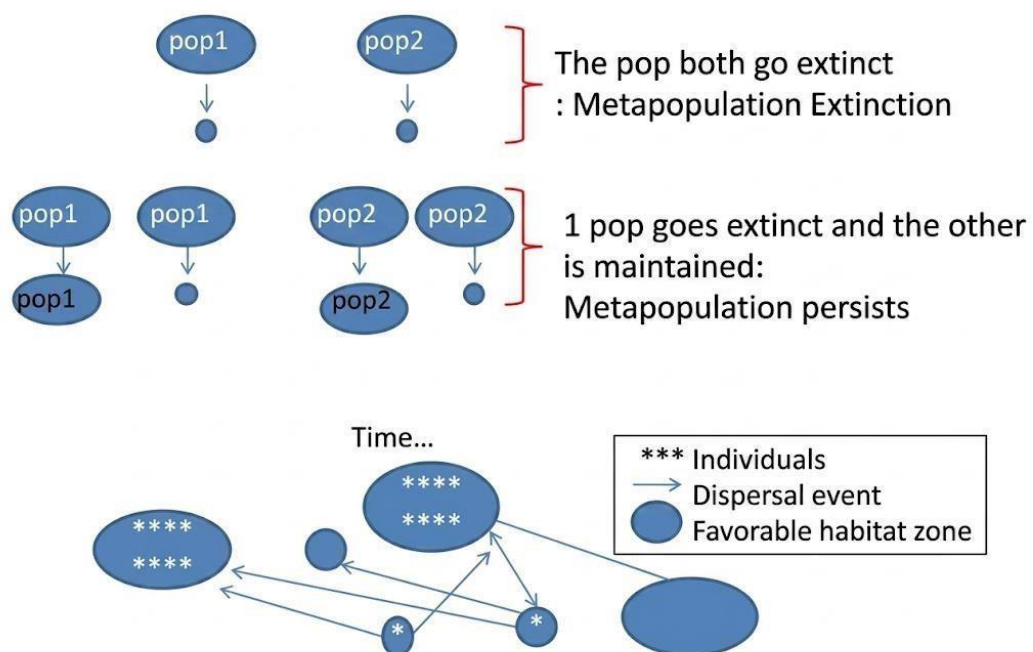


Figure 6 : The different metapopulation models

III. The Population–Environment System

For the population ecologist, the true functional unit is the population–environment system, because in nature populations are never isolated units and the environment is always characterized by :

— A climatic and physicochemical framework within which the population evolves, influencing its dynamics (**Figure 7 et 8**).

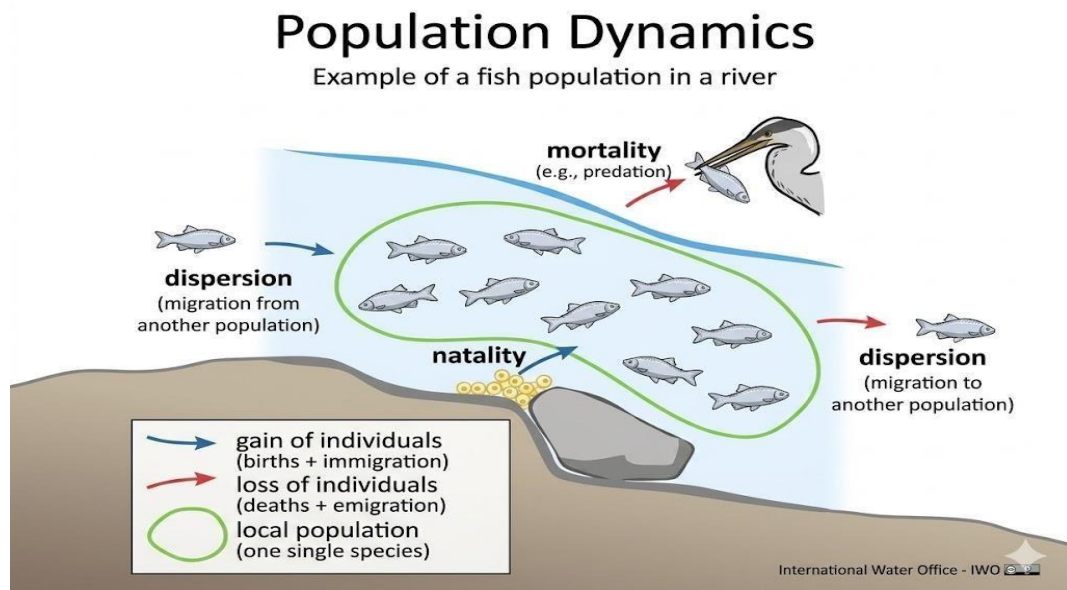


Figure 7 : population dynamics in aquatic environments

Text

A community is the set of populations that live in the same territory and interact together. Community dynamics therefore studies the interactions of populations of diverse dynamic species that live in the same habitat.

Video

Population Dynamics

Watch... Share...

Population Dynamics

YouTube

0:00 / 0:00

Speed 1.0x

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To create a link to this unit from an HTML component in this course, enter "jump_to_id: location_id" as the URL value.

Figure 8 : population dynamics

The population takes various forms relative to the species studied, either as :

- Proie ou source de nourriture ;
- Enemies such as predators and parasites ;
- Competitors for space use or food exploitation ;
- Cooperators to improve or ensure certain functions.

The following figure presents a marine ecosystem — an aquatic environment with a large quantity of dissolved salts (seawater). It encompasses the great oceans, coastal seas, and seafloors, each with different physical and biological characteristics.

Marine and coastal zones represent some of the most complex socio-ecological systems in the world. They constitute biodiversity hotspots, endowed with unique flora and fauna. They provide essential habitats for species reproduction and supply multiple ecosystem services that meet material, cultural, and spiritual needs. These systems are vital for most of the world's population, supporting their livelihoods and well-being in diverse ways (**Figure 9**).

The functioning of the marine ecosystem is linked to interactions between abiotic (physical and chemical) and biotic factors. The benthos is one of the main components of marine ecosystems and plays key functions. Benthic organisms living in or on sediments or other solid substrates are important in marine ecosystems, as they serve as prey for commercially important fish and also participate in nutrient recycling.

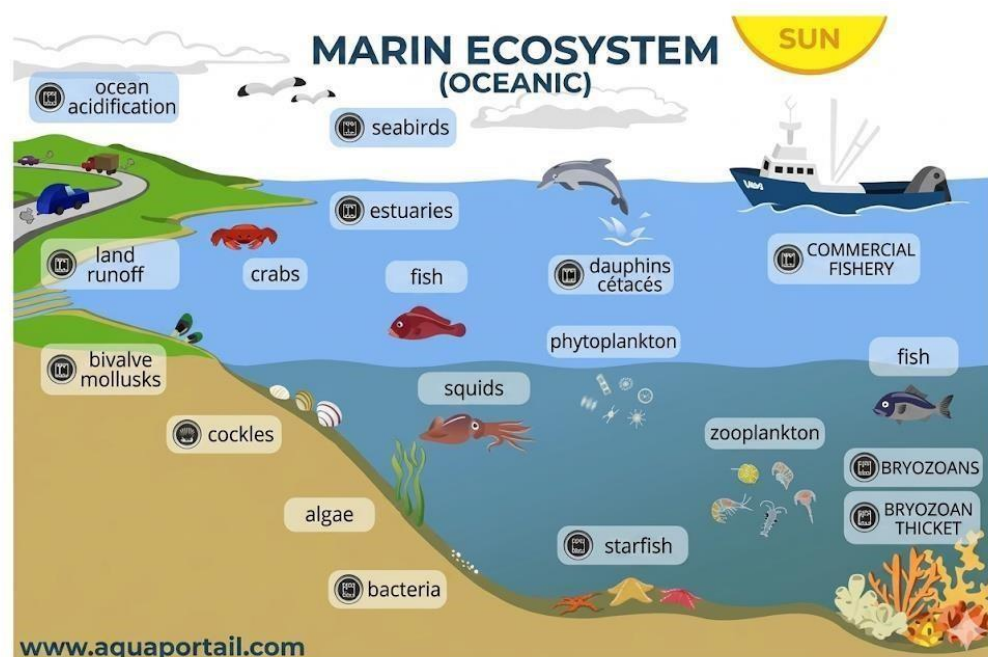


Figure 9 : Floristic and faunal biodiversity in the marine ecosystem

The dynamics of demographic processes (**Fig. 10**) results from :

- Properties of the individuals composing the population = intrinsic values : (Ecological fitness or competence, reproductive power, dispersal power, colonization power, competitive power, adaptive power, and means of defense).
- Properties of the environment = extrinsic values : (Abundance of resources, space, interspecific relationships such as predation and symbiosis, intraspecific relationships such as the mass effect which is generally negative, the group effect which is positive, and finally physicochemical and climatic conditions).

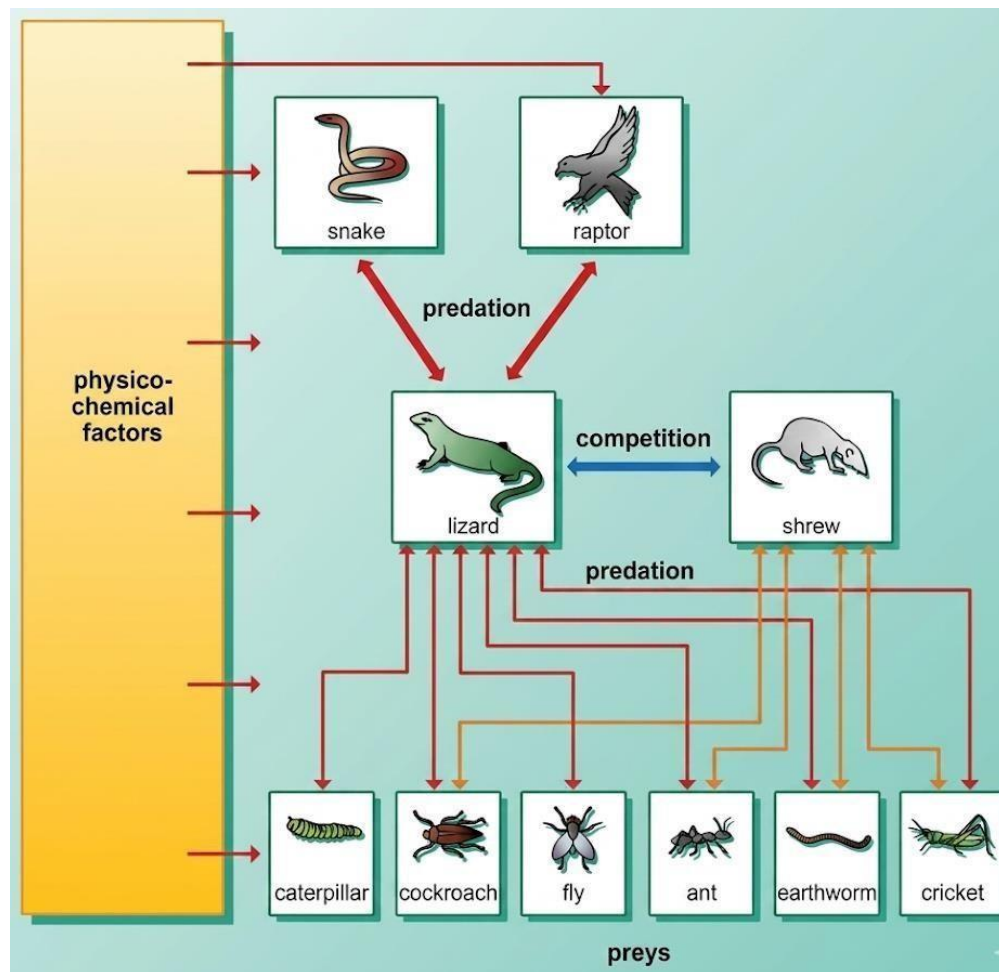


Figure 10 : Schematic representation of a population–environment system

The system can self-regulate and evolve when the population as a whole exhibits feedback responses (**Figure 11**). Other aspects of these feedback responses can affect certain capabilities of future individuals through genetic alleles up to the phenotypic level.

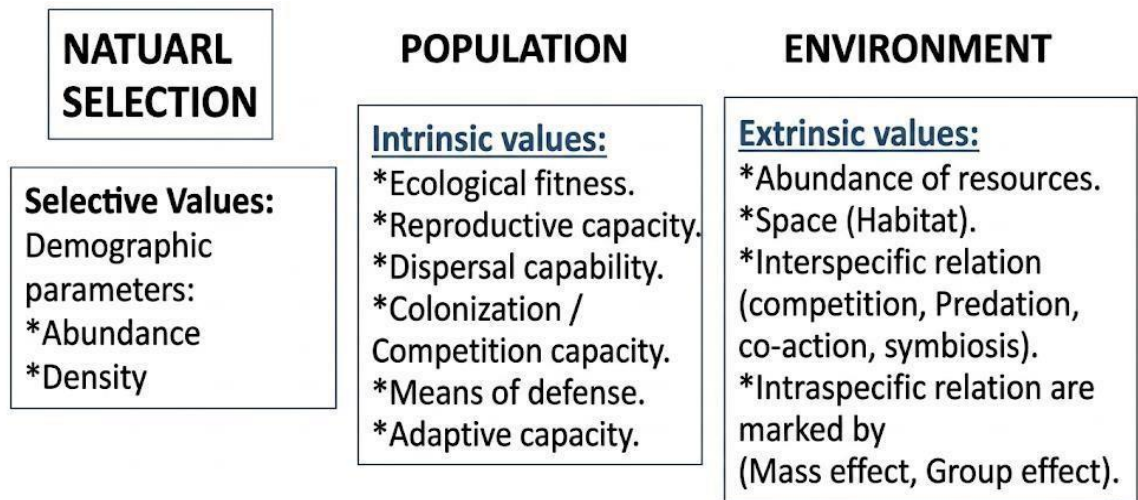


Figure 11 : Representation of self-regulation and evolution

EXAMPLE

Researchers analyzed hundreds of cod caught between 1996 and 2019 in the Baltic Sea. Using small bones in their auditory apparatus called otoliths, they were able to trace individual growth year by year. In parallel, they extracted DNA from these same fish and conducted very detailed genomic sequencing (**Angèle Ingrand, 2025**).

In barely two decades, the average size of adult cod dropped by half, from over 40 cm to 20 cm. And it is indeed the fault of humans, explain the researchers. Generation after generation, this selective pressure favored cod that grow slowly and reach maturity earlier. This is now written in their DNA : researchers discovered that certain genes associated with cod size have become more common over time, particularly those favoring slower growth. This is scientifically fascinating but ecologically alarming, explains the professor **Thorsten Reusch**, co-author of the study (**Figure 12**).

Today, cod stocks are severely weakened and their recovery is uncertain. Even the cessation of targeted fishing at sea does not seem sufficient to restart the populations. And since genetic evolution is not easily reversed, it will take decades — or more — to hope to see large cod reappear.



Figure 12 : Feedback effect on the genetic structure of cod

In terrestrial environments, voles (a group of rodents) exhibit cyclic density variations (3–4 years) that produce fluctuations in certain allele frequencies, which subsequently induce a phenomenon of selective emigration — represented by density increases causing preferential emigration of individuals with certain genotypes (**Fig. 13**).



Figure 13 : example of rodent companions Naturally, feedback can also affect the environment.

EXAMPLE

An aquatic ecosystem with an excessive input of nutrients — particularly nitrogen and phosphorus of human origin — undergoes eutrophication (**Figure 14**).



Figure 14 : Plant cover of a eutrophied pond

This phenomenon stimulates the growth of vegetation (**Camus.G, Delarue.M, 2014**) up to proliferation, which is intensified by elevated temperatures, abundant light, and above all the absence of water renewal.

EXAMPLE

En environment terrestre (**Figure 15**), an increase in the population density of antelopes (gazelles, wildebeest) causes overgrazing with habitat deterioration and a decrease in fecundity, which subsequently leads to increased mortality and emigration.



Figure 15 : example of gazelle antelopes

Evolution is defined as a change

- whether positive or negative
- as a function of intrinsic factors related to :
- The adaptive capacity of the species.
- Biotic factors.
- Abiotic factors.

Co-evolution corresponds to the evolutionary variation of two species — called pairwise co-evolution — or of several species — called diffuse co-evolution — in interaction. The latter occurs in different cases, such as among mutualistic species and among antagonistic species.

EXAMPLE

Hydrophilous pollination exists in submerged freshwater plants, such as *Vallisneria*, where pistillate flowers have long stems while staminate flowers float on the water surface (**Fig.16**). (Hydrophilous pollination, published 11/05/2008, updated 10/02/2025.)

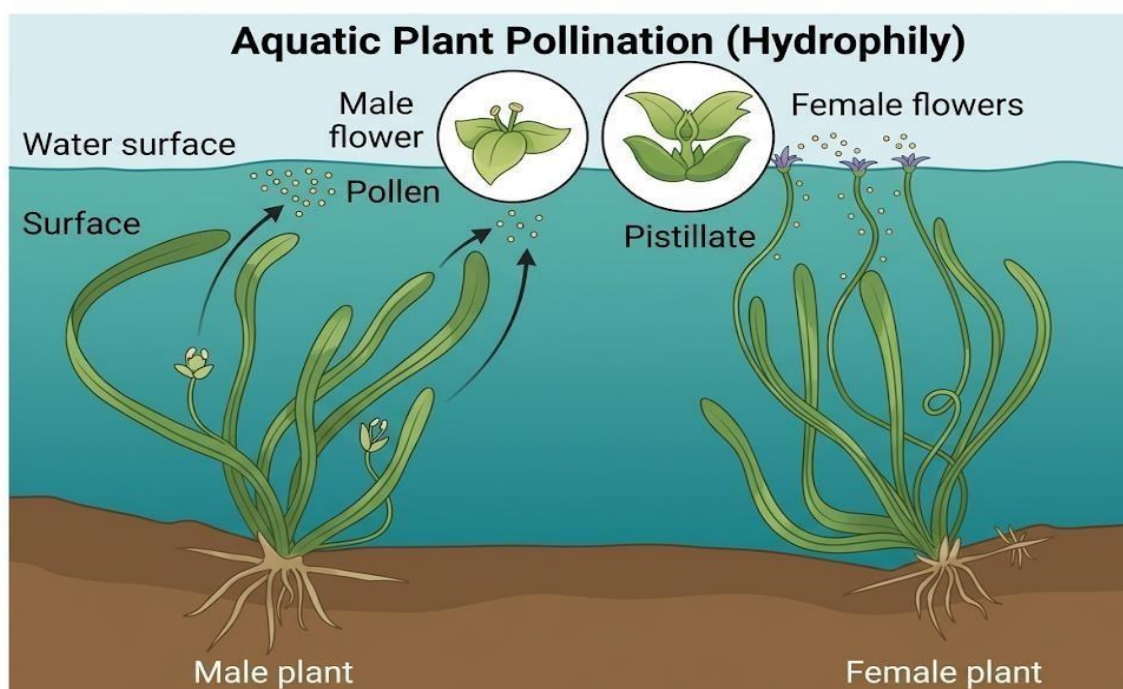


Figure 16 : hydrophilic pollination

EXAMPLE

In terrestrial environments, certain pollinating insects have developed close relationships with flowering plants, to the point of specific preferential selection (**Figure 17**).

The principle is as follows :

- Population A exerts greater pressure on certain specific phenotypes of population B;
- The selective value of phenotypes in population B is affected by the pressure exerted by the most prevalent phenotypes.



Figure 17 : Co-evolution phenomenon in terrestrial environments

CHAPTER II : EXPONENTIAL GROWTH AND POPULATION GROWTH RATES

I. Demographic Growth Rate

The term demographic growth represents an increase in the size of a population within a defined habitat ; in contrast, the rate of this change — whether increase or decrease — describes the demographic growth rate.

The combination of natural growth and migratory flows yields what is called the demographic growth rate.

II. A Habitat with Unlimited Resources Facilitates the Temporal Evolution of Population Size

II.1. Overview

In conditions where there is no relationship or interaction with another population, the variation in the number of individuals of a closed population is defined as follows :

$$dN / dT = B - M$$

M = number of deaths

B = number of births

N = number of individuals constituting a population

This equation can be defined relative to a single individual ; the formula is:

$$DN / DT = rN$$

Where : $r = b - m$ and if r is greater than 0, the population grows

Two conditions must be met to apply the preceding formula across more than one reproductive season :

— Reproduction occurs at the maximum reproductive capacity of individuals ; — The natural resources of a given habitat are abundant and unlimited.

This is referred to as the Malthus model, which describes exponential population growth.

II.2. Exponential Model : The Malthus Model

Thomas Malthus (1766-1834) identified the obstacle to geometric growth.

Resource production increases only arithmetically, whereas population grows geometrically if unchecked. Exponential growth is illustrated by the introduction of a species into a territory that possesses all favorable conditions for that species.

A well-known example is that of elephants introduced into a national park under optimal conditions and protected from poaching. The result led park managers to employ contraception due to exponential population growth (**Fig.18**).

Exponential Growth Model (J-curve)

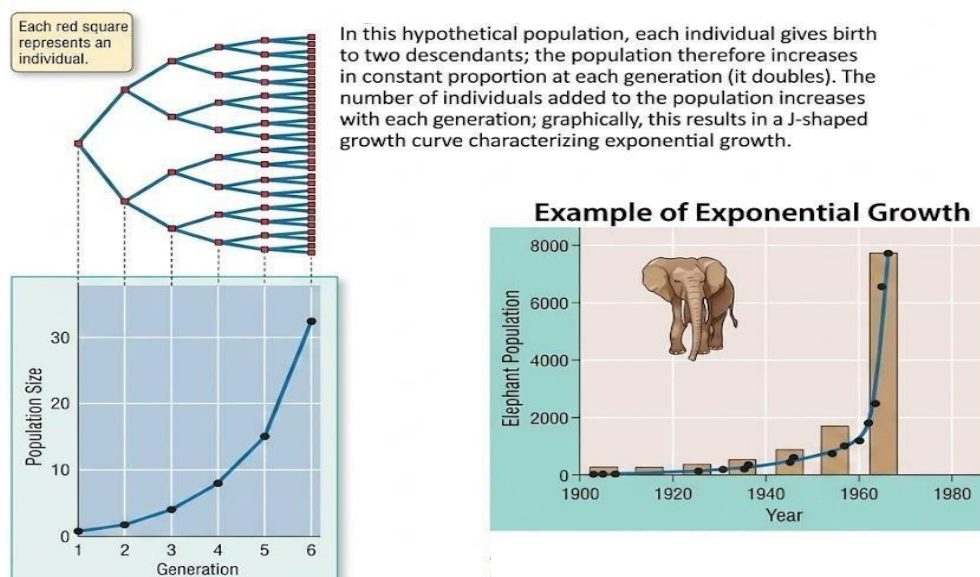


Figure 18 : Exponential population growth of elephants in South Africa

III. The Number of Individuals for Sustainable Development Describes the Carrying Capacity of the Habitat

III.1. Overview

At any given time, the maximum number of individuals of a species that can live in a habitat and develop without destroying the environment is called the carrying capacity (K) of the habitat.

Under conditions where K is lower than the population, there will be resource depletion and the environment contains an overpopulation. This explains the overlap of K depending on the resources available in a biotope at a given time.

III.2. The Logistic Model or Verhulst Model (1804–1849)

Density can slow the growth of a population. This is described by the logistic model.

When population size approaches the carrying capacity, the per-capita growth rate also approaches zero. Density influences growth through increases or decreases, which modify the earlier exponential model.

$$\frac{dN}{dt} = r \max N (1 - N / K)$$

Density reduces the population growth rate as it approaches the carrying capacity of the habitat.

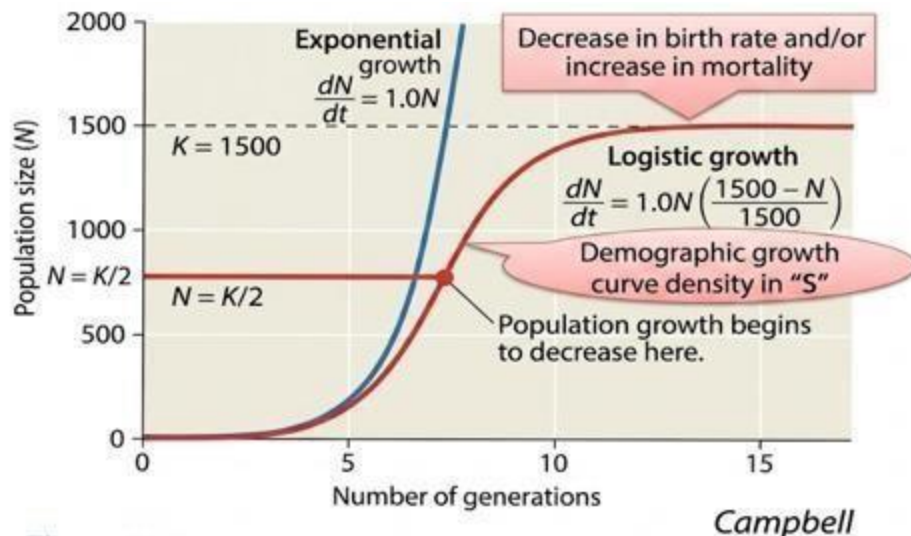


Figure 19 : prédiction using model logistic

III.3. Different Models Incorporating Carrying Capacity

III.3.1. Exemple A : species unicellulaire

These species — represented by certain bacteria, small animals such as beetles and crustaceans, or even paramecia — are particularly relevant in agri-food and pharmaceutical industries (Fig. 20).

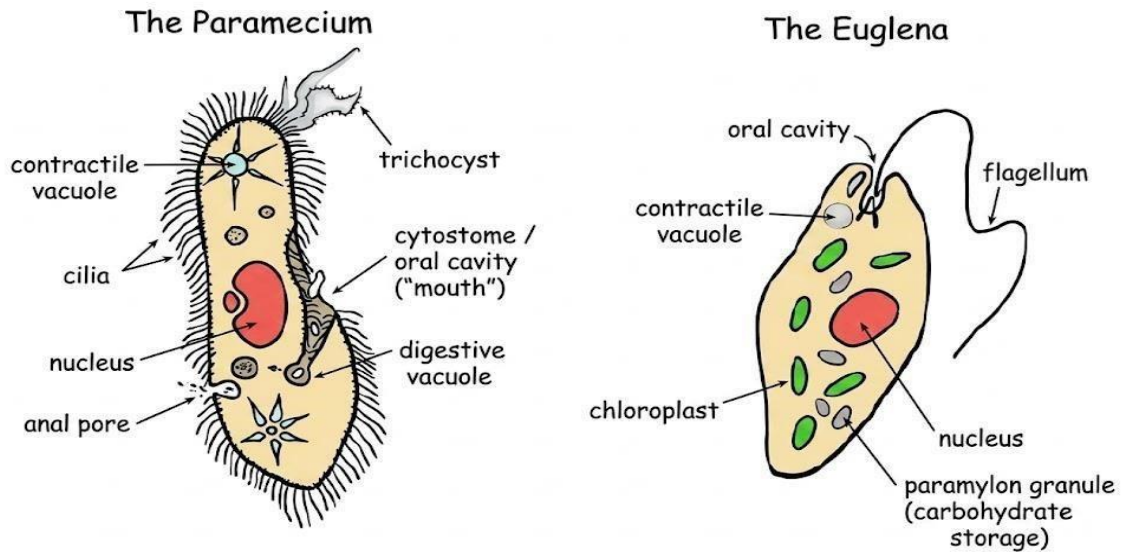


Figure 20 : paramecium culture under constant conditions

III.3.2. Exemple B : ...but the ajustements are not instantaneous

Population size adjusts according to resource availability in the habitat, and the model undergoes an instantaneous adjustment since food reduction negatively affects individual reproduction. In this case, the majority of females rely on their internal reserves, and the limit of the biotope may be temporarily exceeded (**Figure 21**).

III.3.3. Exemple C : ... provided that the biotope remains stable

La figure (21) represents the population of songbirds (*Melospiza méloia*) in their natural habitat. Females nesting on Mandarte Island periodically decline due to harsh winters, and demographic growth does not conform well to the logistic model.

Population Growth: Comparing the Logistic Model with Reality

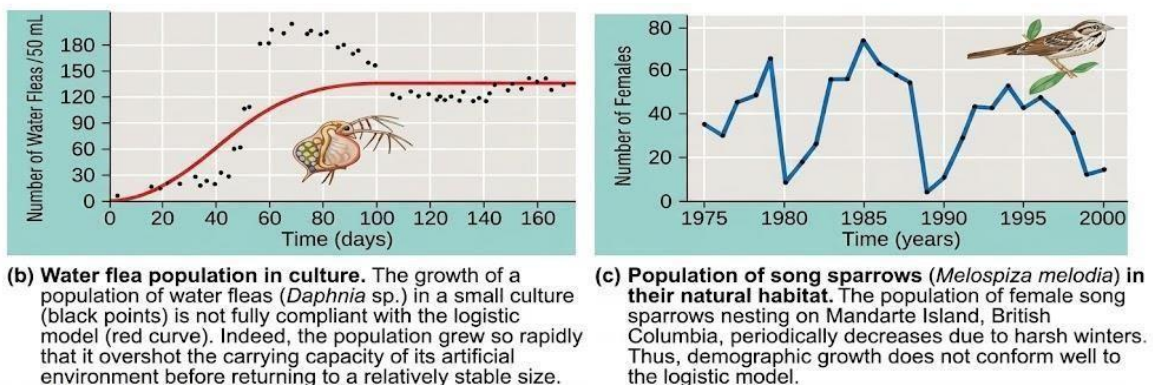


Figure 21 : oppositions between the model logistic and reality

CHAPTER III : DENSITY DEPENDENT REGULATION : ROLE OF ECOLOGICAL FACTORS

I. The Concept of Density Dependence

The concept of density dependence in the natural properties of populations tends toward relative stability. Animal and plant species rarely exhibit amplitude overlap, as most oscillate around a mean value.

Si tous individus d'une population se comportaient de façon homogène, on observe une augmentation brutale de :

- Natality
- Mortality
- All other responses linked to the action of an ecological factor.

In reality, in addition to the genetic heterogeneity of individuals, environmental heterogeneity is superimposed, such that population growth or decline is established along the gradient of the ecological factor considered.

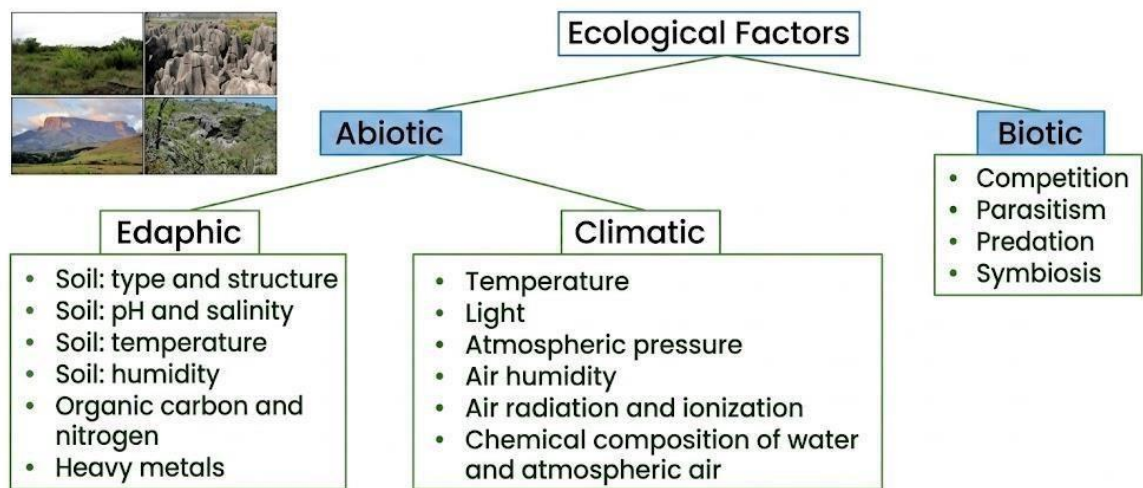
In poorly diversified systems, abiotic (environmental) factors undergo significant changes, and population regulation is directly affected by these physicochemical conditions.

In highly diversified and differentiated systems, these same conditions have no effect on the population, as control is provided by other biotic factors.

Overpopulation affects all living species, enabling them to develop a self-regulatory system through selection phenomena that allows for natural evolution over time.

II. Factors Subject or Not Subject to Density

Biotic factors in aquatic environments encompass all living interactions (fauna, flora, microbes) that influence ecosystems, such as predation, competition (intraspecific or interspecific), parasitism, and symbiosis. They regulate the structure of fish, algae, and bacterial populations (**Figure 22**).



Based on aquaportail.com

Figure 22 : aquatic ecological factors

In demoeology, the importance of the concept of density is highlighted by the analysis of various ecological factors. We have two types :

- **Density-independent factors** : this group includes almost all abiotic factors (physicochemical, drought, cold, climatic factors), and their effects are completely independent of population density.
- **Density-dependent factors** : characterized primarily by their biotic nature, directly linked to population density — whether for food allocation per individual or contagious diseases.

II.1. Abiotic and Density-Independent Factors

These are the effects of environmental characteristics that do not depend on density on living organisms, and are classified into several categories.

Density-Independent Factors = Abiotic Factors

II.1.1. Edaphic Factors (Soil)

-texture, structure, porosity, permeability, water retention, aeration, temperature, dead organic matter, C/N, fertility, mineral salts.

II.1.2. Chemical Factors

- Concentration of gases in the air, such as oxygen and carbon dioxide
- Various concentrations of mineral elements (Ca, Fe, phosphate, and nitrate).

II.1.3. Climatic Factors

- Quantity et quality of water ;
- Temperature ;
- Light ;
- Air and atmospheric components.

II.1.4. Topographic Factors

Characterized mainly by slope, altitude, and solar exposure.

II.2. Density-Dependent Factors = Biotic Factors

II.2.1. Negative Interactions Between Species

This is the effect of one living being another living being and there are two types depending on whether interactions between the species are positive or negative.

II.2.1.1. Predation : an individual is considered as predator when it hunts and kills its prey, on which it feeds (+/-).

Predators contribute to limiting the size of their prey populations, even if the offtake seems very small, constituting just one natural mortality factor among others (**Figure 23**).

Both predator and prey adopt behaviors to escape the other. These manifest as mimicry, alarm behaviors, or even rapid reproduction of offspring.

Chemical defense of prey against predation



Poison dart frogs are extremely venomous to vertebrates. They are warning you!



Figure 23 : predation in aquatics environments

II.2.1.2. Parasitism : a parasite is an organ that lives at the expense of another, called a host. This is negative interactions between species (+/-). (**Fig. 24**).



Figure 24 : parasitism in aquatic and terrestrial environments

II.2.2. Positive Interactions Between Species

II.2.2.1. Cooperation : a favorable but not obligatory association between two individuals (+/+). Example of remora on the backs of large sharks predators (**Figure 25**).



Figure 25 : remora on backs of sharks

II.2.2.2. Commensalism : it's a relationship where the commensal individual lives at the expense of a host individual without causing harm (+/0). Aquatic snails crawl on plant surfaces and as they move, they disturb sediments and algal particles.

Daphnia (water fleas) feed on suspended matter, particularly algae and microorganisms. When snails dislodge small food particles into the water column, Daphnia access to these particles is facilitated.

Example 2 : Common eiders in terrestrial environments, which shelter among terns to simply protect themselves from vultures and gulls (**Fig.26**).



Figure 26 : commensalism in different environments

II.2.2.3. Symbiosis or mutualism : Two individuals need each other. Association is mandatory for both species (+/+).

Example1 : Symbiosis between the clownfish *Premnas biaculeatus* and a sea anemone with a sea anemone *Heteractis magnifica* is obligatory in the oceanic environment. Thanks to this symbiotic association, both species protect each other from predators.

Example 2 : Symbiosis between a green alga and fungi, known as lichens. The alga provides food and the fungi provide shelter for the alga.

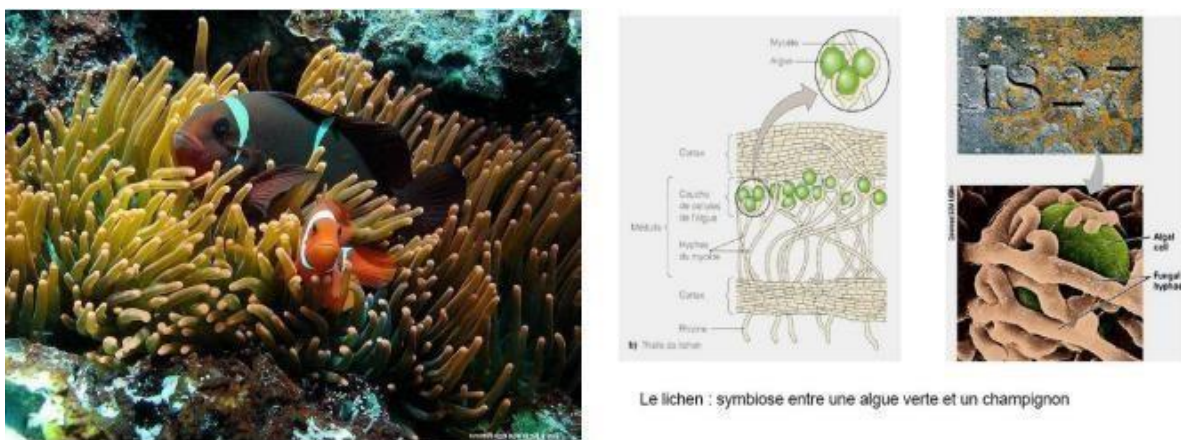


Figure 27 : symbiosis in different environments

II.2.2.4. Amensalism: An organism inhibits or slows down the growth of an amensal organism. This phenomenon is frequent relationship in certain animals.

Example : A large tree that prevents the development of another by depriving it of light (**Figure 28**).



Figure 28 : amensalism in different environments

II.2.2.5. Competition : two organisms are competing for a resource, whether it be food or shelter. It is a biotic factor of crucial ecological importance.

- **Intraspecific competition :** competition between individuals of the same species.

The example of interference competition between two seals for space is illustrative. (**Figure 29**).



Figure 29 : interference competition between two harbor seals

- **Specific competition** : Competition between two populations of different species. The first example about interspecific competition between marine fish darters and corals (**Figure 30**).

As for the second example, the resource is shared and superabundant between two species that mutually interfere with each other's access to food. This is referred to as competitive exclusion.

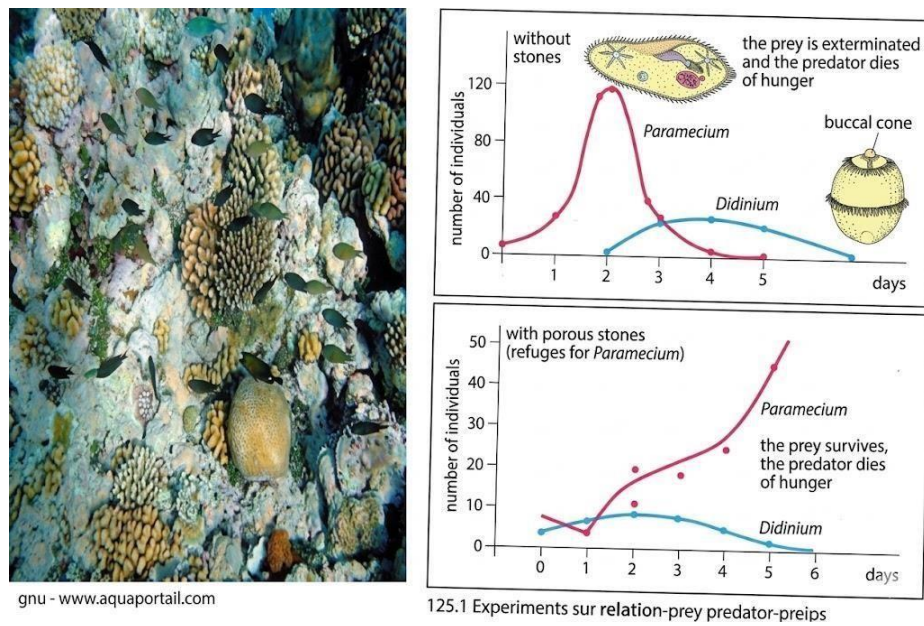


Figure 30 : Exclusion competitive

CHAPTER IV : BIODEMOGRAPHIC PARAMETERS

I. Overview

Biodemographic parameters are derived from demography, a discipline that studies the qualitative and quantitative characteristics of a population and its dynamics. We have two types of interesting properties :

- ❖ Properties of each individual that makes up the population, namely ecological fitness, reproductive capacity, competitive ability, and means of defense. This is simply translated into the values within the population, called : intrinsic values.
- ❖ Environmental properties, namely the abundance of resources in space, climatic and physico-chemical conditions, and interspecific relationships. These external values are called : extrinsic.

1. Natality and Mortality

The number of individuals added to /or conversely removed from a population reflects the increase or decline of that population, which is directly related to density. In other words, this depends on the difference between births and deaths, as well as between migratory flows.

1.1. Natality Rate

The birth rate, also expressed as the natality ratio, measures the production of new individuals (births / hatchings) per unit of time in aquatic environments. It's fundamental to population dynamics, determining, along with mortality, growth, decline or stability. The characteristics of the aquatic birth rate are :

- **Definition :** the number of individuals born within a population during a specific period.
- **Influencing factors :** water pollution or conversely oxygenation directly and strongly influences reproduction.
- **Dynamics :** in population ecology, it allows for the analysis of the growth of aquatic species.
- **Measurement :** unlike human birth rates, it is often measured by the species specific fecundity.

The birth rate in aquatic environments measures the production of new individuals relative to the total population. It is generally calculated for 1000 individuals using the following formula :

$$T = (N / P) \times 1000$$

T : birth rate ;

N : total number of births or hatchings ;

P : average total population (adults) during the same period.

In animals and humans, the birth rate per 1000 individuals is calculated in almost the same way and is usually expressed as a percentage (‰) using the following formula :

$$TN = n / P \times 1000$$

-n : the number of births per year

- P : the average total population during the same year.

1.2. Mortality Rate

In aquatic environments, the mortality rate is expressed as the number of death relative to the average total population, and for a fisheries management approach, total mortality is the sum of natural mortality (M) and fishing mortality (F) according to the following formula :

$$Z = M + F$$

While fishing mortality (F) is calculated :

$$F = q \times f$$

Where q is the catchability coefficient (efficiency) and f is the fishing effort.

In the same way, the mortality rate in animals and humans is calculated per 1,000 individuals and is also expressed in per mille (‰).

EXERCISE :

On an island, the total population was 500 individuals. 50 individuals were born and 30 individuals died. Can you calculate the birth and death rates of this island ?

2. Natural Growth Rate

In aquatic environments, the difference between the birth and death ratios of species, whether fish, plants or microorganisms, constitutes the natural growth ratio. This ratio is strongly influenced by environmental factors such as temperature and the quality of available food, which affect growth in aquatic environments.

- **Température** : it directly influences the basal metabolism, an increase in temperature can increase energy requirements from 28 to 67 Kj/Kg/Day for example for carp between 10° and 0°C.
- **Nutrition** : growth is directly correlated with the amount of food ingested.
- **Type of environment** : the dynamics vary between watercourses, lakes, ponds and estuaries influenced by ecological connectivity.
- **Submerged aquatic plants (Hydrophytes)** : submerged aquatic plants (hydrophytes) play a vital role in oxygenation promoting life.

Individual growth is measured by body weight, length, or condition factors all essential in aquaculture production. Wetland and aquatic environments harbor a diversity of microorganisms, plants, and insects that respond to environmental changes, making biomass a bioindicator of their health status.

Le taux ou rapport de croissance naturelle en environnements aquatiques, souvent exprimé comme spécifique (TCS), mesure la vitesse de multiplication de la biomasse (poissons, algues, bactéries) par unité de temps. La formule principale est :

$$TCS = [Ln (Wf) - Ln (Wi) / t_f - t_i] \times 100$$

TCS : rate growth spécifique (% day / time) ;

Ln(Wf) : natural logarithme the final weight / biomass ratio ; Ln

(Wi) : natural logarithme the initial weight / biomass ratio ; $t_f - t_i$

: period duration (day, heure).

For aquatic populations, the migration of species particularly diadromous fish is severely impaired, with 85% of them threatened or near-threatened. This critical situation is due to flow obstacles (one every 6 km of habitat), which harm their reproduction and survival.

The net migration rate (NMR) in aquatic environments measures the difference between individuals entering a population and those leaving it, relative to the average population size. Generally expressed per 1,000 individuals, it indicates whether the population increases or decreases through movement.

$$TMN = (I - E) / P \times 1000$$

I : number of immigrants ;

E : number d'emigrants ;

I - E : Solde migratoire (net) ;

P : average of total population over the period.

TMN $\geq$ 0 : population gain

TMN $\leq$ 0 : population loss.

Alternatively, net migration can be calculated indirectly by subtracting natural increase from total population growth :

$$\text{Net migration} = (\text{final population} - \text{initial population}) - (\text{births} - \text{deaths})$$

Regarding both human and animal populations, net migration is calculated in the same way and can be either positive or negative, depending on the gain or loss of individuals.

3. Natural Growth or Increase

The fluctuations occurring in a population through the addition or removal of individuals describe natural increase.

4. Demographic Growth

Human overexploitation of water resources, degradation of ecosystem quality, and overexploitation of aquatic species are so excessive as to alter hydraulic regimes, threatening aquatic biodiversity and favoring certain species at the expense of others.

According to the technical portal of the French Biodiversity Agency (OFB), the consequences of demographic pressure lead to a decrease in ecosystem resilience, making water management even more complex.

When discussing the growth rate of an animal or human population, we multiply by 1000 inhabitants and divide by the total population. Population growth is then calculated using various formulas :

:

Demographic Growth = Natural Increase + Net Migration

Or even :

$$DG = (\text{births} + \text{immigration}) - (\text{deaths} + \text{emigration}) \quad \textbf{EXERCISE}$$

:

The following table shows the number of births and deaths for three consecutive years. Calculate the natural increase ?

Year	Births	Deaths
2020	380	125
2021	530	220
2022	650	450

During the year 2021, the city received 980 immigrants and 775 inhabitants left the city to live elsewhere.

-Calculate net migration ?

- how is growth démographique (CD) ?

5. The Fertility Rate

In aquatic environments, the fertility rate is generally higher, constituting an adaptation to high egg and larval mortality. Aquatic organisms produce massive quantities of eggs, ranging from thousands in trout to millions in sea urchins (60 million) or mussels (10 million).

Quantitative strategies, reduced protection and the dispersal of larvae and aquatic plants make aquatic environments areas of high biological productivity. Fecundity in aquatic environments (fish / invertebrates) is generally measured by absolute fecundity (F), which is the total number of eggs per female. A classic formula, related to size, is :

$$F = a L^b$$

Where L represents length, and a, b are species-specific constants. Relative fecundity (F/W) relates this number to the body weight of the female.

6. Sex Ratio

In aquatic environments (fish, invertebrates), the sex ratio generally represents the percentage of females. The ratio is expressed as the number of males (M) and females (F), and it is very important in biodemographic parameters as it affects the reproductive factor.

The following figure represents the sex ratio in a population of the micro-lepidopteran insect that attacks tomato fruit.

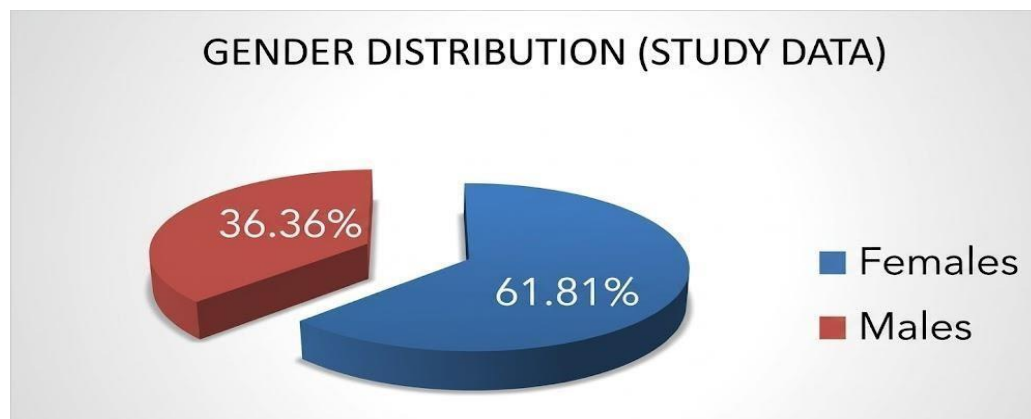


Figure 31 : the male /female ratio of *Tuta absoluta* from laboratory colonies

7. Age Pyramids

In aquatic environments, the age pyramid structures the distribution of a specific species population (fish, invertebrates) by age class and sex, always displaying a broad base (young) and a narrow apex (old). It evaluates equilibrium, reproduction, habitat structure, and the transition from eggs to adults (Figure 32).

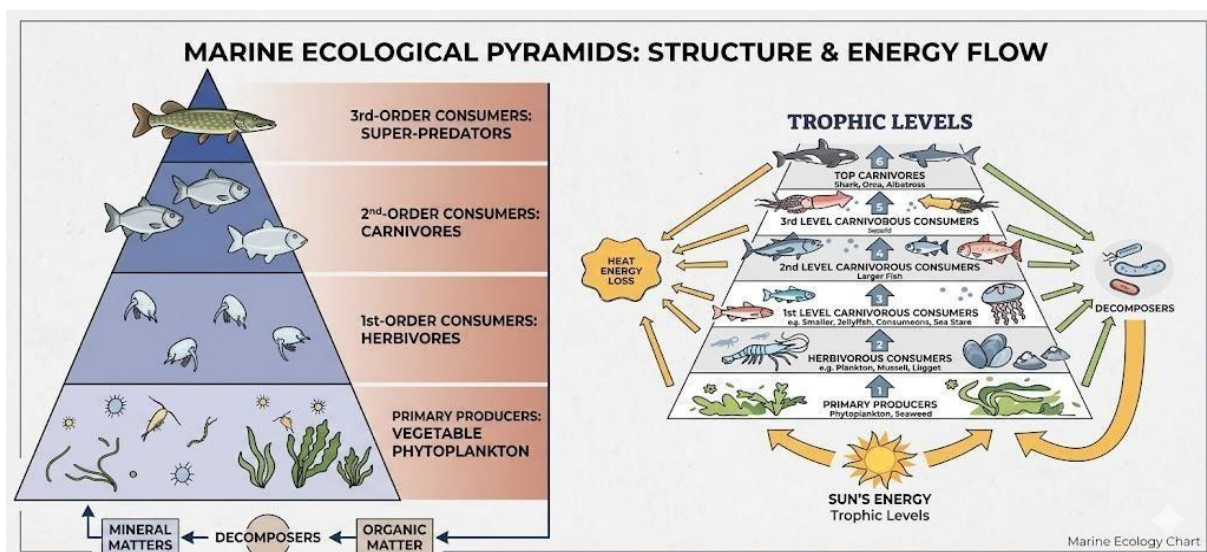


Figure 32 : trophic level in aquatic environments

- **Structure and reading** : representation of young and old divided by sex.
- **Health indicator** : a wide base indicates a growing population (high birth rate), while a broad peak with a narrow base may signal an aging population or reproductive failure.
- **Variation in environments** : the structure depends on the type of aquatic environments (cold streams, slow rivers, oceans) and the quality of habitats for reproduction and growth.
- **Use** : Scientists use it to manage fish populations, assess the impact of fishing or pollution, and the survival of larvae and adults.

Although often confused, this age pyramid (individuals) differs from the biomass pyramid, which is sometimes inverted in aquatic environments, where producers (phytoplankton) have shorter lifespans than consumers.

The age pyramid in terrestrial environments also applies to human populations and also has a typically broad base and a rather narrow apex (**Fig.33**).

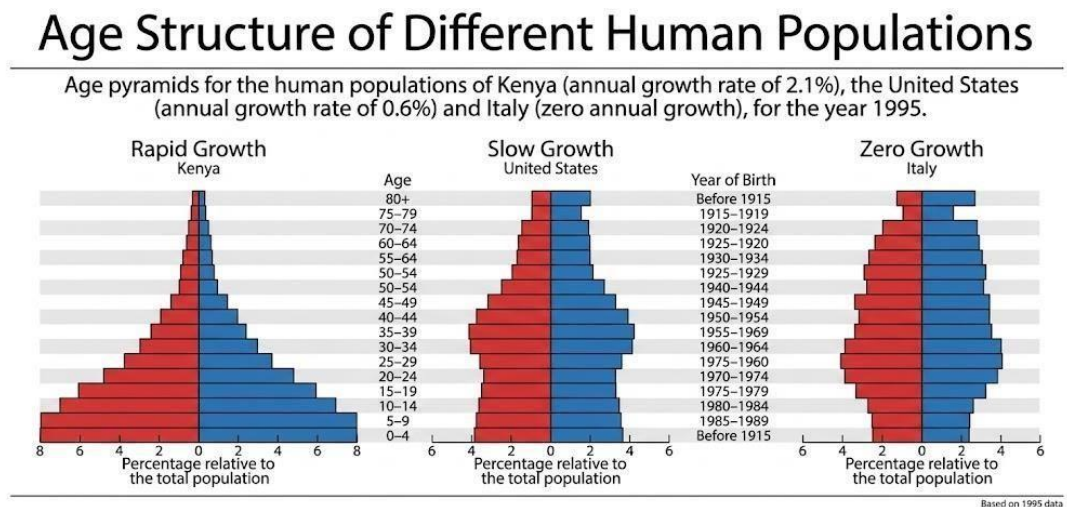


Figure 33 : age pyramid of different human populations

EXAMPLE :

The preceding figure is an example of age pyramids of human populations in Kenya, the United States, and Italy.

- Annual growth rate is 2.1% (Kenya), 0.6% (United States), and 0% (Italy).
- Rapid growth (Kenya), slow growth (United States), and zero growth (Italy).

8. Density

Density in aquatic environments, generally close to 1 (1000 kg/m³) for fresh water at 4°C, varies primarily according to water temperature and salt content. As it sinks, warm, fresh water becomes less dense and floats on the surface.

This density in aquatic environments is calculated as follows :

$$D = P_{\text{substance}} / P_{\text{eau}}$$

The density of water is generally taken as a reference at 1g/cm³ or 1000g/L. It is dimensionless and varies with temperature and salinity.

CHAPTER V : EVOLUTIONARY BIOLOGY : EVOLUTIONARY ECOLOGY AND ADAPTIVE STRATEGIES

I. Evolutionary Ecology

A distinct discipline that is particularly interested in the forms and functioning of organisms as adaptations to their environment.

I.1. Nature of Adaptations

Adaptations have a genetic basis.

Animal and plant ecology reflects an interaction between the genetic potential of organisms and the selective factors of their environment.

Genetic variability will make certain adaptations more advantageous (primarily reproductive mechanisms).

I.2. Evolutionary Fitness

Evolutionary fitness primarily represents the number of descendants left behind by an individual, involving allelic frequencies in the genetic domain. In unpredictable environments (temperate regions), the selected trait increases the growth rate = rselection.

The environment is more stable through adaptations that increase the degree of competition and efficient resource use, which are selected for = K-type selection.

I.3. The Domain of Strategy in Ecology

Strategies that bring together the full set of morphological, behavioral (ethological), and physiological traits that function together and co-evolve simultaneously, representing population adaptations to their environment (**Figure 34**).

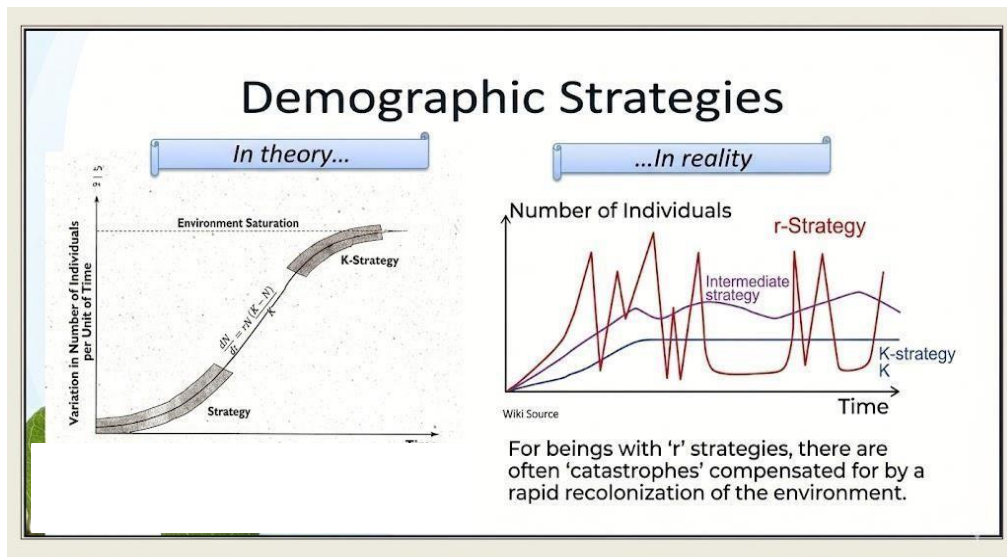


Figure 34 : démographic strategies in réalité and théorie

II. R-Strategy : The Outcome of Density-Independent Selection

Among the species exhibiting the r-strategy are invasive species, including amphibians, fish, and plants. Their enemies are non-specific, as predators prefer other prey and the majority of diseases are non-contagious.

II.1. Characteristics of r-Strategy Species

Most of the descriptive characteristics of these species include being unregulated, exhibiting large population fluctuations, and being saturated within the community. They appear as generalists with a broad diet and accelerated growth, thanks to energy being dedicated primarily to reproduction at the expense of parental care for offspring. This results in small body size and early mortality of descendants.

III. K-Strategy : The Outcome of Density-Dependent Selection

Among the species of this selection category are large animals or plants such as cetaceans and large mammals. Their enemies are specific predators and parasites target particular prey and the majority of diseases are contagious.

III.1. Characteristics of K-Strategy Species

In contrast to r-strategy species, K-strategy populations are regulated by density, resulting in low population fluctuations. They are specialist species with a very narrow diet, which leads to strong competition between species.

Productivity is low, yielding few descendants but with long lifespans, allowing extensive parental care for offspring and efficient energy use. The conditions for their occurrence favor stable habitats.

CONCLUSION

The biology and dynamics of populations is based on understanding and assimilating the relationships that exist between individuals composing a population first among themselves, and second in terms of their distribution and dispersal in the surrounding environment. Stability is controlled, on one hand, by biodemographic parameters, and regulation is achieved by factors that are either density-dependent or density-independent.

Growth is established and shaped by individuals entering the population through natality and immigration, and by individuals leaving through mortality and emigration. Finally, evolution is discussed through the adaptations and characteristics of species, whether they are subject to r-selection or K-selection.

PERSPECTIVES

Designing effective distance learning programs in collaboration with colleagues requires rigorous planning. Defining objectives, target audience, and appropriate format is crucial. Selecting the right tools and platform then allows for the structuring of pedagogical content. The creation of high-quality educational materials and testing of modules ensures an optimal learning experience. Facilitating sessions, monitoring participants, and evaluating effectiveness are all essential steps for collective success. Finally, ensuring rigorous monitoring and assessment allows for the continuous improvement of training and the ability to meet participants' needs.

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Biography



My name is Bouayad Alam Samira, I am currently a Senior Lecturer (Level B) in the Department of Ecology and Environment at Aboubakr Belkaid University, Tlemcen.

My main strengths are discipline, diligence, motivation, teamwork, and a commitment to continuous learning. My goal is to develop my skills to succeed in my professional career and contribute positively to society.

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