NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: BIO 314

COURSE TITLE: ANIMAL ECOLOGY

BIO 314: ANIMAL ECOLOGY

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BIO 313 COURSE GUIDE

Introduction

Animal Ecology (313) is a first semester course. It is a two credit unit elective course which all students offering Bachelor of Science (BSc) in Biology can take.

Animal ecology is an important area of study for scientists. It is the study of animals and how they related to each other as well as their environment. It can also be defined as the scientific study of interactions that determine the distribution and abundance of organisms. Since this is a course in animal ecology, we will focus on animals, which we will define fairly generally as organisms that can move around during some stages of their life and that must feed on other organisms or their products. There are various forms of animal ecology. This includes:

• Behavioral ecology, the study of the behavior of the animals with relation to their environment and others
• Population ecology, the study of the effects on the population of these animals
• Marine ecology is the scientific study of marine-life habitat, populations, and interactions among organisms and the surrounding environment including their abiotic (non-living physical and chemical factors that affect the ability of organisms to survive and reproduce) and biotic factors (living things or the materials that directly or indirectly affect an organism in its environment).

• Evolutionary ecology is the study of how animals evolve over time to meet the demands on them

This course deals with the historical concept of ecology, ecology of local and aquatic animals. The other contents are growth rate, age structure of animal population, Natality and Mortality, Survivorship Curves, Life Tables and K-Factor Analysis, Competition, The Natural Regulation of Animal Numbers, Population Cycles, Dynamics of Predator-Prey Systems, Ecology of African Mammals and Behavioural Ecology.

What you will learn in this course

In this course, you have the course units and a course guide. The course guide will tell you briefly what the course is all about. It is a general overview of the course materials you will be using and how to use those materials. It also helps you to allocate the appropriate time to each unit so that you can successfully complete the course within the stipulated time limit.

The course guide also helps you to know how to go about your Tutor-Marked-Assignment which will form part of your overall assessment at the end of the course. Also, there will be tutorial classes that are related to this course, where you can interact with your facilitators and other students. Please I encourage you to attend these tutorial classes.

This course exposes you to Animal Ecology, a sub-discipline and very interesting field of Biology.

Course Aims

This course aims to enable you to know/understand the relationship between animals in their ecosystem and environment.

Course Objectives

To achieve the aim set above, there are objectives. Each unit has a set of objectives presented at the beginning of the unit. These objectives will give you what to concentrate and focus on while studying the unit and during your study to check your progress.

The Comprehensive Objectives of the Course are given below. At the end of the course/after going through this course, you should be able to:

1.0 Explain the historical background of animal ecology

2.0 Mention the names of the scientists involved and their contribution to the development of animal ecology

3.0 Explain the basic fundamental of ecology and its components
4.0 Explain the various relationships influencing the ecological community
5.0 State and explain the different type of ecosystem components
6.0 Describe the levels of energy flow in ecosystem.
7.0 Explain the ecology of different fish species
8.0 Explain the ecology of Sea-turtle species

9.0 Define demography
10.0 Explain the term direct and indirect demographic
11.0 List and explain eight methods used in demographics.
12.0 List and discuss three ways by which population can be changed

Working through the Course

To successfully complete this course, you are required to read each study unit, read the textbooks and other materials provided by the National Open University.

Reading the reference materials can also be of great assistance.

Each unit has self –assessment exercise which you are advised to do. At certain periods during the course you will be required to submit your assignments for the purpose of assessment.

There will be a final examination at the end of the course. The course should take you about17 weeks to complete.

This course guide provides you with all the components of the course, how to go about studying and how you should allocate your time to each unit so as to finish on time and successfully.

The Course Materials

The main components of the course are:

1 The Study Guide

2 Study Units

3 Reference/ Further Readings

4 Assignments

5 Presentation Schedule

Study Units

The study units in this course are given below:

BIO 313 ANIMAL ECOLOGY (2 UNITS)

Module 1: Introduction to Animal Ecology

Unit 1: Historical Background of Animal Ecology

Unit 2: Fundamentals of Ecology

Unit 3: Ecology of Terrestrial animals and aquatic animals

Module 2: Ecological Population

Unit 1: Growth rate and Age structure of animal population

Unit 2: Factors affecting Population

Unit 3: Measurement of Population dynamics

Unit 4: Life tables and K-factor analysis

MODULE 3: COMPETITION IN ORGANISMS

Unit 1 Competition (Biology)

Unit 2 Resources Contributing To Competition among Organisms.

MODULE 4: POPULATION IN ANIMAL ECOLOGY

Unit 1 Population

Unit 2 Population Cycle

Unit3 Animal Population Control

Unit 4 Population Cycles In A Predator-Prey System

Unit 5 Demography

MODULE 5: BEHAVIORAL ECOLOGY OF AFRICAN MAMMALS

Unit 1 Behavioral Ecology

Unit 2 Bat - Case Study Of An African Mammal

In Module One, unit one deals with the history and current understanding of Animal Ecology and how organisms and its environment relate and influence one another in their various ecosystems. You are taught about the fundamentals of ecology; the ecology of animals integrate the organisms (animal) and their environment dependently

Module Two is concerned with the growth and regulation of population size, as well as the factors influencing them. Populations are not stable and always exhibit up and down variations in response to changes in environmental or intrinsic factors. The measurement of population dynamics is very important in ecological study of animals. Life table and Key-factor analysis has been applied to a variety of animal species.

Module Three, unit one and two deals with competition and resources that gave a forum for competition.

In Module Four, the first four units deal with predators, prey, plants, and parasites and how all influence changes in population sizes over time. Simple systems may undergo large, cyclical changes, but communities with more complex food webs are likely to experience more subtle shifts in response to changes in parasite load, predation pressure, and herbivore. In unit five, demography is explained.

Module Five, unit one is focused on Behavioral ecology and a case study of African mammal e.g Bat in unit two.

Each unit will take a week or two lectures, will include an introduction, objectives, reading materials, self assessment question(s), conclusion, summary, tutor-marked assignments (TMAs), references and other reading resources.

There are activities related to the lecture in each unit which will help your progress and comprehension of the unit. You are required to work on these exercises which together with the TMAs will enable you to achieve the objective of each unit.

Presentation Schedule

There is a time-table prepared for the early and timely completion and submissions of your TMAs as well as attending the tutorial classes. You are required to submit all your assignments by the stipulated date and time. Avoid falling behind the schedule time.

Assessment

There are three aspects to the assessment of this course.

The first one is the self-assessment exercises. The second is the tutor-marked assignments and the third is the written examination or the examination to be taken at the end of the course.

Do the exercises or activities in the unit applying the information and knowledge you acquired during the course. The tutor-marked assignments must be submitted to your facilitator for formal assessment in accordance with the deadlines stated in the presentation schedule and the assignment file.

The work submitted to your tutor for assessment will account for 30% of your total work.

At the end of this course you have to sit for a final or end of course examination of about a three hour duration which will account for 70% of your total course mark.

Tutor Marked Assignment

This is the continuous assessment component of this course and it accounts for 30% of the total score. You will be given four (4) TMAs by your facilitator to answer. Three of which must be answered before you are allowed to sit for the end of the course examination.

These answered assignments must be returned to your facilitator.

You are expected to complete the assignments by using the information and material in your reading references and study units.

Reading and researching into the references will give you a wider view point and give you a deeper understanding of the subject.

1 Make sure that each assignment reaches your facilitator on or before the deadline given in the presentation schedule and assignment file. If for any reason you are not able to complete your assignment, make sure you contact your facilitator before the assignment is due to discuss the possibility of an extension. Request for extension will not be granted after the due date unless there is an exceptional circumstance.

2 Make sure you revise the whole course content before sitting for examination. The self-assessment activities and TMAs will be useful for this purposes and if you have any comments please do before the examination. The end of course examination covers information from all parts of the course.

Course Marking Scheme

Assignment	**Marks**
Assignment 1-4	Four assignments, best three marks of the four count at 10% each - 30% of course marks.
End of course examination	70% of overall course marks
Total	100% of course materials

Facilitators/ Tutors and Tutorials

Sixteen (16) hours are provided for tutorials for this course. You will be notified of the dates, times and location for these tutorial classes.

As soon as you are allocated a tutorial group, the name and phone number of your facilitator will be given to you.

These are the duties of your facilitator:

- He or she will mark and comment on your assignment
- He will monitor your progress and provide any necessary assistance you need.
- He or she will mark your TMAs and return to you as soon as possible.

(You are expected to mail your tutored assignment to your facilitators at least two days before the schedule date).

Do not delay to contact your facilitator by telephone or e-mail for necessary assistance if

- You do not understand any part of the study in the course material.
- You have difficulty with the self assessment activities.
- You have a problem or question with an assignment or with the grading of the assignment.

It is important and necessary you attend the tutorial classes because this is the only chance to have face to face contact with your facilitator and to ask questions which will be answered instantly. It is also a period where you can point out any problem encountered in the course of your study.

Summary

Animal Ecology (313) is a course that introduces you to the concepts and principles of how species of animals in his habitat relate with their environment. Animal ecology has three areas of fundamentals; population, community and ecosystem. These interrelate with the environment.

Also, the growth pattern and age structure in ecological population, the measurement of population, factors affecting the population growth and the use of life table and K-factor analysis were expansiated.

On the completion of this course, you will have an understanding of basic knowledge of historical background of Animal Ecology. Population growth pattern, mortality and natality rate, immigration and emigration etc you will understand the concept behind animal ecology. In addition you will be able to answer the following questions:

1. Explain the basic fundamentals of ecology and its components
2. Explain the various relationships influencing the ecological community
3. State and explain the different types of ecosystem components
4. Describe the levels of energy flow in ecosystem.
5. Explain the ecology of different fish species
6. Explain the ecology of Sea-turtle species
7. Define demography
8. Explain the term direct and indirect demographic
9. List and explain eight methods used in demographics.
10. List and discuss three ways by which population can be changed

The list of questions you are expected to answer is not limited to the above list.

I believe you will agree with me that Animal Behaviour is a very interesting field of biology.

I wish you success in this course.

CONTENT PAGE

BIO 313 ANIMAL ECOLOGY (2 UNITS)

BIO 313 ANIMAL ECOLOGY (2 UNITS)

MODULE 1: INTRODUCTION TO ANIMAL ECOLOGY

Unit 1: Historical Concept of Ecology

CONTENT

1.0 Introduction

2.0 Objectives

3.0 Main Content

3.1 Historical Background

4.0 Conclusion

5.0 Summary

6.0 Tutor-marked Assignment

7.0 References

I.0 INTRODUCTION

Ecology (from Greek: οἶκος, "house"; -λογία, "study of") is the scientific study of the relation of living organisms with each other and their surroundings. Ecosystems are defined by a web, community, or network of individuals that arrange into a self-organized and complex hierarchy of pattern and process. Ecosystems create a biophysical feedback between living (biotic) and nonliving (abiotic) components of an environment that generates and regulates the biogeochemical cycles of the planet. Ecosystems provide goods and services that sustain human societies and general well-being. Ecosystems are sustained by biodiversity within them.[1][2] Biodiversity is the full-scale of life and its processes, including genes, species and ecosystems forming lineages that integrate into a complex and regenerative spatial arrangement of types, forms, and interactions.

Ecology is a sub-discipline of biology, the study of life. The word "ecology" ("oekologie") was coined in 1866 by the German scientist Ernst Haeckel (1834–1919). Haeckel was a zoologist, artist, writer, and later in life a professor of comparative anatomy. Ancient philosophers of Greece, including Hippocrates and Aristotle, were among the earliest to record notes and observations on the natural history of plants and animals; the early rudiments of modern ecology. Modern ecology mostly branched out of natural history, science that flourished in the late 19th century. Charles Darwin's evolutionary treatise and the concept of adaptation as it was introduced in 1859 is a pivotal cornerstone in modern ecological theory.

Ecology is not synonymous with environment, environmentalism, natural history or environmental science. Ecology is closely related to the biological disciplines of physiology, evolution, genetics and behavior. An understanding of how biodiversity affects ecological function is an important focus area in ecological studies. Ecosystems sustain every lifesupporting function on the planet, including climate regulation, water filtration, soil formation (pedogenesis), food, fibers, medicines, erosion control, and many other natural features of historical, spiritual or scientific value. Ecologists seek to explain:

- life processes and adaptations
- distribution and abundance of organisms
- the movement of materials and energy through living communities
- the successional development of ecosystems. and
- the abundance and distribution of biodiversity in context of the environment.

There are many practical applications of ecology in conservation biology, wetland management, natural resource management (agriculture, forestry, fisheries), city planning (urban ecology), community health, economics, basic and applied science, and it provides a conceptual framework for understanding and researching human social interaction (human ecology).

2.0 OBJECTIVE

At the end of this course, students should be able to:

13.0 Explain the historical background of animal ecology

14.0 Mention the names of scientists involved and their contributions to the development of animal ecology

3.0MAIN CONTENT

3.1 Historical Background

Studies of animal distribution began in the nineteenth century, but the formal development of animal ecology did not occur until the 1920s. British zoologist Charles Elton, whose field research emphasized the study of populations in the wild, was perhaps the most influential figure. Elton's work, often involving northern fur-bearing animals of commercial value, made a number of concepts part of the naturalist's vocabulary, including the ecological niche, the food chain, and the pyramid of numbers, that is, the decrease in numbers of individual organisms, or total quantity (weight) of organisms, at each successive stage in a food chain, from plants and plant-eating animals at the bottom to large carnivores at the top. Just as with plant ecology, diverse schools of animal ecology emerged in Europe and the United States during the first half of the twentieth century. Some schools, like Elton's, focused on empirical studies of predator-prey interactions and population fluctuations, others focused on animal community organization, still others on broader patterns of distribution and abundance.

Although some of the early work in animal ecology, particularly in the United States, attempted to model itself on plant ecology, by the 1930s animal ecology had emerged as an independent field. There was little overlap or interaction between the work of animal and plant ecologists. Effective impetus for an integrated perspective in ecology came from work in aquatic biology, best exemplified in the late nineteenth century by Karl Möbius's studies of the depleted oyster bank off Germany's north coast and the pioneering limnological (freshwater) studies of François Alphonse Forel on Swiss lakes. This work was continued and refined in the early twentieth century by many researchers, including August Thienemann in Germany and Einar Naumann in Sweden. Möbius's concept of the “biocenosis,” the integrated community consisting of all living beings associated with a given habitat or a particular set of environmental conditions, was adopted widely by German and Russian ecologists in the 1920s and 1930s. An integrative perspective also emerged in soil science, as in Sergei Winogradsky's turn-of-the-century studies of soil microbiology, and in studies of biogeochemical cycles, as in the work of Russian geochemist Vladímir Vernadsky, who introduced the term “biosphere” in 1914. However, the integrative concept that had the broadest appeal and played a central role in bringing together the many different strands of ecological science was that of the “ecosystem,” introduced by British botanist Arthur G. Tansley in 1935 but first used effectively in an aquatic setting.

Tansley was Britain's foremost plant ecologist and the founder in 1913 of the British Ecological Society, the first such national organization, formed two years earlier than its American counterpart. A pioneer in vegetation surveys, a critic of Clements's idea of the climax community, a passionate conservationist, and a student of Sigmund Freud, Tansley brought his broad experience and erudition to bear on the problem of identifying the ideal ecological unit of study. He suggested that the term “ecosystem” captured this concept best without implying any mysterious vital properties. The new term received its fullest early treatment in a seminal paper published in 1942 by a young American limnologist, Raymond Lindeman. Making use of the concept of ecological succession, Elton's pyramid of numbers and food chains, earlier studies of energy flow in aquatic systems, and Clements's notion of the stable climax community, Lindeman traced the flow of energy through the different trophic (feeding) levels (producers, primary consumers, secondary consumers) in a small Minnesota pond as a way to mapping its structure as an ecosystem and to demonstrate its progress in development toward a stable, equilibrium state.

World War II proved to be a watershed for ecology. Although earlier preoccupations with community classification and structure, population dynamics, and patterns of distribution continued in the postwar years, newer methodologies, practices, and conceptual schemes took hold, and ecology as a science and a profession grew in size, status, and organization. In the postwar period, Lindeman's groundbreaking work on ecosystem ecology found a home among biologists funded by the U.S. Atomic Energy Commission, who used radionuclides to trace the flow of materials and energy through natural ecosytems. Ecosystem research soon expanded from its base in the Atomic Energy Commission. It also prospered among a small group of Tansley's followers at the new Nature Conservancy in Britain. It became an essential feature of modern ecological science, a message conveyed to several generations of students worldwide through the successive editions of Eugene P. Odum's *Introduction to Ecology*, first published in 1953. Meanwhile, the prewar synthesis of Darwinian natural selection theory with Mendelian genetics resulted in the gradual postwar emergence of a more strongly Darwinian perspective in population and community ecology.

The postwar years also saw a shift toward quantitative aspects of ecology. Mathematical techniques developed in the United States, Europe, and the Soviet Union during the interwar period joined with war-born techniques involving information systems and cybernetics to produce a movement toward mathematical modeling and computer simulation of populations, communities, and ecosystems. Much of this modeling and its techniques came under attack during the last decades of the twentieth century. Some ecologists abandoned model building for empirical studies, others worked on refining and improving the models, and many called into question the underlying notions of stability and equilibrium upon which most of the models were based.

The devastation brought by World War II also contributed to greater post-war interest in the conservation of natural resources, protection of wildlife, and preservation of natural environments, a trend that, when linked in the 1960s with social criticism, blossomed into an international environmental movement that drew heavily upon concepts and theories of ecology. As had occurred before the war in a more limited way among a few visionaries, ecology now came to be widely viewed not only as the source of remedies for environmental ills but also as the scientific underpinning for a new social order. This proved to be a mixed blessing for ecologists. On the one hand, funding for ecological research increased considerably, and many more people were drawn into the field. On the other hand, the theoretical framework of ecological science, being neither unified nor consistent, could not provide easy, unambiguous solutions to environmental problems, let alone unified and consistent social visions. Toward the end of the twentieth century, this disagreement and uncertainty among ecologists was used as fuel in legislative and legal debates arguing against the protection of endangered species and the maintenance of pristine nature reserves. This situation encouraged the further refinement and integration of ecological science toward the incorporation of human disturbance and the notion of managed ecosystems.

4.0 CONCLUSION

In this unit you, learnt about the historical background to animal ecology. Also the contribution of each scientist to the development of animal ecology

5.0 SUMMARY

You have been introduced to the field of animal ecology including some of its most fundamentals; early history, and current understanding of its development. Animal Ecology asks questions about how organisms and its environment relate and influence one another in their various ecosystems.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the historical background of animal ecology
2. Mention the names of scientist involved and their contributions to the development of animal ecology

6.0 REFERENCES

- Donald Worster, *Nature's Economy: A History of Ecological Ideas*, 2d ed. (1994).
- Eugene Cittadino, *Nature as the Laboratory: Darwinian Plant Ecology in the German Empire, 1880–1900* (1990).
- Leslie A. Real and James H. Brown, eds., *Foundations of Ecology* (1991).
- Gregg Mitman, *The State of Nature: Ecology, Community, and American Social Thought, 1900–1950* (1992).
- Michael Shortland, ed., *Science and Nature: Essays in the History of the Environmental Sciences* (1993).
- Robert P. McIntosh, The Background of Ecology (1985).
- Sharon Kingsland, Modeling Nature: Episodes in the History of Population Ecology, 2d ed. (1995).
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- Pascal Acoted., The European Origins of Scientific Ecology *(1800–1901)*, 2 vols. (1998).

MODULE 1

Unit 2: Fundamentals of Ecology

CONTENT

1.0 INTRODUCTION

Fundamentally, ecology is like a society, only it is much bigger than ours; ecologists are like economists, only they investigate the economy of nature instead of that of human. We will be talking about ecology in three basic scales after the introductory section: population, community, and ecosystem. They are stacked and connected one by one, each acts as the building block of the superior system, until finally we arrive at the global level, with the most dynamic, diversified, and ultimate living things system on the planet, the biosphere.

2.0 OBJECTIVES

At the end of this unit, the student should be able to;

1 Explain the basic fundamentals of ecology and its components

2 Explain the various relationships influencing the ecological community

3 State and explain the different types of ecosystem components

4 Describe the levels of energy flow in ecosystem.

3.0MAIN CONTENT

3.1 Ecologoical Community

A *community* is *comprised of all the various populations interacting in an area*. An example of a community is a coral reef where numerous populations of fishes, crustacea and corals exist and interact. Ecologists try to know at this level how different relationships like predation and competition are influencing the organization and evolution of a community.

3.1.1 Composition and Diversity

Communities distinguish from each other by two characteristics: composition and diversity. The *composition* of a community is simply *a listing of the various species in the community*. The

diversity digs deeper than mere composition in that it *involves both species richness(the number of species) as well as evenness (the relative abundance of different species)*.

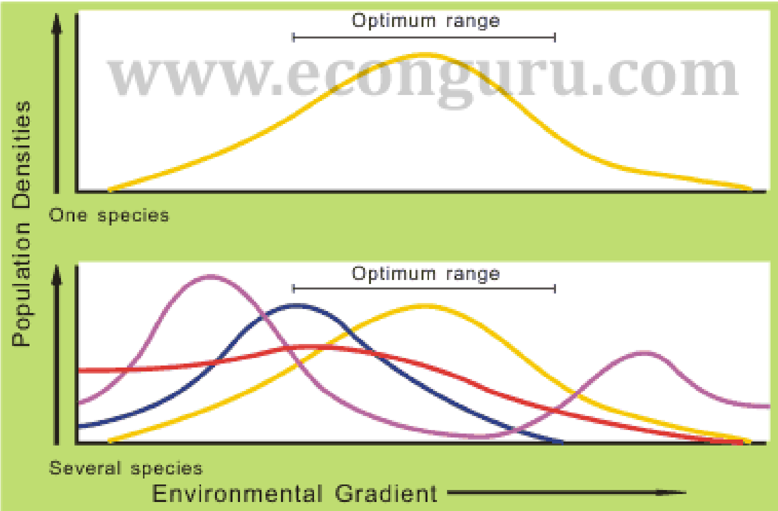


Figure 1: Community Individualistic Model

A species' spreading range is based on its tolerance for such abiotic factors in the environment as temperature, light, water availability, salinity, and so forth. To determine a species' tolerance range, we plot the species' ability to survive and reproduce under a particular gradient of environmental conditions, resulting a bell-shaped curve. If we put together several species' range in one graph, a community is formed because their tolerance ranges simply overlap.

However, other models exist such as *interactive model* to explain community and most ecologists supported it for many years, because it bases its hypothesis not only on species' responses to abiotic factors but also biotic factors. Search the web if you want to learn more about it.

3.1.2. Habitat and Ecological Niche

Just as Elton John sings the Circle of Life, each species plays its role in a community, eats or be eaten, lives or let live. They occupy particular positions both in a spatial sense(where to live) and a functional sense(what is the part). A *habitat* is *an environment wherein an organism lives and reproduces*, while the *ecological niche* is *the functional role the organism plays in its community, including its habitat as well as the interactions with other organisms*. Niche includes everything(e.g. resources an organism needs to meet its energy, nutrient, and survival demands) and every aspects of the way(e.g. the environmental features it needs to hunt and to escape successfully) an organism live with the environment, since it's difficult to delve into one niche completely, most observations concentrate on certain aspects of it.

Since an organism's niche is affected by abiotic factors(such as climate and habitat) and biotic factors(such as competitors, parasites, and predators) simultaneously, usually two types of niches are looked at separately by ecologist, the fundamental niches and the realized niches. The *fundamental niche* of an organism comprises all conditions whereunder it can potentially survive and reproduce; the *realized niche* is the set of conditions whereunder it exists in nature.

3.1.3. Interactions

Competition for resources, predator-prey, parasite-host, and other types of interactions integrate species into a system of dynamic interacting populations.

Species Interactions

Type of Interaction	Expected Outcome	
Competition	- -	Decrease in both species
Predation	+ -	Predator increases, prey decreases
Symbiotic Relationships		
Parasitism	+ -	Parasite increases, host decreases
Commensalism	+ 0	One increases, the other not affected
Mutualism	+ +	Increase in both species

As indicated in the above table, *competition* for limited resources between two species has a negative effect on the population abundances of both species. In *predation* and *parasitism*, the abundances of predator and parasite are expected to increase at the expense of that of prey and host, since predators feed on prey and parasites obtain nutrients from the host. In *commensalism* one species is benefited whereas the other is not harmed. In *mutualism*, two species help one another and both species are benefited.

3.1.3a Competition among Populations

Interspecific competition occurs when members of different species try to utilize the same resource like light, space, or nutrients that is in limited supply, or when their niches overlap. If it is unlimited, no competition would have been triggered. Competition leads to several possible outcomes. One of them is the extinction of one of the competitors. The following graphs depict this pattern.

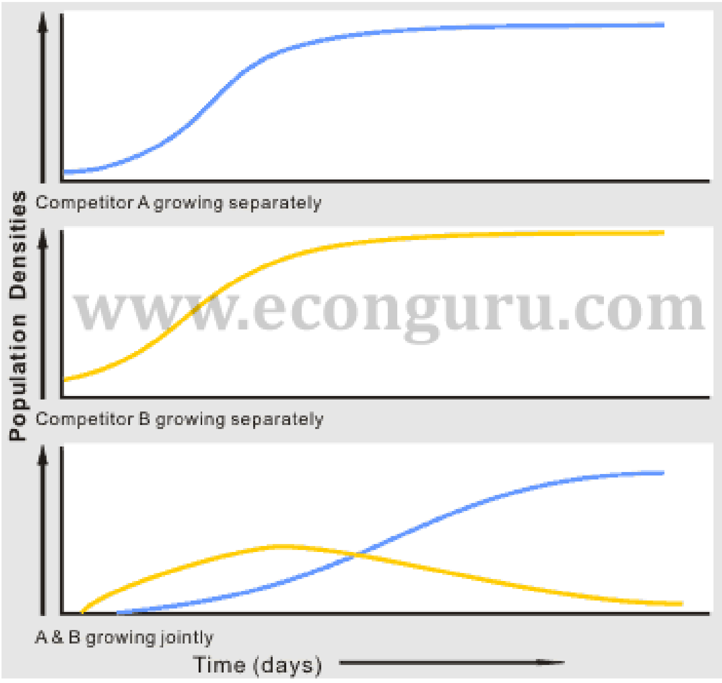


Figure 2: Compete to Extinction
When grown alone in pure culture, both A and B exhibit a somewhat logistic growth pattern, expanding their colonies rapidly till reaching the *carrying capacity* of the environment. However, when the two species come to mixed culture together, A is the better competitor who drives B out in the end.

You might wonder, now that competitions lead to extinctions, why the world is still filled with myriads of living things that share the resources. Good question, but you are partly right, and partly wrong. Extinction is not the only result of competition, two species can both survive the competition, but they have to change, or more technically, their niches have to adapt. In the light of *competitive exclusion principle* that no two species can concurrently occupy the same niche, either one of the species die out or both shift their niches. One of the embodiment of niche shift, or *niche partitioning* is *resource partitioning*. Resource partitioning decreases competition between two species, and it is more observable than other subtle forms of niche partitioning.

Example of Resource Partitioning

When three species of ground finches of the Galapagos Islands occur on isolated islands, their bills tend to be the same intermediate size, enabling them to feed on a wider rage of seeds. Where they co-occur, selection has favored divergence in beak size because the size of the beak affects the kinds of seeds that can be eaten. In other words, competition has led to resource partitioning.

The tendency for characteristics to be more divergent when populations belong to the same community than when they live separately is termed *character displacement*. And it is often used as evidence for that competition and resource partitioning have taken place.

3.1.3b. Predator-Prey Interactions

In *predation, one organism, called the predator feeds on another, called the prey*. With common sense, there should be no dispute on that the relationship between lion and zebra is that of predation. But what is the relationship that herbivorous deer feeds on trees and bushes? This might be a little bit surprising, but in a broader sense, predaceous consumers include not only animals but also herbivores that feed on plants.

By observation, we have revealed the interacting pattern between the populations of predator and prey, cycles of fluctuation that one drives the other and vice versa. Population of the prey increases as that of the predator decreases, since fewer prey are being eaten. At the *carrying capacity* of the environment, the number of prey reaches its summit and stops growing. The predators now are provided with plenty of prey to feed on, so the population increases as that of prey decreases. Again, the predators' increased number overconsume the prey, as the prey population declines, so does the prey population. See the graph below.

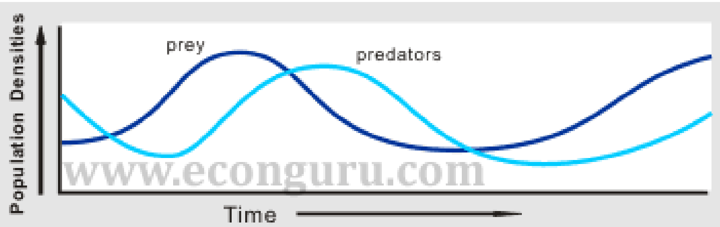


Figure 3: Predator-Prey Population Dynamics

Notice that the predator population is smaller than that of prey, and that it fluctuates lagging behind the prey also.

Most predator-prey population cycles are like what we have discussed, probably with more elaboration of the dynamics and curves. However, their interactions involve more than just population cycles, other behaviors like prey defenses might also interest you. If so, do check the picked links below.

3.1.3c Symbiotic Relationships

A *symbiotic relationship*, or *symbiosis* is *one in which members of two populations interact very closely*. As indicated by the figure 3 in section 3.1.3, three types of symbiotic relationships exist and by the way at least one species benefits from such a relationship while the other is harmed or unaffected or benefited.

Parasitism resembles predation in that *an organism called a parasite derives nourishment from another called the host*(just as the predator derives nourishment from its prey), though parasites also take hosts as habitats and springboards to transmit themselves to other hosts. Parasites appear in all kingdoms of life. Some of the frequently heard of parasites include viruses(e.g., HIV), bacteria(e.g., strep infection), protists(e.g., malaria), fungi(e.g., rusts and smuts), plants(e.g., mistletoe), and animals(e.g., leeches).

Commensalism is a symbiotic relationship wherein *one species is benefited and the other is neither benefited nor harmed*. Well known instances are those in which one species provides a habitat or a means of transportation for the other.

Example of Commensalism

Animalia: Barnacles attach themselves to the backs of whales and the shells of horseshoe crabs to get a free home and ticket for transportation. Remoras are fishes that attach themselves to the bellies of sharks by means of modified dorsal fin acting as a suction cup.

Plantae: Epiphytes grow in branches of tree in order to receive light, but not to take nourishment from the trees. Instead, their roots obtain nutrients and water from the air.

Mutualism is a symbiotic relationship in which *both species benefit*. In many cases, mutualistic relationships help organisms obtain food or avoid predation. As with parasitism, it is possible to find examples of mutualism in all kingdoms.

Example of Mutualism

Human and Bacteria: Human cannot synthesize vitamins by themselves, but can benefit from some bacteria residing in their intestinal tract that make vitamins. Meanwhile, bacteria are provided with food.

Termites and Protozoa: Termites rely on the protozoa in their intestinal tract to digest wood.

To sum up, symbiotic relationships do occur between species, but the three patterns we provided may be too simple to embrace all the natural forms of symbiosis. We were just skimming roughly. Many other derivative forms of symbiosis are developed, look for other materials if you are interested.

3.2 Ecosystem

Ecosystem *extends a community by involving also the abiotic environment*, *that is, the physical and chemical environment*. Energy flow and nutrient cycling (cycling of chemicals) are significant aspects in understanding how ecosystems function. An ecosystem often includes cycles and flows that involve dozens of living things as well as non-living matters, not very much like when we are talking about populations and communities where organisms are studied independently, and interactions are only between no more than two participants. Ecologists focus not only on organic living things of an ecosystem, but also those vital inorganic conditions and materials that are indispensable for living things to survive.

3.2.1 Abiotic Components

Abiotic components are *such physical and chemical factors of an ecosystem as light, temperature, atmospheric gases (nitrogen, oxygen, carbon dioxide are the most important), water, wind, soil*. These specific abiotic factors represent the geological, geographical, hydrological and climatological features of a particular ecosystem. Separately:

- Water, which is at the same time an essential element to life and a milieu
- Air, which provides oxygen, nitrogen, and carbon dioxide to living species and allows the dissemination of pollen and spores
- Soil, at the same time source of nutrients and physical support. The salinity, nitrogen and phosphorus content, ability to retain water, and density are all influential.
- Temperature, which should not exceed certain extremes, even if tolerance to heat is significant for some species
- Light, which provides energy to the ecosystem through photosynthesis
- Natural disasters can also be considered abiotic. According to the *intermediate disturbance hypothesis*, a moderate amount of disturbance does good to increase the biodiversity.

Example of Water Requirements of Plants

As we all know, water is essential for life and all organisms depend on it to survive in especially desert areas. Plants can be classified into 3 groups according to their water requirements:

Hydrophytes: plants which grow in water, e.g. water-lilies and rushes. *Mesophytes*: plants with average water requirements, e.g. roses, sweetpeas. *Xerophytes*: plants growing in dry environments where they often experience a shortage of water, e.g. cacti and often succulents.

Adaptations of plants to survive without water include reversed stomata rhythms, sunken stomata, thick cuticles, small leaves (or the absence of leaves) and the presence of water-storage tissues.

3.2.2. Biotic Components

Organisms are the biotic components of an ecosystem. In ecosystems, living things are classified after the way they get their food.

Autotrophs produce their own organic nutrients for themselves and other members of the community; therefore, they are called the *producers*. There are basically two kinds of autotrophs, chemoautotrophs and photoautogrophs. *Chemautotrophs* are bacteria that obtain energy by oxidizing inorganic compounds such as ammonia, nitrites, and sulfides, and they use this energy to synthesize carbohydrates. *Photoautotrophs* are *photosynthesizers such as algae and green plants that produce most of the organic nutrients for the biosphere.*

Heterotrophs, as *consumers that are unable to produce, are constantly looking for source of organic nutrients from elsewhere. Herbivores* like giraffe are animals that graze directly on plants or algae. *Carnivores* as wolf feed on other animals; birds that feed on insects are carnivores, and so are hawks that feed on birds. *Omnivores* are animals that feed both on plants and animals, as human.

Detritivores are *organisms that rely on detritus, the decomposing particles of organic matter, for food.* Earthworms and some beetles, termites, and maggots are all terrestrial detritivores. Nonphotosynthetic bacteria and fungi, including mushrooms, are *decomposers* that carry out *decomposition,* the breakdown of dead organic matter, including animal waste. Decomposers perform a very valuable service by releasing inorganic substances that are taken up by plants once more.

3.2.3Energy Flow

Everything needs energy for motion, living things are no exceptions. Sun is the ultimate source of energy for every ecosystem. The energy flow of an ecosystem starts the moment photosynthesizers capture sun light and transform it into a stock of organic compound like glucose that stores heat and energy for later use, and ends until the energy is used up or released into the surroundings in metabolic processes. In between them, energy transfers from one organism to another at the aid of food webs, each of the organisms receiving only a small percentage of the total energy carried in the one being consumed, because of all the processes indicated in this diagram:

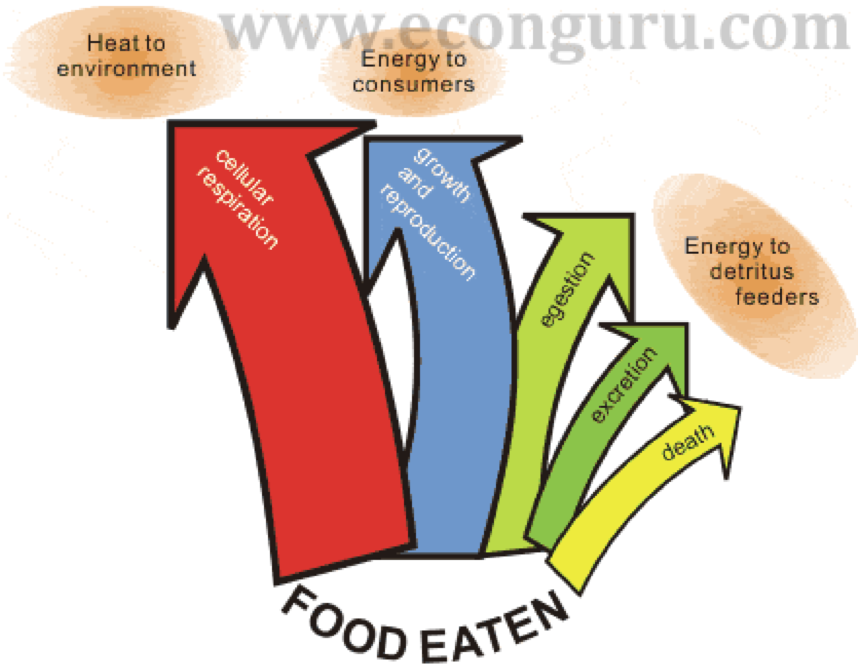


Figure 4: Energy Flow

A certain amount of energy is egested in faeces or excreted in urine and sweat. Of the assimilated energy, a portion is utilized in cellular respiration and thereafter becomes heat. The remaining portion of energy is converted into increased body weight or additional offspring.

3.2.3a. Primary Productivity and Secondary Productivity

Approximately 1% to 2% of the solar energy that falls on a plant is converted to food or other organic material. *Primary productivity* is *the term used to describe the amount of organic matter an ecosystem produces from solar energy within a given area during a given period of time*. Related to the concept, *gross primary productivity* is *the total amount of organic matter produced by all autotrophs in an ecosystem, including that used by themselves*. It is incurred through the process of photosynthesis that is carried out by green plants, algae, and some bacteria. *Net primary productivity*, on the other hand, is defined as *the total amount of energy fixed per unit of time minus the amount of energy expended by the metabolic activities of the photosynthetic organisms in the community, denoting the amount of organic matter produced by autotrophs that is available for heterotrophs*.

Example of Primary Productivity

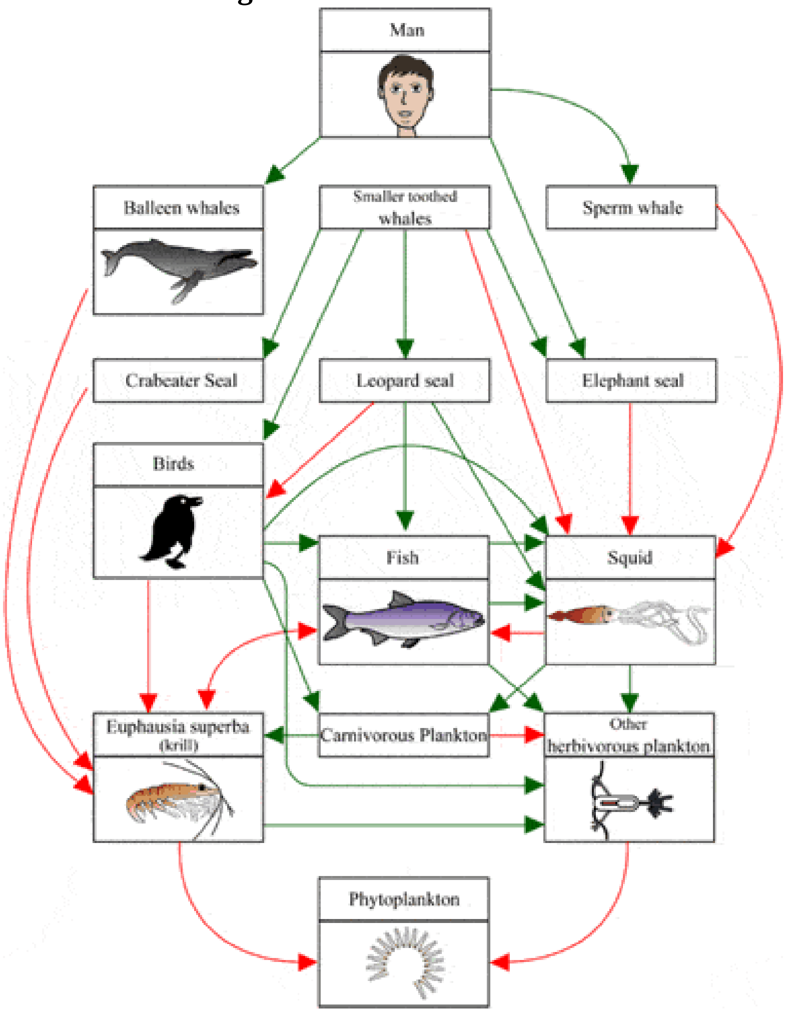
In tropical forests and in marshlands, between 1500 and 3000 grams of organic material are normally produced per square meter per year. Corresponding figures for other communities are: temperate forests, 1100 to 1500 grams; dry deserts, 200 grams. For such highly productive communities as estuaries, coral reefs, and sugarcane fields, the figures may range from 10 to 25 grams per day, for comparable annual yields of 3600 to 9100 grams.

We are now going to explore what happens to the energy stored in autotrophic biomass. *Biomass*, is *the net weight of all organisms living in an ecosystem, which, increases as a result of its net production*. *Secondary productivity* is defined as *the rate of biomass accumulation by heterotrophs (herbivores, carnivores and detritivores)*. Refer back to the energy flow illustration in figure 4, secondary productivity is just the portion that is used to increase body weight and nurture offspring.

3.2.3b Food Webs and Trophic Levels

Food webs refer to *the complicated feeding relationships that exist among organisms in natural ecosystem*. The ocean food web displayed below, however, is just the *grazing food web* that begins with green plant, or the producer**.**

An Ocean Grazing Food Web

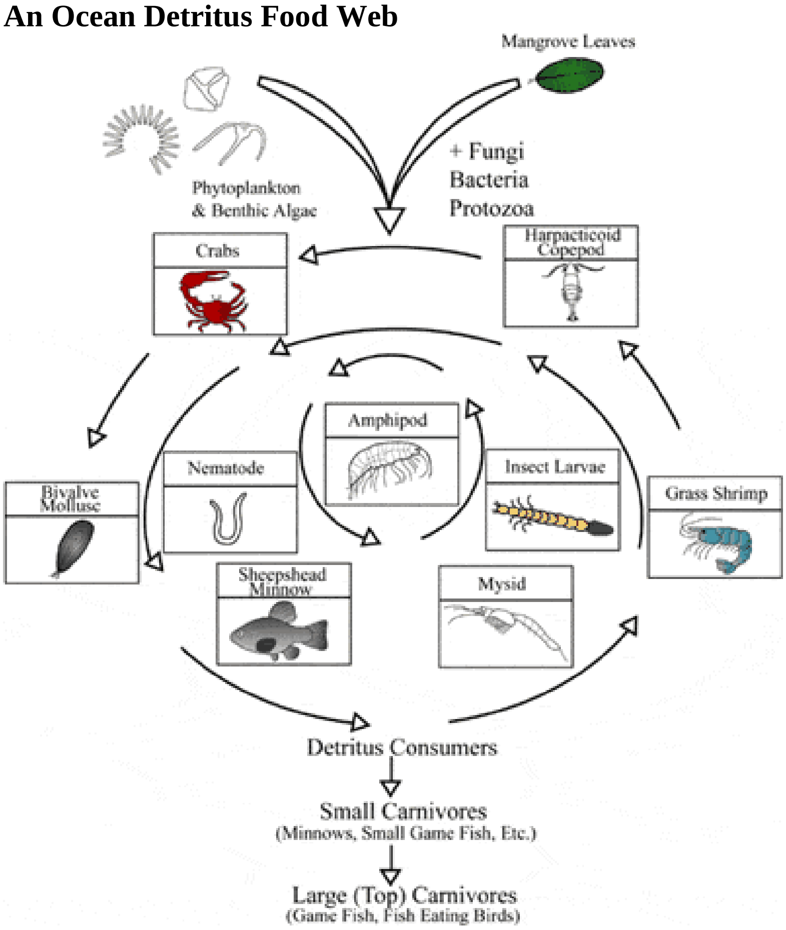


Adapted from http://ocw.mit.edu/OcwWeb/Biology

This ocean food web displayed above shows that krill and other herbivorous plankton feed on phytoplankton, the producer, while birds and fish feed on krill, but they are in fact omnivores because they also feed on plankton; squid hunts fish for food while enjoying some plankton once in a while as well. These *herbivores* and *omnivores* all provide energy and nutrients for a number of different *carnivores*, such as seals and whales.

Another sort of food web called *detrital food web* is revealed in the diagram below. Compared with grazing food web, it is a food web more involved with decomposition processes, and more engaged in abiotic components of an ecosystem**.**

An Ocean Detritus Food Web



Adapted from http://ocw.mit.edu/OcwWeb/Biology

This decomposer food web is modeled upon the detritus food chains that are based on mangrove leaves which fall into shallow estuarine water of South Florida. The bacteria and fungi of decay are the decomposers, but they can be food for other detritivores. Note that *detritivores* are not necessarily bacteria or fungi, they can also be large scavengers such as crabs and shrimps that feed on dead organisms and also the cast-off parts of them.

There are producers and consumers in a food web. *Producers* are those able to synthesize food for themselves, like phytoplankton; and all the others are *consumers* that rely on producers directly or indirectly for a living. Among these consumers, several different levels may be recognized. *Primary consumer*, or herbivores, feed directly on the green plants; *secondary consumers*, carnivores and parasites of animals, feed in turn on the herbivores. *Decomposers* or detritivores break down the organic matter accumulated in the bodies of other organisms.

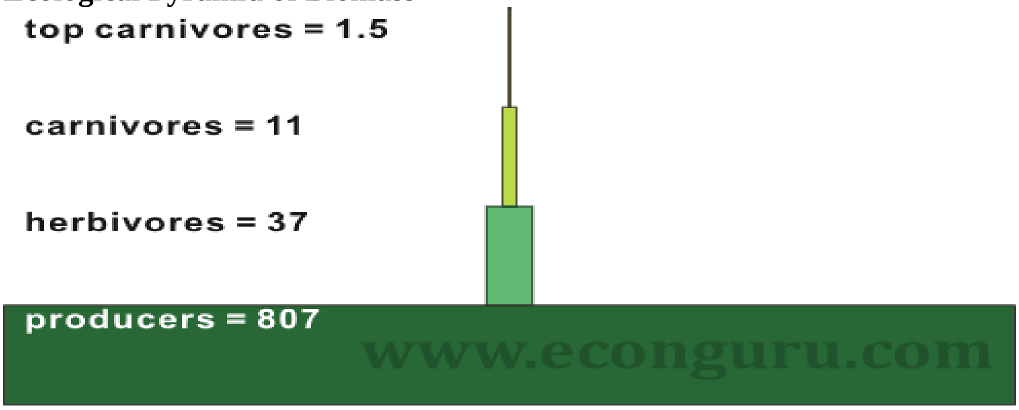
All these levels, if we link them one to another in a straight-line manner, according to who eats whom, we have food chains. Food chains are selected single-lane food relationships in a series among organisms from a more complicated food web, as follows:

phytoplankton ==> Krill ==> Fish ==> seal ==> whale

Diagrams like this that tell who eats whom are called *food chains*. And a *trophic level* is *all the organisms that feed at a particular level in a food chain*. In the grazing food web given at the beginning of the section, going from bottom to top, the phytoplanktons are primary producers(*first trophic level*), the first herbivores that feed on the them, namely the krills and herbivorous planktons are primary consumers(*second trophic level*), and the next group of animals are secondary consumers(*third trophic level*).

Frequently when we talk about the trophic levels, we think about a pyramid like this that exhibits four trophic levels:

Ecological Pyramid of Biomass



Numbers indicated in the diagram are measures of biomass, and the widths of the colored rectangles are so drawn that the proportions are respected. A plant fixes about 1% of solar energy that falls on its green parts. The successive members of a food chain, in turn, process into their own bodies about **10%** of the energy available in the organisms on which they feed.

Aside from pyramids of biomass, there are also *ecological pyramids of numbers* and *energy*, more or less in the same impressive construction that slender representations of top consumers are set upon a huge foundation of that of producers. At the top of most food webs, just imagine the number of plants that have to be grown to support all human beings.

4.0 CONCLUSION

In this unit, you learnt about the fundamental of ecology, which is the economy of nature. The population community and ecosystems.

5.0 SUMMARY

You are taught about the fundamentals of ecology; Composition and diversity, habitat and ecological niche, interactions, *competition among populations, predator-prey. Interactions, Symbiotic Relationships,* abiotic and biotic Components, energy flow, *primary productivity and Secondary Productivity, food webs and trophic levels.*

6.0 TUTOR-MARKED ASSIGNMENT

1 Explain the basic fundamentals of ecology and its components

2 Explain the various relationships influencing the ecological community

3 State and explain the different types of ecosystem components

4 Describe the levels of energy flow in ecosystem.

7.0 REFERENCES

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Unit 3: Ecology of Terrestrial and aquatic animals

CONTENT

1.0 INTRODUCTION

Animal ecology is an important area of study for scientists. It is the study of animals and how they relate to each other as well as how they relate to their environment. There are various forms of animal ecology. By studying this information, you learn more about what makes these animals prosper or what potentially holds them back. With animal ecology, there are many factors, most of which are human caused, that is currently threatening them.

Perhaps the best examples are in the water. A look at area lakes, coastlines and even marine life will show you just how much human environmental damage has hurt these animals. Animal ecology has changed drastically in an effort to keep up. Here are some examples of how the environment and human interaction has changed the scope of many animals.

o Animal habitats in many marine areas have ceased to exist. Coral reefs and other very delicate ecosystems have been harmed by human presence.
o In the arctic regions, melting ice has limited the lifespan of polar bears, which make the ice their home. Additionally, sea lions and other marine life that use the ice to rest on have been unable to do so.
o Dams and other waterway changes have hurt animal ecology throughout the country. Animals are no longer able to get to the source of water they need.
o Deforestation in jungles and other habitats has caused many of the only locations for animals to live to be wiped away.
o Sprawling city growth has also pushed animals farther and farther out of their natural habitats.

There are many other ways that animal ecology has changed. The goal of scientists is to find out what is happening and why it is happening that way. It is often very much a worry when animal species are dying or are unable to evolve naturally because of the drastic changes in their lifestyles and living areas. Through study of animal ecology, scientists hope to understand better what really is happening and what effect it will have both in the short and in the long term.

2.0 **OBJECTIVES**

At the end of this unit, the student should be able to:

1 Explain the ecology of different fish species

2 Explain the ecology of Sea-turtle species

3.0 MAIN CONTENT

3.1 Ecology of some terrestrial and aquatic Animals

3.1. Ecology and Biology of Fish Species

3.1 Clupeidae

Most clupeid species are marine, but some are anadromous (shads) and Ethmalosa fimbriata (bonga) are adopted to withstand low salinities particularly in the rainy season.

a. Bonga (*Ethmalosa fimbriata)*

Bonga is the most important clupeid species in the coastal inshore waters of Nigeria. This species rarely goes below 20 m. It is more euryhaline than the flat sardinella and it is found in estuaries, the sea, lagoons and also in places that are liable to have great variations in salinity. It prefers warm and turbid waters. Because of these ecological preferences, it tends to replace the flat sardinella, and even more clearly the round sardinella, in those sectors without upwelling but with strong surface desalination. Its biology and migrations seem small in extent and limited to estuaries and the adjacent coastal areas (Longhurst, 1960).

Ethmalosa is a non-selective filter-feeder subsisting mainly on large diatoms and phytoplankton. The species migrates into and out of the estuaries following seasonal changes in salinity as well as with the abundance of plankton in the estuaries during the dry season. Ethmalosa tends to be more abundant in Nigerian estuaries during the period October-April. Its migration is possibly due to spawning and feeding. Juveniles are definitely more abundant in rivers and in estuaries, while young spawners and adults can be found both in estuaries and at sea. This pelagic fish is a target species for the artisanal gillnet and beach seine fisheries.

b. Shad (*Ilisha africana*)

Shad is an anadromous clupeid inhabiting inshore waters, sand beaches and estuaries (in almost all fresh waters). Ilisha africana has a maximum length (L_∞) of about 22 cm and it has a good preference for crustacea and small fishes (juveniles). It may be caught at the surface or near the bottom down to about 25 m. Hence it can be a target species for beach seine, gillnet, purse seine and inshore trawl fisheries.

c. Sardine (*Sardinella spp.)*

The flat sardinella is found from Mauritania to Angola. It is coastal fish, more euryhaline, most often found to be abundant near the outlet of water courses. It prefers warmer waters with a temperature above 24°C and seems to avoid waters that are not clear. It is not very abundant in areas without upwelling where the warm and low saline superficial layer is permanently present as in the Baight of Biafra and a large portion of the Nigerian shelf.

In Nigeria Sardinella spp. are caught by canoe fishermen using ringnets, castnets, gillnets, beach seines and also by trawlers. But Sardinella is not a target species of any of the main fisheries.

3.2 Carangidae

The following carangid species are fairly abundant in Nigerian waters: Caranx spp., Chloroscombrus chrysurus, Decapterus rhonchus amd Trachurus spp. There are mostly schooling species distributed on the continental shelf but some occur in brackish waters especially when young.

a. Various jacks (*Caranx spp.)*

Caranx spp. have wide distribution along the West African coast from Senegal to Angola. Some species inhabit inshore waters and estuaries and the others are located in deeper waters (over 100–m depth). Hence, this fish group can be vulnerable to both artisanal and industrial fleets. Caranx spp. feed mainly on fish but also on shrimps, some crabs and invertebrates. This fish species group is caught in pelagic and bottom trawls, seines, set and ring gillnets and sometimes on line gear.

b. Atlantic pumber (*Chloroscombrus chrysurus*)

Chloroscombrus chrysurus occurs along the West African coast from Mauritania to Angola. This schooling pelagic species inhabits the Nigerian continental shelf at depths of 10–50 m. It also occurs in estuaries and the mangrove fringed lagoons and brackishwater areas. Its juveniles are sometimes located offshore in association with jellyfish. Atlantic bumper can be a target species of the artisanal fleet using set gillnets and seines as well as for the industrial fleets using trawls and operating in waters of 10–50 m depth.

c. False scad (“*Decapterus rhonchus*” = *Caranx rhonchus*)

This is a schooling carangid species inhabiting near bottom waters, mostly between 30 m and 50 m but can be located in waters over 200 m depth. It feeds on small fish and invertebrates. This species is mostly exploited by industrial fleets using trawls, but it can also be fished by artisanal motorized canoes using gillnets.

d. Horse mackerel (*Trachurus spp.)*

Horse mackerel occurs in schools in sandy bottom localities and usually at 100–200 m depth. Since the main fishing grounds are on the continental shelf, the species is not normally caught by artisanal fishermen. It is usually a target species of the offshore trawl and purse seine fisheries and sometimes it can be caught with longlines. It appears that the Nigerian industrial fisheries can exploit *Trachurus capensis* (Cape horse mackerel) and *Trachurus trecae* (Cunene horse mackerel).

3.3 Polynemidae

a. Lesser African threadfin (*Galeoides decadactylus*)

Galeoides decadactylus does not appear to penetrate below the thermolcline. It occurs in inshore waters adjacent to sandy beaches. The species is known to develop female gonads by passage through a nonfunctional hermaphroditic stage arising from a normal male. Understanding its reproductive and recruitment strategy appear to be vital in the managing of this fish species.

Galeoides prefers silty and sand-silty bottoms. It is a semi-diadromous fish with spawning migration into estuaries and lower reaches of rivers. it feeds on benthic organisms such as crustacea and polychaetes. It is a target species for the artisanal fishery using gillnets and beach seines as well as the industrial fleets employing trawls in the inshore areas.

b. Royal threadfin (*Pentanemus quinquarius*)

Pentanemus quinquarius has a normal reproductive cycle. It occurs on sandy bottoms down to a depth of 50 m. It is caught by the artisanal gillnet fishery on nearshore sandy bottoms but the species is also harvested offshore by the industrial fleet using trawls. Additionally Pentanemus can be caught with beach seines.

c. **Giant African threadfin (*Polydactylus quadrifilis*)**

The giant African threadfin (*Polydactylus quadrifilis*) can grow up to lengths 150–200 cm. The species inhabits inshore and offshore sandy bottoms up to a depth of 50 m. It also occurs in estuaries and lagoons fringed by mangrove. This fish species is jointly harvested by the artisanal fishermen and industrial fleets. Its attractive size has made it extremely vulnerable to gillnet and beach seine fisheries.

3.4 Sciaenidae

The croakers and drums are the important sciaenid species in Nigeria. This fish species group is primarily marine but also occurs seasonally in brackishwater areas. Most of the species inhabit sandy and muddy bottoms in coastal areas with large river flows.

a. **Bobo croaker (*Pseudotolithus elongatus*)**

Pseudotolithus elongatus prefers surroundings that are less saline. In fact, commercial concentrations correspond to the great estuaries in the gulf of guinea where the species can be caught in large quantities in certain seasons.

They inhabit mud bottoms in coastal waters up to 50-m depth but also enter estuaries and coastal lagoons. This species, with maximum length of about 45 cm, moves further offshore to spawn during the rainy season. P. elongatus is jointly harvested by the artisanal and industrial fleets. It can be caught with bottom trawls, setnets, beach seines and longlines.

b. **Longneck croaker (*Pseudotolithus typus*)**

Pseudotolithus typus grows to a larger size than P. elongatus. It attains a maximum length ($L\infty$) of 100 cm and fish of 50-cm length are common in the catch. The main fishing ground for this species is from the Gulf of Guinea to the Congo. It is the most important commercial sciaenid species in Nigeria.

It inhabits mud and sandy bottoms up to a depth of 150 m but it is more abundant in waters of less than 60 m and temperature above 18°C. It also occurs in estuaries. Hence, it is fished by artisanal and industrial fleets using bottom trawls, bottom setnets and longlines.

c. **Boe drum (*Pteroscion peli*)**

Pteroscion peli occurs along the west coast of Africa, from Senegal to Angola. It inhabits mud and sandy-mud bottoms in coastal waters extending to 200-m depth. But it is most common in waters of less than 50-m depth. This species is more accessible to the industrial fisheries using trawls and hook on line than to the artisanal fisheries using gillnets and beach seines.

3.5 Sparidae

The seabreams occur in fairly deep waters of the continental shelf and off the slope. The small young individuals do occur in shallow waters but mostly at a depth greater than 15 m, forming aggregations. The adult

seabreams are more solitary. The most common species are *Dentex angolensis* and *Pagellus bellottii*. The seabreams are mainly exploited by industrial fleets in Nigeria. Many species are hermaphroditic (having both male and female gametes). Sometimes the majority of individuals are male at first maturity and the females appear later (protandric hermaphroditisms). In some cases the females are more at first maturity and the males appear later (protogynic hermaphroditism). Since protogynic hermaphroditism is associated with efficient utilization of good resources and parental care, it appears to be a better strategy for exploited sparid species.

a. **Angola dentex (*Dentex angolensis*)**

Dentex angolensis occurs along the West African coast from Morocco 33°N to Angola. It inhabits various bottoms on the continental shelf and the slope from about 15 m to about 300-m depth. It is a protogynic hermaphrodite with most individuals beginning as females and changing to males at a length 18–23 cm.

They are known to occur in Nigerian waters but the species is not an important element of the artisanal fisheries. It is caught by the trawl fishery but separate statistics are not available. Angola dentex is a carnivorous species feeding on crustacea, small fish, molluscs and other invertebrates. It can be caught in bottom trawls, bottom setnets and longlines.

b. Red pandora (*Pagellus bellottii*)

The geographical distribution of *P. bellottii* extends from the straits of Gibraltar to Angola and also around the Canary Islands. It is a protogynic hermaphrodite (the majority of individual are first females), then become males. Red pandora is omnivorous with a predominantly carnivorous diet consisting of crustacea, cephalopods, small fish and worms.

This is one of the most abundant sparid species in the CECAF area but it is not a target species of artisanal fisheries in Nigeria. It is possibly caught by the trawl fishery but separate catch data are not reported.

3.6 Other fish species

Some information concerning the biology and ecology of other exploited fish (e.g., Ariidae, Bagridae, Cynoglossidae, Pomadasyidae, Serranidae, etc.) plus species groups treated above also reveals interaction between the brackishwater and open-sea fisheries and possible competition between various sectors of any of the fisheries on certain species.

3.7 Penaeid shrimps

Three commercially important penaeid shrimps occur in Nigerian waters. *Penaeus notialis* (the pink shrimp) is by far the most dominant species. It occurs in the lagoons, estuaries, creeks and open sea. *Parapenaeopsis atlantica* (Guinea shrimp) is also fairly abundant in the open sea depth 10–16 m. The estuarine white shrimp (*Palaemon hastatus*) occurring in brackish waters and open sea is mainly exploited by artisanal fishermen.

The coastal penaeid shrimps have interesting recruitment features, The first phase in the life of coastal penaeid shrimps takes place at sea between three weeks, and one month and thereafter in the coastal zones, in bays, estuaries, in mangrove swamps which are rich in food, or in submerged vegetation. As their development progresses the shrimps migrate toward greater and greater depths. When the areas of distribution of juveniles and adults are clearly separated geographically, a true migration seaward occurs after which spawning takes place.

Since the types of exploitation (and the operational zones of the various gears) are extremely diversified, there are in fact several successive recruitment phases:

i. when the shrimps leave the nursery edges and become accessible to artisanal fisheries;
ii. when they reach the large bays where they are accessible to small trawlers;
iii. during migration, when they are caught by fixed nets;
iv. when they reach the sea and are caught by industrial trawlers.

The entry process into the different fisheries is associated with the development stage of the shrimps. If recruitment is defined as the probability of a shrimp of a given size to be found in the fishing area this probability can be expressed for shrimps of each size as the percentage of shrimps at that size, in the total population that is present in that area. If the percentages are plotted against size a recruitment curve will be obtained.

4.0 ECOLOGY AND LIFE HISTORY OF SEA TURTLE

LEATHERBACK SEA TURTLE

Conservation status

The **leatherback sea turtle** (***Dermochelys coriacea***) is the largest of all living sea turtles and the fourth largest modern reptile behind three crocodilians. It is the only living species in the genus ***Dermochelys***. It can easily be differentiated from other modern sea turtles by its lack of a bony shell. Instead, its carapace is covered by skin and oily flesh. *Dermochelys coriacea* is the only extant member of the family **Dermochelyidae**.

Habitat

Leatherback turtles can be found primarily in the open ocean. Scientists tracked a leatherback turtle that swam from Indonesia to the U.S. in an epic 20,000 kilometers (12,427 mi) foraging journey over a period of 647 days. Leatherbacks follow their jellyfish prey throughout the day, resulting in turtles "preferring" deeper water in the daytime, and shallower water at night (when the jellyfish rise up the water column). This hunting strategy often places turtles in very frigid waters. One individual was found actively hunting in waters that had a surface temperature of 0.4 °C (32.7 °F).

Its favored breeding beaches are mainland sites facing deep water and they seem to avoid those sites protected by coral reefs.

Feeding

Adult *D. coriacea* turtles subsist almost entirely on jellyfish. Due to their obligate feeding nature, leatherback turtles help control jellyfish populations. Leatherbacks also feed on other soft-bodied organisms, such as tunicates and cephalopods.

Pacific leatherbacks migrate about 6,000 miles across the Pacific from their nesting sites in Indonesia to eat California jellyfish. One cause for their endangered state are plastic bags floating in the ocean. Pacific leatherback sea turtles mistake these plastic bags for jellyfish; an estimated one third of adult leatherbacks have ingested plastic. Plastic enters the oceans along the west coast of urban areas, where leatherbacks forage; with Californians using upwards of 19 billion plastic bags every year. Several species of sea turtles commonly ingest plastic marine debris, and even small quantities of debris can kill sea turtles by obstructing their digestive tracts. Nutrient dilution, which occurs when plastics displace food in the gut, affects the nutrient gain and consequently the growth of sea turtles. Ingestion of marine debris and slowed nutrient gain leads to increased time for sexual maturation that may affect future reproductive behaviors. These turtles have the highest risk of encountering and ingesting plastic bags offshore of San Francisco Bay, the Columbia River mouth, and Puget Sound.

Death and decomposition

Dead leatherbacks that wash ashore are micro-ecosystems on their own while decomposing. In 1996, a drowned carcass held sarcophagid and calliphorid flies after being picked open by a pair of *Coragyps atratus* vultures. Infestation by carrion-eating beetles of the Scarabaeidae, Carabidae, and Tenebrionidae families soon followed suit. After days of decomposition, beetles from the families Histeridae and Staphylinidae and anthomyiid flies invaded the corpse as well. Organisms from more than a dozen families took part in consuming the carcass.

Life history

Baby leatherback turtle at Gumbo Limbo Environmental Complex in Boca Raton, Florida

Like all sea turtles, leatherbacks start as hatchlings, climbing out of the sands of their nesting beaches. Birds, crustaceans, other reptiles, and people prey on hatchings before they reach the water. Once in the ocean, they are rarely seen before maturity. Few turtles survive this period. *Dermochelys* juveniles spend more of their time in tropical waters than do adults.

Adults are prone to long-distance migration. Migration occurs between the cold waters where mature leatherbacks feed, to the tropical and subtropical beaches in the regions where they hatch. In the Atlantic, females tagged in French Guiana have been recaptured on the other side of the ocean in Morocco and Spain.

Mating takes place at sea. Males never leave the water once they enter it, unlike females which nest on land. After encountering a female (who possibly exudes a pheromone to signal her reproductive status), the male uses head movements, nuzzling, biting, or flipper movements to determine her receptiveness. Females mate every two to three years. However, leatherbacks can breed annually. Fertilization is internal, and multiple males usually mate with a single female. This polyandry does not provide the offspring with any special advantages.

While other sea turtle species almost always return to their hatching beach, leatherbacks may choose another beach within the region. They choose beaches with soft sand because their softer shells and plastrons are easily damaged by hard rocks. Nesting beaches also have shallower approach angles from the sea. This is vulnerability for the turtles because such beaches easily erode.

Females excavate a nest above the high-tide line with their flippers. One female may lay as many as nine clutches in one breeding season. About nine days pass between nesting events. Average clutch size is around 110 eggs, 85% of which are viable. After laying, the female carefully back-fills the nest, disguising it from predators with a scattering of sand.

Cleavage of the cell begins within hours of fertilization, but development is suspended during the gastrulation period of movements and infoldings of embryonic cells, while the eggs are being laid. Development then resumes, but embryos remain extremely susceptible to movement-induced mortality until the membranes fully develop after incubating for 20 to 25 days. The structural differentiation of body and organs (organogenesis) soon follows. The eggs hatch in about sixty to seventy days. As with other reptiles, the nest's ambient temperature determines the sex of the hatchings. After nightfall, the hatchings dig to the surface and walk to the sea.

Leatherback nesting seasons vary by location; it occurs from February to July in Parismina, Costa Rica. Farther east in French Guiana, nesting is from March to August. Atlantic leatherbacks nest between February and July from South Carolina in the United States to the United States Virgin Islands in the Caribbean and to Suriname and Guyana.

HAWKSBILL SEA TURTLE

Anatomy and morphology

E. imbricata has the typical appearance of a marine turtle. Like the other members of its family, it has a depressed body form and flipper-like limbs adapted for swimming.

E. imbricata.

The carapace's serrated margin and overlapping scutes are evident in this individual. Adult hawksbill sea turtles have been known to grow up to 1 metre (3 ft) in length, weighing around 80 kilograms (180 lb) on average. The heaviest hawksbill ever captured was measured to be 127 kilograms (280 lb). The turtle's shell, or carapace, has an amber background patterned with an irregular combination of light and dark streaks, with predominantly black and mottled brown colors radiating to the sides.

The hawksbill sea turtle has several characteristics that distinguish it from other sea turtle species. Its elongated, tapered head ends in a beak-like mouth (from which its common name is derived), and its beak is more sharply pronounced and hooked than others. The hawksbill's arms have two visible claws on each flipper.

A close-up of the hawksbill's distinct beak

One of the hawksbill's more easily distinguished characteristics is the pattern of thick scutes that make up its carapace. While its carapace has five central scutes and four pairs of lateral scutes like several members of its family, *E. imbricata*'s posterior scutes overlap in such a way as to give the rear margin of its carapace a serrated look, similar to the edge of a saw or a steak knife. The turtle's carapace has been known to reach almost 1 metre (3 ft) in length.

Distribution

Hawksbill sea turtles have a wide range, found predominantly in tropical reefs of the Indian, Pacific, and Atlantic oceans. Of all the sea turtle species, *E. imbricata* is the one most associated with tropical waters. Two major subpopulations are acknowledged to exist, the Atlantic and Indo-Pacific subpopulations.

Another model of the possible distribution of *E. imbricata*. Red circles represent known major nesting sites. Yellow circles are minor nesting sites.

A hawksbill sea turtle

Ecology

Habitat

Adult hawksbill sea turtles are primarily found in tropical coral reefs. They are usually seen resting in caves and ledges in and around these reefs throughout the day. As a highly migratory species, they inhabit a wide range of habitats, from the open ocean to lagoons and even mangrove swamps in estuaries. While little is known about the habitat preferences of early-life stage *E. imbricata*, like other sea turtles' young, they are assumed to be completely pelagic, remaining at sea until they mature.

Feeding

E. imbricata in a coral reef

While they are omnivorous, sea sponges are the principal food of hawksbill sea turtles. Sponges constitute 70–95% of their diets in the Caribbean. However, like many spongivores, *E. imbricata* feed only on select species, ignoring many others. Caribbean hawksbill populations feed primarily on the orders Astrophorida, Spirophorida, and Hadromerida in the class Demospongiae. Select sponge species known to be fed on by these turtles include *Geodia gibberosa*.

Aside from sponges, hawksbills feed on algae and cnidarians comb jellies and other jellyfish and sea anemones. The hawksbill also feeds on the dangerous jellyfish-like hydrozoan, the

Portuguese Man o' War (*Physalia physalis*). Hawksbills close their unprotected eyes when they feed on these cnidarians. The Man o' War's stinging cells cannot penetrate the turtles' armored heads.

E. imbricata are highly resilient and resistant to their prey. Some of the sponges eaten by hawksbills, such as *Aaptos aaptos*, *Chondrilla nucula*, *Tethya actinia*, *Spheciospongia vesparium*, and *Suberites domuncula*, are highly (often lethally) toxic to other organisms. In addition, hawksbills choose sponge species that have a significant amount of siliceous spicules, such as *Ancorina*, *Geodia*, *Ecionemia*, and *Placospongia*.

Life history

Young *E. imbricata*

Not much is known about the life history of *E. imbricata*. The life history of sea turtles can be divided into three phases, namely the pelagic phase running from hatching to about 20 cm, the benthic phase, when the immature turtles recruit to foraging areas and the reproductive phase when turtles reach sexual maturity. The pelagic phase possibly lasts 1 to 4 years. Hawksbills show a degree of fidelity after recruiting to the benthic phase, however movement to other similar habitats is possible.

Breeding

Hawksbills mate biannually in secluded lagoons off their nesting beaches in remote islands throughout their range. Mating season for Atlantic hawksbills usually spans April to November. Indian Ocean populations such as the Seychelles hawksbill population, mate from September to February. After mating, females drag their heavy bodies high onto the beach during the night. They clear an area of debris and dig a nesting hole using their rear flippers. The female then lays a clutch of eggs and covers them with sand. Caribbean and Florida nests of *E. imbricata* normally contain around 140 eggs. After the hours-long process, the female then returns to the sea.

The baby turtles, usually weighing less than 24 grams (0.85 oz) hatch at night after around two months. These newly emergent hatchlings are dark-colored, with heart-shaped carapaces measuring around 2.5 centimeters (0.98 in) long. They instinctively walk into the sea, attracted by the reflection of the moon on the water (possibly disrupted by light sources such as street lamps and lights). While they emerge under the cover of darkness, baby turtles that do not reach the water by daybreak are preyed upon by shorebirds, shore crabs, and other predators.

E. imbricata hatchling

Early life

The early life history of juvenile hawksbill sea turtles is unknown. Upon reaching the sea, the hatchlings are assumed to enter a pelagic life stage (like other marine turtles) for an undetermined amount of time. While hawksbill sea turtle growth rates are not known, when *E. imbricata* juveniles reach around 35 centimeters (14 in) they switch from a pelagic life style to living on coral reefs.

Maturity

Hawksbills evidently reach maturity after thirty years. They are believed to live from thirty to fifty years in the wild. Like other sea turtles, hawksbills are solitary for most of their lives; they meet only to mate. They are highly migratory. Because of their tough carapaces, adults' only predators are sharks, estuarine crocodiles, octopuses, and some species of pelagic fish.

A series of biotic and abiotic cues, such as individual genetics, foraging quantity and quality or population density, may trigger the maturation of the reproductive organs and the production of gametes and thus determine sexual maturity. Like many reptiles, it is highly unlikely that all marine turtles of a same aggregation reach sexual maturity at the same size and thus age. Age at maturity has been estimated between 10 and 25 years for Caribbean hawksbills. Turtles nesting in the Indo-Pacific region may reach maturity at a minimum of 30 to 35 years.

OLIVE RIDLEY SEA TURTLE

An olive ridley

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Reptilia
Order:	Testudines
Family:	Cheloniidae
Genus:	*Lepidochelys*
Species:	***L. olivacea***

The **olive ridley sea turtle** (*Lepidochelys olivacea*), also known as the Pacific ridley, is a species of sea turtle.

Description

The olive ridley is a small extant sea turtle, with an adult carapace length averaging 60 to 70 cm. The heart-shaped carapace is characterized by four pairs of pore-bearing inframarginal scutes on the bridge, two pairs of prefrontals, up to nine lateral scutes per side. Olive ridleys are unique in that they can have a variable and asymmetrical lateral scute count ranging from five to nine plates on each side, with six to eight being most commonly observed. Each side of the carapace has 12-14 marginals. The carapace is flattened dorsally and highest anterior to the bridge. It has a medium–sized, broad head that appears triangular in planar view. The head has concave sides, most obvious on the upper part of the short snout. It has paddle-like forelimbs, each having two anterior claws. The upperparts are grayish green to olive in color, but sometimes appear reddish due to algae growing on the carapace. The bridge and hingeless plastron of an adult varies from greenish white (younger) to a creamy yellow on older specimens.

Hatchlings are dark gray with a pale yolk scar, but appear all black when wet. Carapace length ranges from 37-50mm. A thin white line borders the carapace, as well as the trailing edge of the fore and hind flippers. Both hatchlings and juveniles have serrated posterior marginals, which become smooth with age. Juveniles also have three dorsal keels; the central longitudinal keel gives younger turtles a serrated profile, which remains until sexual maturity is reached.

Olive ridleys rarely weigh over 50 kilograms. A study in Oaxaca, Mexico reported an adult sample ranging from 25 to 46 kilograms. Adult females weighed an average of 35.45 kg (n= 58), while adult males weighed significantly less averaging 33.00 kg (n=17). Hatchlings usually weigh between 12.0 to 23.3 grams. Adults are somewhat sexually dimorphic. Mature males have a longer and thicker tail than females, which is used for copulation. The presence of an enlarged and hooked claw on the front flipper of males allows them to grasp the female carapace during copulation. Males have a longer, tapered carapace than females, which have a round, dome-like carapace. Males also have a more concave plastron, believed to be another adaptation for mating. The plastra of males may also be softer than females.

Distribution

The olive ridley turtle has a cirumtropical distribution living in tropical and warm waters of the Pacific and India Oceans from India, Arabia, Japan, and Micronesia south to southern Africa, Australia, and New Zealand. In the Atlantic Ocean, it has been observed off the western coast of Africa and the coasts of northern Brazil, Suriname, Guyana, French Guiana, and Venezuela. Additionally, there have been records of the olive ridley in the Caribbean Sea as far north as Puerto Rico. It is also found in the eastern Pacific Ocean from the Galapagos Islands and Chile north to the Gulf of California, and along the Pacific coast to at least Oregon Migratory movements have been studied less intensely in olive ridleys than other species of marine turtles, but they are believed to use the coastal waters of over 80 countries. Historically, this species has been widely regarded as the most abundant sea turtle in the world. According to Carr (1972), more than 1 million olive ridleys were commercially harvested off the coasts of Mexico in 1968 alone. Cliffton et al. (1982) had estimated the population of Pacific Mexico to be at least 10 million prior to the era of mass exploitation. More recently, Spotilia (2004) estimated that the global population of annual nesting females has been reduced to approximately 2 million, and Abreu-Gabrois and Plotkin (2008) estimated that number to have been further reduced to 852 550. This indicated a dramatic decrease of 28-32% in the global population within only one generation (i.e. 20 years).

Olive ridley turtle

Ecology and behavior

An olive ridley sea turtle laying eggs

Reproduction

Mating is often assumed to occur in the vicinity of nesting beaches, however, copulating pairs have been reported over 1 000 kilometers from the nearest beach. Research from Costa Rica revealed that the number of copulating pairs observed near the beach could not be responsible for the fertilization of the tens of thousands of gravid females. Therefore, it was believed that a significant amount of mating must have occurred elsewhere at other times of the year.

Olive ridleys generally begin to aggregate near nesting beaches approximately two months before nesting season, although this may vary throughout its range. In the eastern Pacific, nesting occurs throughout the year with peak nesting events (i.e. arribadas) occurring between September and December. Nesting beaches can be characterized as relatively flat, mid-beach zone, and free of debris. Beach fidelity is common, but not absolute. Nesting events are usually nocturnal, however diurnal nesting has been reported especially during large arribadas. Exact age of sexual maturity is unknown, but this can be somewhat inferred from data on minimum breeding size. For example, the average carapace length of nesting females(n = 251) at Playa Nancite, Costa Rica was determined to be 63.3 cm, with the smallest recorded at 54.0 cm. Females can lay up to three clutches per season, but most will only lay one or two clutches. The female will remain near shore for the inter-nesting period, which is approximately one month. Mean clutch size varies throughout its range and decreases with each nesting attempt[4]. A mean clutch size of 116 (30-168 eggs) was observed in Surinam, while nesting females from the eastern Pacific were found to have an average of 105 (74-126 eggs). The incubation period is usually between 45–51 days under natural conditions, but may extend to 70 days in poor weather conditions. Eggs incubated at temperatures of 31-32 degrees Celsius will produce only females; eggs incubated at a temperature of 28 degrees or less will produce solely males; and incubation temperatures of 29-30 degrees will produce a mixed sex clutch. Hatching success can vary by beach and year, due to changing environmental conditions and rates of nest predation.

Habitat

Most observations are typically within 15 kilometers of mainland shores in protected, relatively shallow marine waters (22-55m). Olive ridleys will occasionally occur in open waters. The multiple habitats and geographical localities used by this species vary throughout its life cycle. More research is needed to acquire data on and use of pelagic habitats.

Feeding

The olive ridley is predominantly carnivorous, especially in immature stages of the life cycle. Animal prey consists of protochordates or invertebrates, which can be caught in shallow marine waters or estuarine habitats. Common prey items include jellyfish, tunicates, sea urchins, bryozoans, bivalves, snails, shrimp, crabs, rock lobsters, and sipunculid worms. Additionally, consumption of jellyfish and both adult fish (e.g. Sphoeroides) and fish eggs may be indicative of pelagic (open ocean) feeding. The olive ridley is also known to feed on filamentous algae in areas devoid of other food sources. Captive studies have indicated some level of cannibalistic behavior in this species.

4.0 CONCLUSION

In this unit you learnt, the ecology of aquatic animals, with reference to biology. Precisely the ecology of some fish species in Nigerian waters and sea-turtle.

5.0 SUMMARY

The ecology of animals integrate the organisms (animal) and their environment dependently, animals inhabit community and interact with the biotic and abiotic factors in the environment to survive. fish species and sea turtle have their favourable environmental condition at their best active. Some of these is discuss in this this unit.

6.0 TUTOR-MARKED ASSIGNMENT

1 Explain the ecology and biology of different fish species

2 Explain the ecology and biology of Sea-turtle species

7.0 REFERENCES

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Module 2: Ecological Population

Unit 1: Growth rate and age structure

Content

1.0 INTRODUCTION

A population is a collection of individuals of the same species that live together in a region. *Population ecology* is the study of populations (especially population abundance) and how they change over time. Crucial to this study are the various interactions between a population and its resources. A population can decline because it lacks resources or it can decline because it is prey to another species that is increasing in numbers. Populations are limited by their resources in their capacity to grow; the maximum population abundance (for a given species) an environment can sustain is called the *carrying capacity*. As a population approaches its carrying capacity, Overcrowding means that there are fewer resources for the individuals in the population and this result in a reduction in the birth rate. A population with these features is said to be *density dependent*. Of course most populations are density dependent to some extent, but some grow (almost) exponentially and these are, in effect, density independent. Ecological models that focus on a single species and the relevant carrying capacity are *single species models*. Alternatively, multi-species or community models focus on the interactions of specific species.
The discipline of population ecology holds a great deal of philosophical interest. For a start, we find all the usual problems in philosophy of science, often with new and interesting twists, as well as other problems that seem peculiar to ecology. Some of the former, familiar problems from philosophy of science include the nature of explanation its relationship to laws, and whether higher-level sciences (like ecology) are reducible to lower-level sciences (like biochemistry). Some of the philosophical problems that arise from within population ecology include whether there is a balance of nature and how the uneasy relationship between the

mathematical and empirical sides of the discipline might be understood. As we shall see, many of these questions are intricately linked, and providing satisfactory answers is no easy matter. But there is no doubt that there are important lessons for philosophy of science to be gleaned from the study of population ecology.

2.0 OBJECTIVES

At the end of this unit, a student should be able to:

1 State and explain the term population growth, age distribution and size

2 Describe the growth pattern

3 Understand how to estimate the size of a population using two different techniques.

4 Determine whether a population is exhibiting exponential or logistic growth and how to estimate the carrying capacity of a population.

3.0 MAIN CONTENT

3.1 Density, Distribution and Size

Population density is *the number of individuals of a certain species per unit area or volume*, and *population distribution* is *the pattern of dispersal of them within that area*. They are indispensable variables for ecologists to analyze and discover the spreading pattern of a certain species within a certain area and time. Consider calculating the average density of people in Nigeria, but we know very well that most people live in cities where the number of people per unit area is dramatically higher than that in the country. Therefore, basing ecological population models solely on density can be misleading.

The density and distribution of a population changes with time, due to abiotic factors(inorganic factors) as well as biotic factors(organic factors). Abiotic factors that could have an influence on a population include temperature, rainfall, type of soil and so forth; biotic factors are those that are related to other living things. For example, a particular kind of plant pervading only in a particular area is very likely to affect the density and distribution of a population of an animal that feeds only on it. In these situations, *limiting factors* are those that *particularly determine whether an organism lives in an area*.

Example of a Limiting Factor

In mountainous regions and high latitudes, timberline is the limit of tree growth. Trees cannot grow above the high timberline because water remains frozen at the low temperature for most of the year. In this case, timberline, or more specifically, temperature is the limiting factor for tree density and distribution.

Population size is *the number of individuals in a population*. Technically, genetic relationship is used to distinguish whether an individual belongs to a population or not. Instead of simply counting, it is necessary to estimate the present population size, using methods which vary with the kind of species in question.

Just as density and distribution, population size fluctuates with time. But what factors would affect the future size of a population? There are generally four sources of contribution to the fluctuation of a population size, natality(rate of birth), mortality(rate of death), immigration and emigration. How they each changes the population size is indicated below.

Factors that Affect Population Size

$$\begin{tikzcd} & \textbf{Immigration} \arrow[d, "+"] & \\ \textbf{Natality} \arrow[r, "+"] & \textbf{Population Size} \arrow[r, "-"] \arrow[d, "-"] & \textbf{Mortality} \\ & \textbf{Emigration} & \end{tikzcd}$$

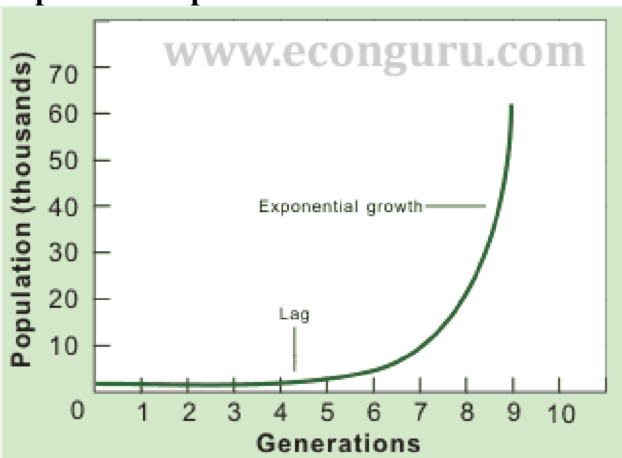
Usually it is acceptable to assume that immigration and emigration are about equal and therefore only necessary to consider natality and mortality.

3.2 Growth Patterns

Theoretically, there exist two distinct and simple growth patterns, or mathematical models for population growth. In the first one, *only one* reproductive chance is given to members of the population during their entire lifespan. Once mission accomplishes, they die. Many insects and annual plants reproduce in this manner. In the other model, members experience *many* reproductive events throughout their lifetime. Most vertebrates and trees have this pattern of reproduction.

Expressed in mathematical equations and graphs, the two growth patterns can be referred to as the *exponential growth pattern* and the *logistic growth pattern* respectively. We are not going to resort to number and equation here, but a glance at the graphs below will be enough for this introductory course.

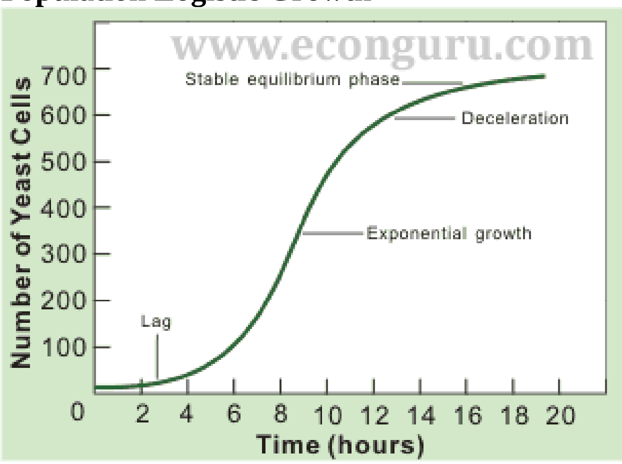
Population Exponential Growth



Two major features of the curve are:

Lag phase: in which *Growth is slow because population base is small and* Exponential growth phase: *in which Growth is accelerating, that is, the rate of growth itself grows.*

Population Logistic Growth



Four major features of the curve are:

Lag phase: *in which Growth is slow because the population base is small*
Exponential growth phase: *in which Growth is accelerating, that is, the rate of growth itself* grows.
Deceleration phase: in which the rate of population growth slows down.
Stable equilibrium phase: in which little growth because births and deaths are about equal.

In fact, since a population is constantly being affected and shaped by its environment, biotically or abiotically, real world growth patterns are more complex and entangling.

2.3. Mortality Patterns and Survivorship Curves

Population growth patterns require an assumption that members of a population are all identical individuals. However, individuals are in their different stages of lifespan. In a given period of time, some are born and some die. See if you can figure out the data in this table:

A Life Table for a Poa annua(a grass) Cohort

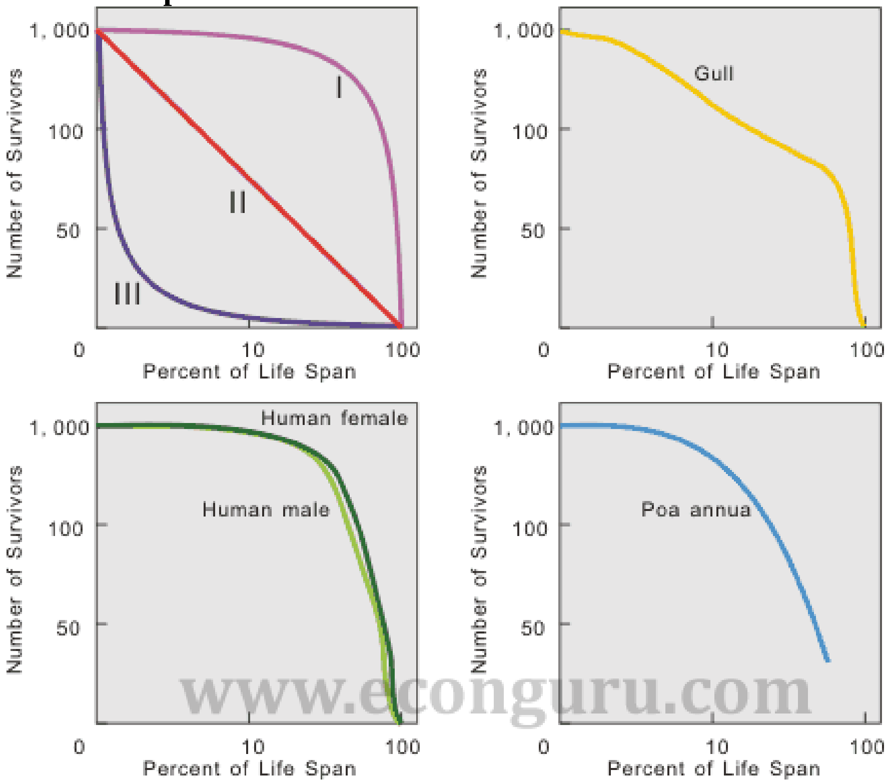
Age (month)	**Number Observed Alive**	**Proportion Surviving**	**Number Dying**	**Mortality Rate Per Capita**	**Avg. Number of Seeds/Individuals**
0-3	843	1,000	121	0.143	0
3-6	722	857	195	0.271	300
6-9	527	625	211	0.400	620
9-12	316	375	172	0.544	430
12-15	144	171	95	0.626	210
15-18	54	64	39	0.722	60
18-21	15	17.8	12	0.800	30
21-24	3	3.6	3	1.000	10
24	0	-	-	-	-

A *cohort* of a population, is the total number of new births of it at the same time. As you can see, the number of grass observed alive at the beginning is 843, and data are noted down every 3 months. The grass are gradually dying out, and the life stages at which they perish vary. From another perspective, let's look at the number that survives instead of focusing on the number dying in each period. After the first observational period, 722 survive the first 3 months. *Survivorship* is *the probability of newborn individuals of a cohort surviving to particular ages*. Plotting the number surviving against percent of life span, we get survivorship curves that show the number of individuals of a cohort still living over time.

For the sake of discussion, we will establish three types of representative survivorship curves hypothetically, displayed in the upper left graph of the following image. Curve I is characteristic of a population in which most individuals survive will pass the midpoint. On the contrary, Curve

III typifies populations wherein most individuals die young. In the type II curve, survivorship decreases at a constant rate throughout the lifespan.

Survivorship Curves



As shown by the other three graphs, the survivorship curves of natural populations do not fit these three idealized curves congruously. However, similarities exist to help understanding. Survivorship curve for *gulls* fits the type II curve somewhat. The survivorship curves of *human males and females* differ slightly but both resemble the type I curve fairly well. The survivorship curve for *Poa annua* seems to be a combination of the type I and type II curves.

Survivorship curves denote mortality patterns of a certain population over a certain period of time. It may vary in abnormal conditions, but in most cases the pattern stay predictable.

3.3. Age Structure

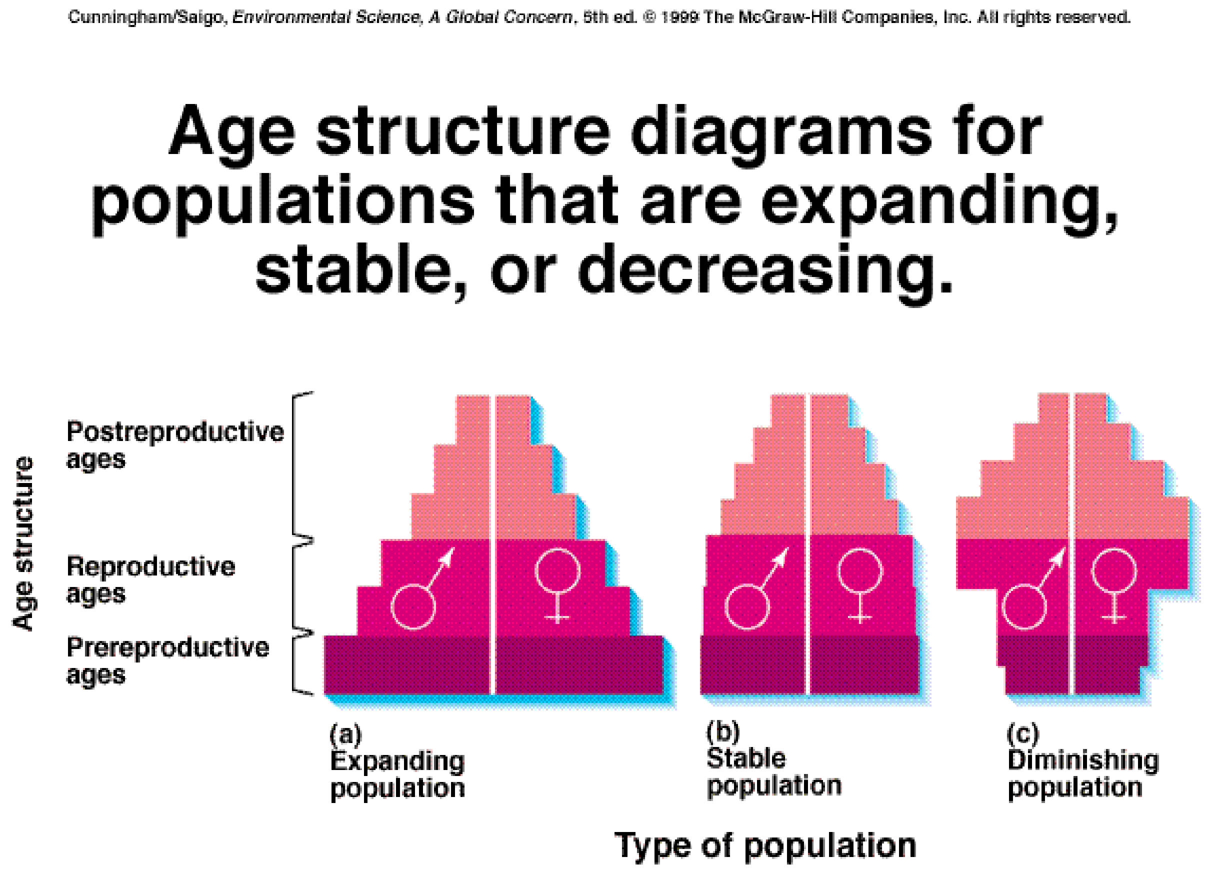
This is the number of individuals in different age classes; pre-reproductive, reproductive, and post-reproductive. Short-lived organisms increase rapidly, with short span between generations Long-lived organisms, increase slowly, and have long span between generations

Determining individual ages

Animals: marking young individuals through time and examining a representative sample of carcasses of individuals wear and replacement of teeth in deer and other ungulates. Annual growth rings in the horns of sheep, plumage changes and wear in birds and growth rings in scales of fishes

Age Pyramids

- comparing the percentages of the population in different age groups, pyramids with a broad base of young suggest growing populations. Pyramids with a narrow base of young and even ratios, suggest a declining or aging population and depict changing dynamics of a population.



3.4 Population Growth Curve

This shows the net result of births, deaths, and dispersion. It usually shows three to five phases. Most organisms show 3 phases: lag phase, exponential growth phase, and equilibrium phase

1) Lag phase - slow growth because the process of growth and reproduction of offspring takes time

2) Exponential growth phase - characterized by more organisms undergoing reproduction, so that the population begins to increase at very fast rate; birthrate exceeds the death rate

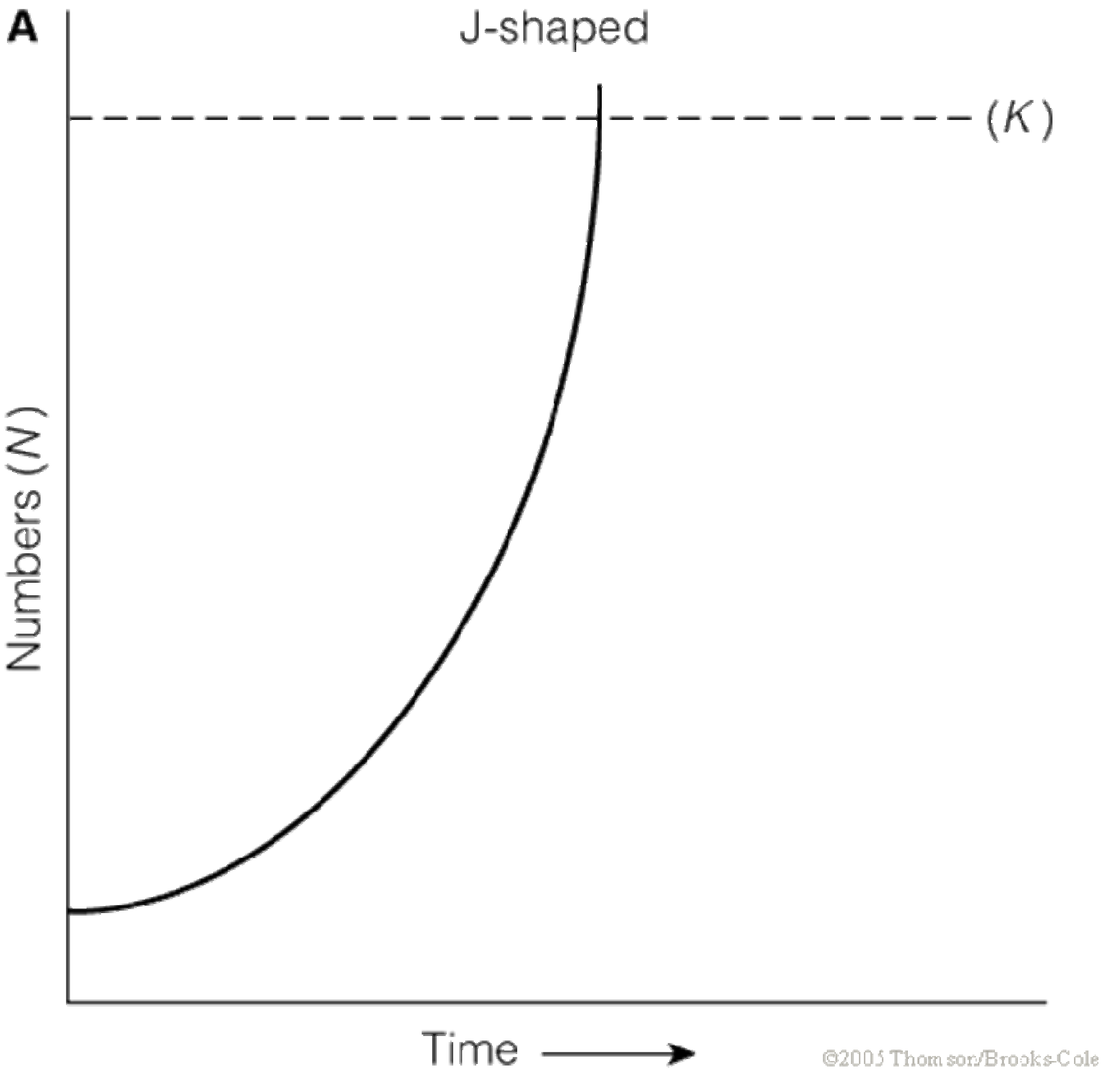
3) Equilibrium phase - characterized by the birth rate and death rate that are equal to one another; population will stop growing and reach a relatively stable population.

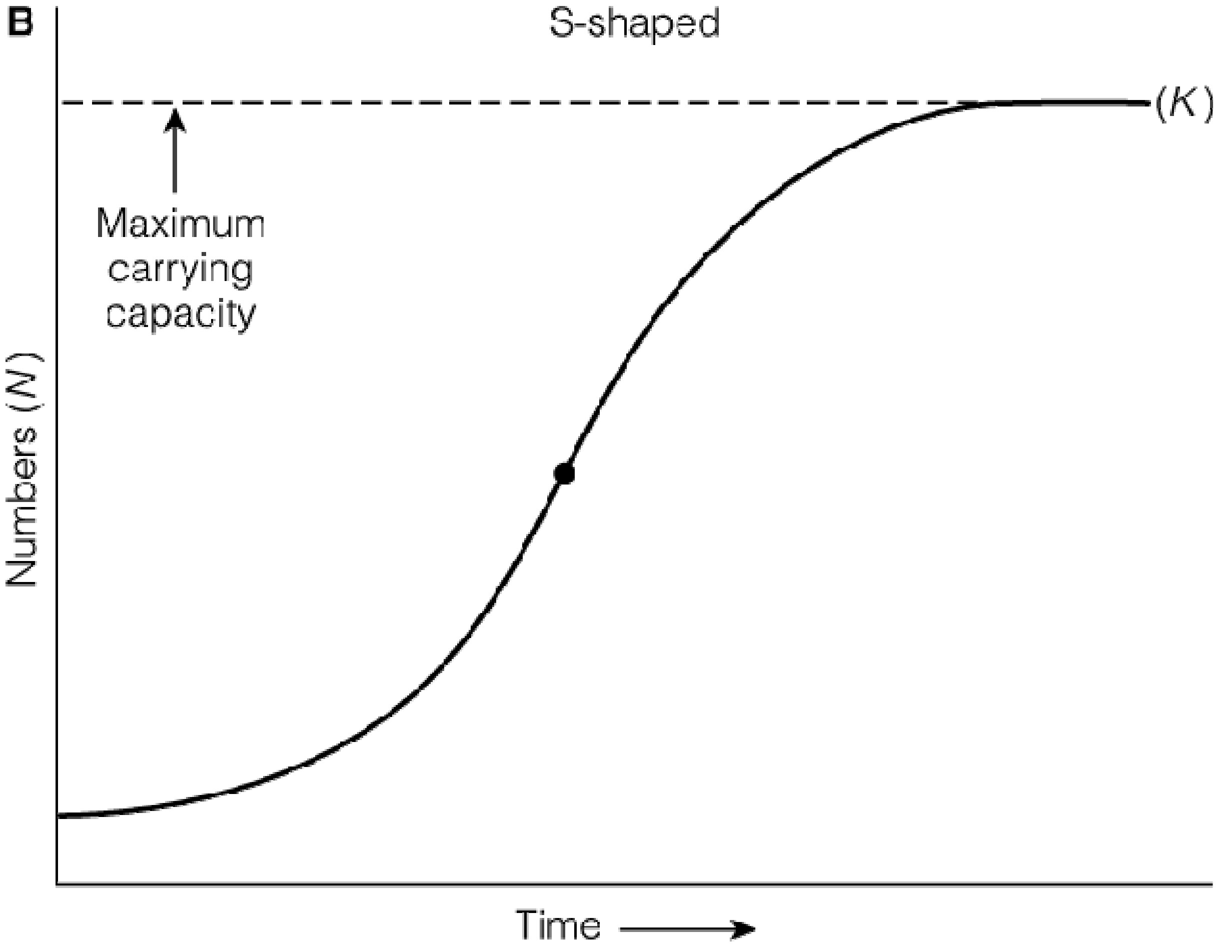
3.4 Population Growth Rate

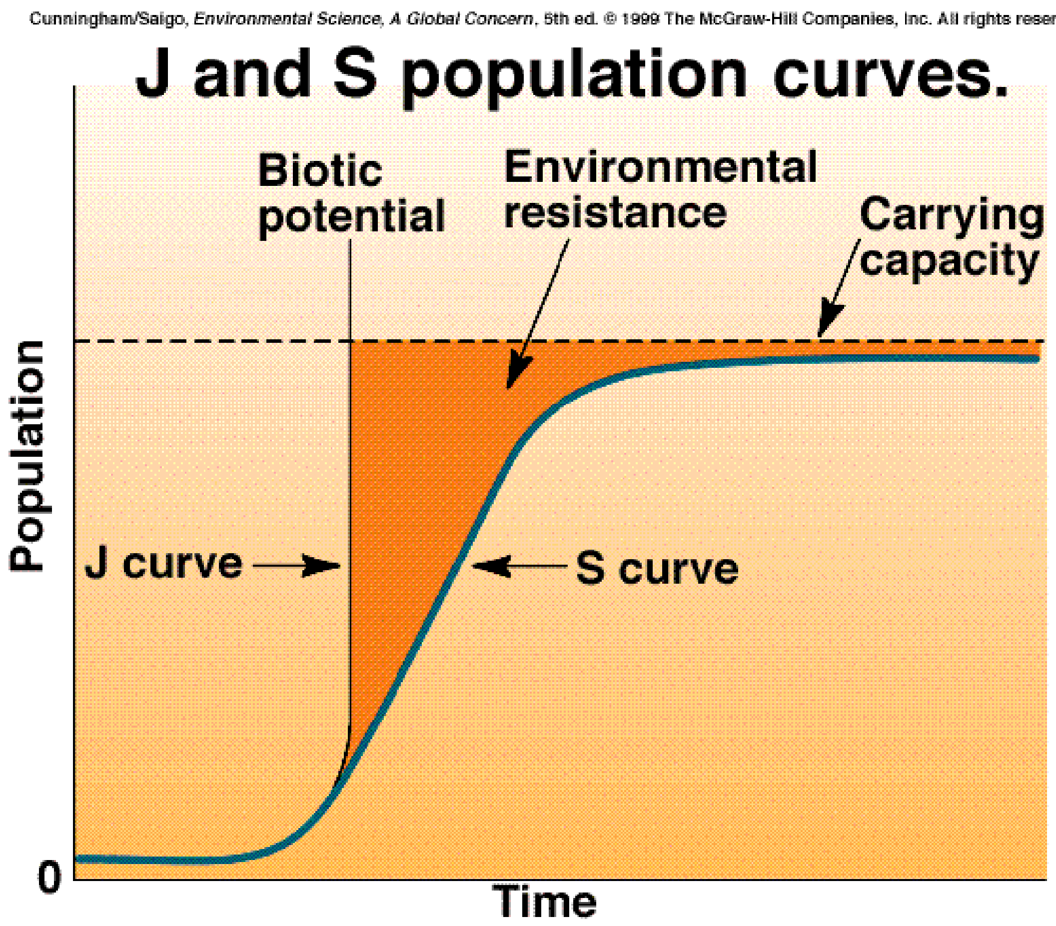
The net result of births, deaths, and dispersion can take a number of forms:

1) J-shaped or exponential growth form – density. Increases in a geometric fashion until the population runs out of some resource or encounters some other limitation

2) S-shaped or Sigmoid growth - limiting factors resulting from crowding provide negative feedback that reduces the rate of growth more and more as density increases. If the limitation is linearly proportional to density, the growth form will be a symmetrical sigmoid curve with density leveling off as to reach the carrying capacity; the carrying capacity represents the maximum sustainable density.


A
J-shaped
(K)
Numbers (N)
Time
©2005 Thomson/Brooks-Cole


B
S-shaped
(K)
Maximum carrying capacity
Numbers (N)
Time

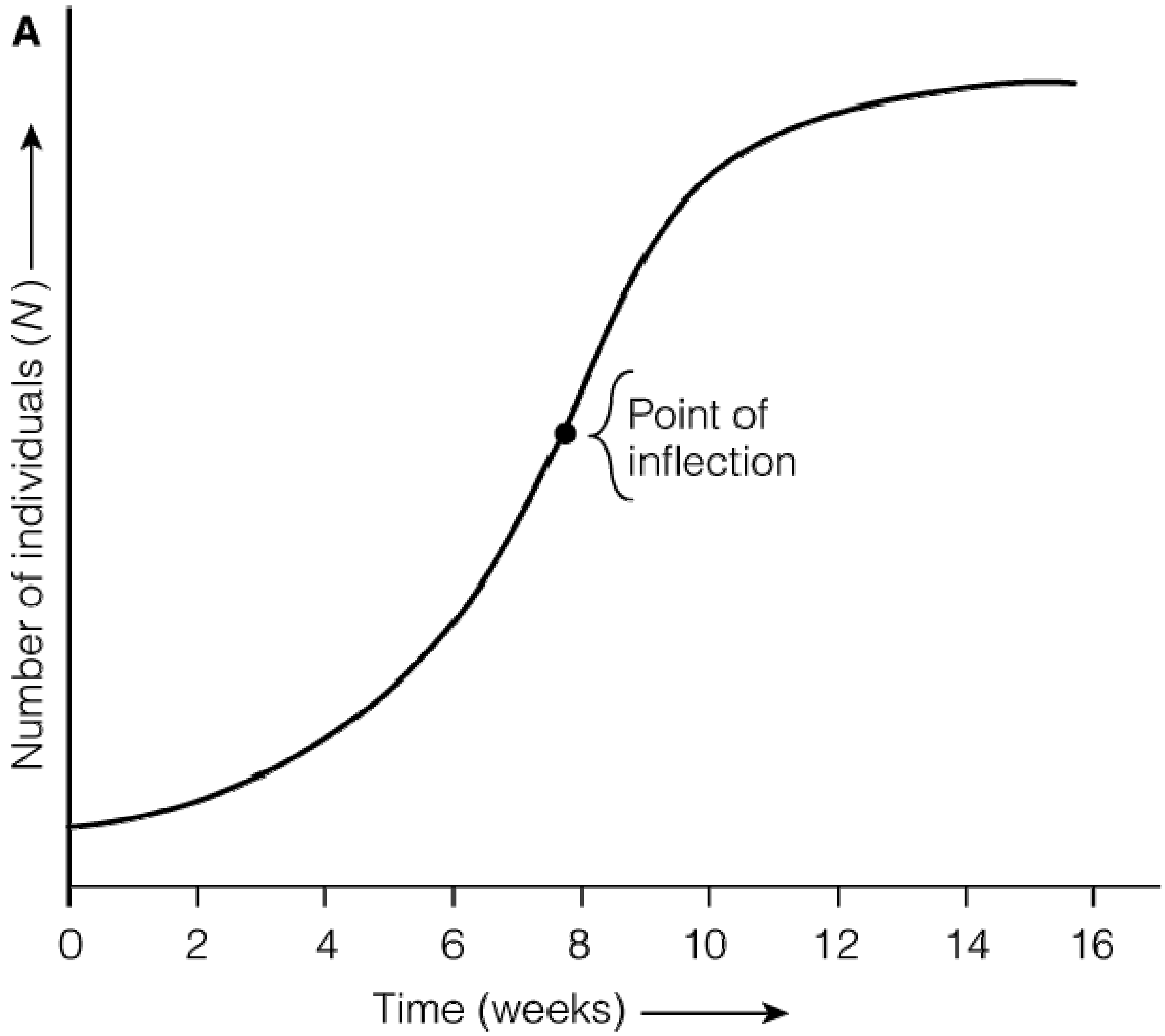


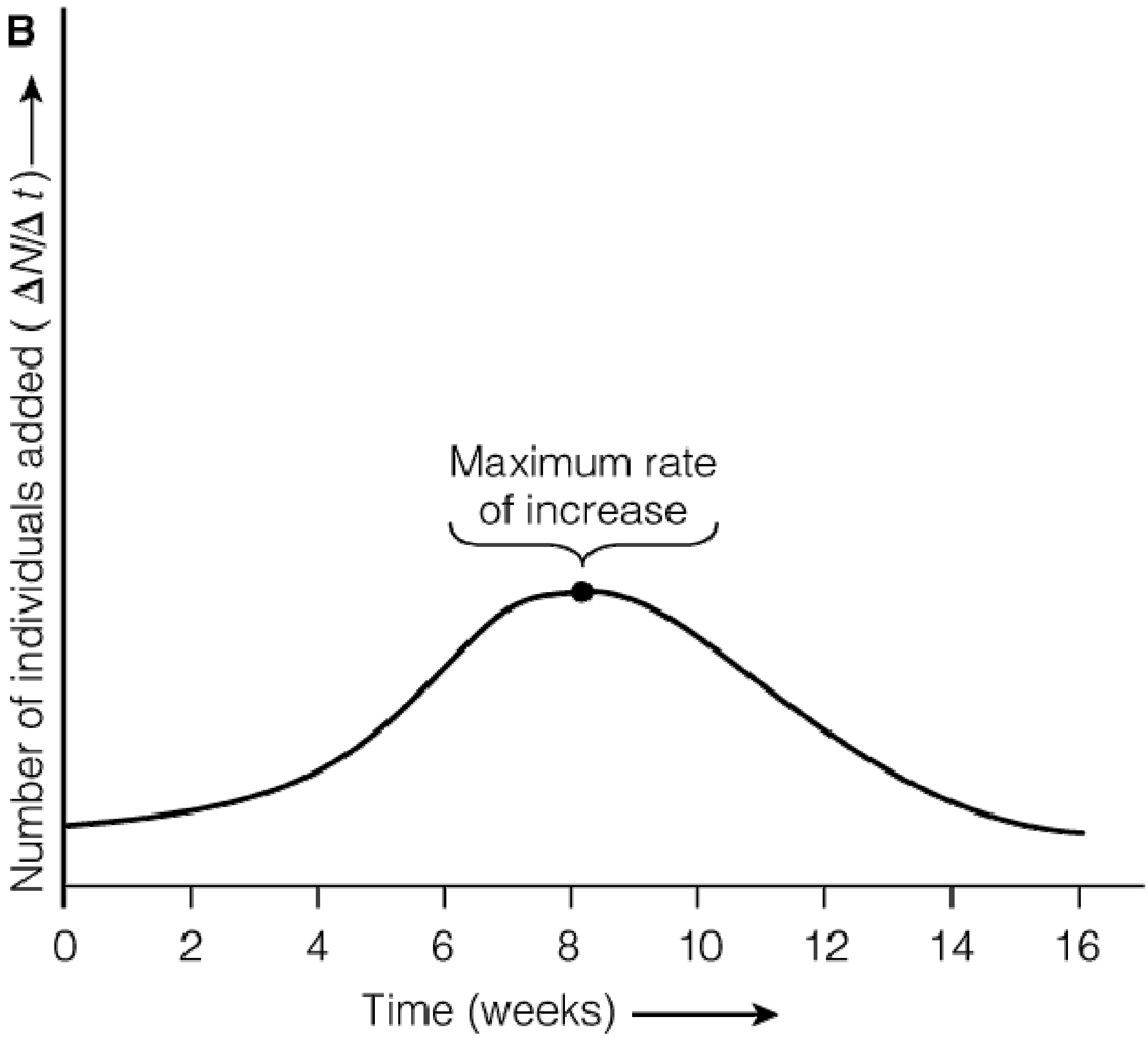
Basic Concepts of Rate

A. Population dynamics - the study of changes in the relative number of organisms in populations and the factor explaining these changes

B. Rate – obtained by dividing the change in some quantity by the period of time elapsed during the change

1. Equation $\Delta N/\Delta t$ = average rate of change in the number of organisms per time. Instantaneous rate: rate at a particular time (rate of change when Δ t approaches 0, d= derivative dN/dt = i.e rate of change in the number of organisms per time at a particular instant) Point of inflection – point where growth rate is maximum.


A
Number of individuals (N)
Point of
inflection
0
2
4
6
8
10
12
14
16
Time (weeks)



4.0 CONCLUSION

In this unit, you learnt the ecological concept of population, how the growth of animal influence the population and age structure, density and distribution.

5.0 SUMMARY

A population *is defined as* the organism belonging to the same species located in the same place at the same time and ecology is the study of those organisms in relation to their environments.. *At this* ecological level, the interest is in the growth and regulation of population size, as well as the factors behind them.

6.0TUTOR-MARKED ASSIGNMENT

1 State and explain the term population growth, age distribution and size

2 Describe the growth pattern

3 Explain how to estimate the size of a population using two different techniques.

4 Determine whether a population is exhibiting exponential or logistic growth and how to estimate the carrying capacity of a population.

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Unit 2: Factors affecting Population

Content

1.0 INTRODUCTION

There are various factors affecting population size: natality, mortality, immigration, and emigration etc. Natality refers to the birth rate. Mortality refers to the death rate. Immigration occurs when individuals from one population of a species join another population of the same species. Emigration occurs when individuals leave a population. The intrinsic population growth rate (r) = (births + immigration) – (deaths + emigration). Zero population growth occurs when the birth rate and immigration are balanced over the long term by the death rate and emigration.

All species of organisms have a great capacity to reproduce. A theoretical growth curve reflects population growth at its maximum rate of increase, per individual, under ideal conditions. Without restraints, the size of any population would increase at an exponential rate. The result is a J-shaped curve. As long as birth rates remain even slightly higher than death rates, a population will grow exponentially.

2.0 OBJECTIVES

At the end of this unit, the student should be able to:

1. State and explain the factors that affect animal population
2. Explain birth and death rates in animal growth pattern
3. Explain immigration and emigration in animal and effect on the distribution of a specific animals.
4. State and explain the factors affecting macro-invertebrate in water.

3.0 MAIN CONTENT

The size and density of a population are affected by various factors. Some of the important ones are:

3.1 Birth rate or Natality rate

Natality rate is the rate at which new individuals are added to a particular population by reproduction (birth of young ones or hatching of eggs or germination of seeds/spores).

It is generally expressed as number of births per 1,000 individuals of a population per year.

'Absolute', 'physiological or maximum natality', refers to the theoretical maximum production of new individuals under ideal conditions. But it is never realised because of environmental resistance (factors like inter and intra specific competitions, availability of food, space etc.)

'Actual birth rate' being achieved under existing conditions, which is much lesser than 'absolute natality is called realized natality. Higher realized natality rate increases the population size and population density.

3.2 Death or Mortality rate

Mortality rate is the rate at which the individuals die or get killed. It is the opposite of natality rate.

Mortality rate is generally expressed as number of deaths per 1,000 individuals of a population per year.

Lowest death rate for a given species in most favourable conditions is called potential mortality while the actual death rate being observed in existing conditions is called realized mortality.

Realized mortality decreases the population size and population density.

The percentage ratio of natality over mortality expressed in percentage is called Vital index.

$$\text{Vital Index} = \frac{\text{Natality rate}}{\text{Mortality rate}} \times 100$$

Vital index determines the normal rate of growth of a population.

Differences between Natality rate and Mortality rate

Character	Natality rate	Mortality rate
1. Definition	Number of births per 1,000 individuals of a population per year	Number of deaths per 1,000 individuals of a population per year
2.Poulation density	Increases population size and population density	Decreases population size and population density

3.3 Age distribution (Age composition)

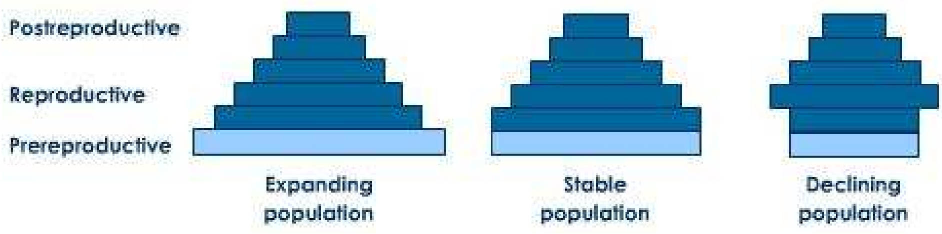
The relative abundance of the organisms of various age groups in the population is called age distribution of population.

With regard to age distribution, there are three kinds of populations.

i) Rapidly growing population is a population, which has high birth rate and low death rate, so there are more number of young individuals in the population.

ii) Stationary population is a population, which has equal birth and death rates, so population shows zero population growth.

iii) Declining population is a population, which has higher death rate than birth rate, so the population has more numbers of older individuals.



Age Structure of Hypothetical Populations which are expected to increase, remain stable or decline with the passage of time

Migration

SOCIAL ASPECT

In its most general sense “migration” is ordinarily defined as the relatively permanent movement of persons over a significant distance. But this definition, or any paraphrase of it, merely begins to delimit the subject, for the exact meaning of the most important terms (“permanent,” “significant”) is still to be specified. A person who goes to another country and remains there for the rest of his life, we say, is a migrant; and one who pays a two-hour visit to the nearest town is not. Between these two extremes lies a bewildering array of intermediate instances, which can only partly be distinguished by more or less arbitrary criteria.

Permanence of movement

What should be the minimum duration of stay that differentiates a migration from a visit? With respect to international migration, the recommendation of the United Nations (and the practice of a number of countries) is to define removal for one year or more as “permanent,” and thus as migration, while a stay for a shorter period is classified as a visit. Note that the data reflect not behavior but statements about future behavior; and persons have been known to lie to immigration officials or to change their minds.

This kind of ambiguity often makes it difficult to interpret migration statistics. More generally, when one speaks of migratory birds, or migrant laborers, or nomads, the connotation is not of a permanent move from one area to another, but rather of a permanently migratory way of life, which often means a cyclical movement within a more or less definite area. Nomads (the word derives from the Greek for *pasturing)* typically follow their herds back and forth over a region delimited either by natural boundaries or by neighbors sufficiently powerful to repel incursions. Similarly, agricultural laborers often move with the growing season, and shepherds (in what is termed transhumance) alternate between high mountain pastureland in the summer and lowlands in the winter. Commutation, the daily “journey to work” constitutes a similar cycle within a smaller compass. One must not accept the common notion that such a separation of place of residence from place of work is peculiar to modern industrial societies.

Migratory selection

That migration is both related to economic trends and yet not, in any simple sense, caused by them, should not occasion any surprise. The same is true of many other complex social phenomena. It would be no contribution to substitute for purely economic causes a list of other “factors,” ranging from the spirit of adventure to the development of transportation facilities; nor would it be a great improvement to divide such a list between circumstances at home that repel and those abroad that attract, that is, between “push” and “pull” factors. Given a sedentary population and an inducement to leave home, typically some persons go and some stay behind. Push and pull factors, in short, do not exert their force equally. The self-selection by which migrants differentiate themselves from the sedentary population is called migratory selection (or, by some authors, selective migration). An analysis of this process can afford a better understanding of why a migration takes place.

It is a valuable extension of the Stouffer-Zipf generalization, for example, to go beyond the counting of heads and differentiate among the types of migrants. It is not sufficient, even in an analysis restricted to economically motivated migrations, to posit job opportunities in general: potential migrants with specific skills go to places where there are openings specifically for them. It is possible to analyze migratory selection by a number of demographic and social characteristics in addition to occupation and race; and although the conclusions from different studies vary widely, some tentative generalizations are possible. In both internal and international movements adolescents and young adults predominate; for not only do the young adapt more easily, but since they are close to the beginning of their working life, they can more readily take advantage of new opportunities. It is feasible, therefore, to analyze migration by cohorts.

Effects on populations

For the two areas concerned, migratory selection determines the significance of the movement almost as much as the number of migrants. Consider the ramifications of what can be taken as the most fundamental question in migration theory: If *X* persons leave country *A* and migrate to country *B*, what changes take place in the size of the two populations. The common-sense answer, that country *A* is decreased and country *B* is increased by *X*, is true only in the short run. If the typically young migrants have their children in their new country, its fertility rate may go up, while that of their native country goes down. Since the remaining population of country *A* will then be older on the average, its death rate may go up, while that of country *B* goes down. In short, after a generation the transfer of *X* persons will in fact amount to *X* plus a certain proportion based on the migration's effects on the population structures, and rates of population growth, of the two countries.

3.4 Immigration

Immigration is the permanent entry of new individuals of same species into a population from outside. It increases the size of local population.

3.4 Emmigration

Emmigration is the permanent movement/departure of individuals of same species out of the local population due to several reasons such as lack of food, scarcity of space (over crowding), etc. Emmigration decreases the size of local population, but the species spread to new areas.

If more individuals are added than lost, then the population will show positive growth. If more individuals are lost than added, then the population will show negative growth. But if the two rates are equal, then the population will become stationary and is called zero growth.

Population growth = (Birth + Immigration) - (Death + Emmigration)

3.5 Carrying capacity (Resources)

Population density of an area is largely determined by available resources like food, water and space in the region.

The maximum number of individuals of a population, which can be provided with necessary resources for healthy living, is called carrying capacity of the habitat. Size of a population increases till it reaches the carrying capacity of the habitat. When the resources become short of requirement, the population size begins to decrease through different determinants like natality, mortality etc.

3.6 Natural calamities

A drastic change in the environment destabilizes or even exterminates a population. Natural calamities such as earthquake, volcanic eruptions etc. cause drastic changes in the environment leading to the destruction of the resources.

3.7 Abiotic and biotic factors

Abiotic factors like temperature, wind, humidity, rainfall, intensity of light has its effect on the density of population.

Biotic factors like organisms of other species living in the same area affect the population, as they involve in different types of food relationships.

For e.g., if the population happens to increase in size, it is brought down by an increase in its predators number or decrease in the amount of available food. Different populations have different ability to tolerate changes in weather, physico-chemical and biotic factors. This is called resilence. In nature, factors like predators, diseases, food scarcity etc. prevent a population to sour towards infinity. The sum of all these factors, which prevent a population from growing at its maximum rate, is called environmental resistance or population regulation.

Examples of Abiotic factors that affect population are:

Water

Wetland conditions such as shallow water, high plant productivity, and anaerobic substrates provide a suitable environment for important physical, biological, and chemical processes. Because of these processes, wetlands play a vital role in global nutrient and element cycles.

The rate of diffusion of carbon dioxide and oxygen is approximately 10,000 times slower in water than it is in air. When soils become flooded, they quickly lose oxygen and transform into a low-concentration (hypoxic -with less than 2 mg O_2l^{-1}) environment and eventually become completely (anoxic) environment where anaerobic bacteria thrive among the roots. Water also influences the spectral composition and amount of light as it reflects off the water surface and submerged particles. Aquatic plants exhibit a wide variety of morphological and physiological adaptations that allow them to survive, compete and diversify these environments. For example, the roots and stems develop large air spaces (Aerenchyma) that regulate the efficient transportation gases (for example, CO_2 and O_2) used in respiration and photosynthesis. In drained soil, microorganisms use oxygen during respiration. In aquatic environments, anaerobic soil microorganisms use nitrate, manganese ions, ferric ions, sulfate, carbon dioxide and some organic compounds. The activity of soil microorganisms and the chemistry of the water reduces the oxidation-reduction potentials of the water. Carbon dioxide, for example, is reduced to methane (CH_4) by methanogenic bacteria. Salt water plants (or halophytes) have specialized physiological adaptations, such as the development of special organs for shedding salt and osmo-regulate their internal salt (NaCl) concentrations, to live in estuarine, brackish, or oceanic environments. The physiology of fish is also specially adapted to deal with high levels of salt through osmoregulation. Their gills form electrochemical gradients that mediate salt excresion in saline environments and uptake in fresh water.

Gravity

The shape and energy of the land is affected to a large degree by gravitational forces. On a larger scale, the distribution of gravitational forces on the earth are uneven and influence the shape and movement of tectonic plates as well as having an influence on geomorphic processes such as orogeny and erosion. These forces govern many of the geophysical properties and distributions of ecological biomes across the Earth. On an organism scale, gravitational forces provide directional cues for plant and fungal growth (gravitropism), orientation cues for animal migrations, and influence the biomechanics and size of animals. Ecological traits, such as allocation of biomass in trees during growth are subject to mechanical failure as gravitational forces influence the position and structure of branches and leaves. The cardiovascular systems of all animals are functionally adapted to overcome pressure and gravitational forces that change according to the features of organisms (e.g., height, size, shape), their behavior (e.g., diving, running, flying), and the habitat occupied (e.g., water, hot deserts, cold tundra).

Pressure

Climatic and osmotic pressure places physiological constraints on organisms, such as flight and respiration at high altitudes, or diving to deep ocean depths. These constraints influence vertical limits of ecosystems in the biosphere as organisms are physiologically sensitive and adapted to atmospheric and osmotic water pressure differences. Oxygen levels, for example, decrease with increasing pressure and are a limiting factor for life at higher altitudes. Water transportation through trees is another important ecophysiological parameter where osmotic pressure gradients factor in. Water pressure in the depths of oceans requires that organisms adapt to these conditions. For example, mammals, such as whales, dolphins and seals are specially adapted to deal with changes in sound due to water pressure differences. Different species of hagfish provide another example of adaptation to deep-sea pressure through specialized protein adaptations.

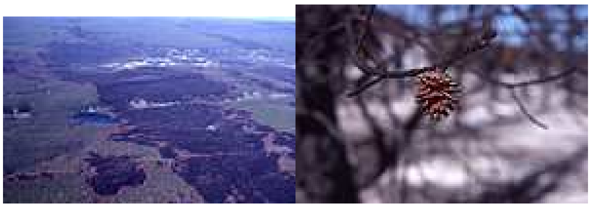
Wind and turbulence

The architecture of inflorescence in grasses is subject to the physical pressures of wind and shaped by the forces of natural selection facilitating wind-pollination (or anemophily).

Turbulent forces in air and water have significant effects on the environment and ecosystem distribution, form and dynamics. On a planetary scale, ecosystems are affected by circulation patterns in the global trade winds. Wind power and the turbulent forces it creates can influence heat, nutrient, and biochemical profiles of ecosystems. For example, wind running over the surface of a lake creates turbulence, mixing the water column and influencing the environmental profile to create thermally layered zones, partially governing how fish, algae, and other parts of the aquatic ecology are structured. Wind speed and turbulence also exert influence on rates of evapotranspiration rates and energy budgets in plants and animals. Wind speed, temperature and moisture content can vary as winds travel across different land features and elevations.

Fire

Main article: Fire ecology



Forest fires modify the land by leaving behind an environmental mosaic that diversifies the landscape into different seral stages and habitats of varied quality (left). Some species are adapted to forest fires, such as pine trees that open their cones only after fire exposure (right).

Plants convert carbon dioxide into biomass and emit oxygen into the atmosphere.[184] Approximately 350 million years ago (near the Devonian period) the photosynthetic process brought the concentration of atmospheric oxygen above 17%, which allowed combustion to occur.[185] Fire releases CO_2 and converts fuel into ash and tar. Fire is a significant ecological parameter that raises many issues pertaining to its control and suppression in management.[186] While the issue of fire in relation to ecology and plants has been recognized for a long time,[187] Charles Cooper brought attention to the issue of forest fires in relation to the ecology of forest fire suppression and management in the 1960s.[188][189]

Fire creates environmental mosaics and a patchiness to ecosystem age and canopy structure. Native North Americans were among the first to influence fire regimes by controlling their spread near their homes or by lighting fires to stimulate the production of herbaceous foods and basketry materials.[190] The altered state of soil nutrient supply and cleared canopy structure also opens new ecological niches for seedling establishment.[191][192] Most ecosystem are adapted to natural fire cycles. Plants, for example, are equipped with a variety of adaptations to deal with forest fires. Some species (e.g., *Pinus halepensis*) cannot germinate until after their seeds have lived through a fire. This environmental trigger for seedlings is called serotiny.[193] Some compounds from smoke also promote seed germination.[194] Fire plays a major role in the persistence and resilience of ecosystems.[195]

Case study: PARAMETERS AFFECTING MACROINVERTEBRATES DISTRIBUTION IN FRESHWATER

Aquatic macroinvertebrates are an important part of the food chain, especially for fish. Many feed on algae and bacteria, which are on the lower end of the food chain. Some shred and eat leaves and other organic matter that enters the water. Because of their abundance and position in the aquatic food chain, benthos plays a critical role in the natural flow of energy and nutrients. As benthos die, they decay, leaving behind nutrients that are reused by aquatic plants and other animals in the food chain.

Unlike fish, benthos cannot move around as much, so they are less able to escape the effects of sediment and other pollutants that diminish water quality. Therefore, benthos can give reliable information on stream and lake water quality. Their long life cycles allow studies conducted by aquatic ecologists to determine any decline in environmental quality. Macro invertebrates constitute a heterogeneous assemblage of animal phyla and consequently it is probable that some members will respond to whatever stresses are placed upon them.

Biomonitoring is the use of the biological responses to assess changes in environment. Therefore, macroinvertebrates are most frequently used as indicator species. Cairns & Pratt conclude that biological surveillance of communities, with special emphasis on characterising taxonomic richness and composition, is perhaps the most sensitive tool now available for quickly and accurately detecting alterations in aquatic ecosystems.

Ecologists and managers should understand the processes which lead to the observed patterns of community structure in unstressed flowing-water systems and that this would provide a firm foundation from which to investigate the processes taking place when environmental stresses lead to community change, both structural and functional.

Many parameters will determine the distribution pattern of macroinvertebrates in freshwaters. Numerous studies and publications have been produced to determine which are the most relevant factors affecting this distribution.

Abiotic factors that predominately seem to affect macroinvertebrate population, they are, in order of importance of impact:

Current speed: many invertebrates have an inherent need for current either because they rely on it for feeding purposes or because their respiratory requirement demands it.

Temperature: intimately related to latitude, altitude, seasons, and relative distance from the source.

Substratum: certain species are confined to fairly well defined types of substratum.

Level of oxygen: main factor in polluted waters.

Salinity, **acidity, hardness, and general water chemistry**.

Those parameters are also defined of prime importance for, which stated that the chief environmental factors affecting distribution of aquatic animals in streams are:

(i) - The chemical nature of the water, this may affect the distribution of aquatic organisms in a number of ways. The concentration of dissolved oxygen is important. Oxygen is not very soluble in water and its solubility depends on the temperature. The calcium content of water is also important for species such as the freshwater shrimp, many snails and mussels, which are abundant in hard water.

(ii) - The physical nature of the water, water movement, and temperature. The surface velocity of water has been shown to have an effect on caddis larvae and it was found that the number of Trichoptera larvae along a current gradient became progressively less numerous with increasing distance from a source.

Temperature has been implicated as a mechanism influencing spatial and temporal isolation and as one of several primary factors influencing life history patterns of aquatic insects. In earlier researches, population of Simuliidae differs in genera to their occurrence in altitude, thus in temperature. Various aspects of water chemistry, e.g., acidity, dissolved oxygen; water hardness, etc. also influence the distribution of freshwater taxa, although ascertaining the effects of selected chemical factors can be difficult.

More recently, ecologists have emphasized their study on one or two particular parameters that will define the distribution of organisms.

Current velocity is often regarded as the most important factor. Current velocity is the most important factor affecting fluvial macroinvertebrates: " Biologists have long believed that water as a medium, and current as a force, strongly determine ecological distributions and shape anatomical and behavioural adaptations". Its importance has even led to the establishment of different criteria for classifying flow environment.

In another study, found out that the two most important factors affecting macroinvertebrates are substrate and suspended sediment. They found that there are four to five physical and chemical factors that have significant influence over biomass and diversity of macroinvertebrates. These factors include substrate, suspended sediment, gradient, water temperature, and stream order and width, supports these findings and provides a literature review of insect-substratum relationships. Have defined in their study that current velocity and substratum are the two main physical factors affecting distribution of lotic macroinvertebrates. Earlier researches tend to demonstrate that substratum/organism relationship was not well understood due to a lack of research on that subject.

Other parameters have to be taken into account when studying factors affecting macroinvertebrates, the importance of scale in studying the impact of different parameters such as substrate type, particle size, current velocity, depth, organic content and habitat heterogeneity on spatial richness. They concluded that at a small scale invertebrate and taxa richness was dependent on detritus accumulation and hydraulic constraints, and a large scale, taxa richness was dependent of climatic and geomorphologic factors.

All these studies have been focused on abiotic factors (i.e. physical and chemical parameters) influencing macroinvertebrates. It is important to also include biotic factors. Biotic factors are more difficult to measure, as they are mainly interaction between organisms. These interactions include predation, competition (intraspecific or interspecific), and parasitism. Numerous potential effects of vertebrate predators on aquatic macroinvertebrates have been described, such as salamander predation on macroinvertebrates. However, other studies showed that salamander/macroinvertebrate predation relationship is not well determined. Other predator such as fish can affect and alter development , species composition, and species abundance of benthic macroinvertebrate communities. The attenuation and elimination of specific taxa.

Relevant literature shows that when investigating the different parameters affecting distribution of macroinvertebrates in order to differentiate the most relevant ones, it is important to take into account that macroinvertebrate ecology is complex, and that interactions with their environment are numerous. All of these interactions will have an effect to a certain extent, upon their distribution.

4.0 CONCLUSION

In this unit you learnt, about the factors affecting the population of animal with reference to Mortality and natality rate.

5.0 SUMMARY

Populations are not stable and always exhibit up and down variations in response to changes in environmental or intrinsic factors. The irregular variations in size of populations are called fluctuations or it is also called as population cycle. This irregularity may be as result of living or non-living factors affecting the organisms. As explained in this unit.Some of the example of the factors are natality and mortality rate, immigration and emigration, abiotic and biotic factors and carrying capacity etc.

6.0 TUTOR-MARKED ASSIGNMENT

1. State and explain the factors that can affect animal population
2. Explain birth and death rate in animal growth pattern
3. Explain immigration and emigration in animal and their effect on the distribution of a specific animal.
4. State and explain the factors affecting macro-invertebrate in water.

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Unit 3: Measurement of Population dynamics

CONTENT

1.0 1NTRODUCTION

There are a number of methods to describe populations from field measurements: dynamic and static life tables, and transition matrices. All are based on censusing individuals in groups, categorized according to their state (age, size, or stage). They are used to explain population dynamics in relation to demographic processes, and to predict the fate of the population.The methods differ in a) convenience of data collection, b) basic assumptions and c) the way they derive population growth rate. Because this also depends on the general biology and life cycle of the organism, some methods are better for some kinds of populations, but not for others.

Dynamic life tables describe survivorship and fecundity (production of eggs, seeds, or young) at different ages of a cohort (a sample of individuals recruited approximately at the same time). Usually the cohort is followed until the last member dies. Survivorship is calculated as the relative change in the number of individuals of the cohort between two successive censuses. The census is very simple, since individuals need only be recognized to differentiate them from other cohorts in the same population, and thus are only counted. No marking is needed, because for an individual to be counted means it survived since last census, and determines its age unambiguously. Transition models, as will be discussed later, require more elaborate censuses.

Age may be convenient to use in cohort studies, but it does not always play a primary role in the development and life cycle of the organisms. This is probably true for all plant and most animal taxa, except birds and mammals. The latter's determinate growth (an individually fixed adult size) and hormonal clock, combined with their ability to learn, make age a suitable attribute to describe population dynamics. In most other cases, size is biologically more important, as it determines resource acquisition, competitive ability, survivorship and sexual maturity and reproductive output. Only if size and age are strongly correlated in such a population, age may be preferable.

Stage is very useful in cohort studies of annual organisms if surviving organisms all pass through relatively short stages, so that stages hardly overlap (occur at the same time), and stage and age are correlated. This is the case in Richards and Waloff's (1954) study of grasshoppers (Table 1), cited in Begon et al. (1990). However, if size or stage is attained at different rates for different individuals in the population, as is often the case, they are not useful for constructing life tables. Then, transition models are more appropriate.

Table 1

Stage (x)	Number observed at start of each stage a_x	Proportion of original cohort surviving to start of each stage l_x	Proportion of original cohort dying during each stage d_x	Mortality rate q_x	$\log_{10}a_x$	$\log_{10}l_x$	$\log_{10}a_x - \log_{10}a_{x+1} = k_x$	Eggs produced in each stage F_x	Eggs produced per surviving individual in each stage m_x	Eggs produced per original individual in each stage $l_x m_x$
Eggs (0)	44 000	1.000	0.920	0.92	4.64	0.00	1.09	—	—	—
Instar I (1)	3513	0.080	0.022	0.28	3.55	−1.09	0.15	—	—	—
Instar II (2)	2529	0.058	0.014	0.24	3.40	−1.24	0.12	—	—	—
Instar III (3)	1922	0.044	0.011	0.25	3.28	−1.36	0.12	—	—	—
Instar IV (4)	1461	0.033	0.003	0.11	3.16	−1.48	0.05	—	—	—
Adults (5)	1300	0.030	—	—	3.11	−1.53	—	22617	17	0.51

$$R_0 = \sum l_x m_x = \frac{\sum F_x}{a_0} = 0.51.$$

2.0 OBJECTIVES

At the end of this unit, student should be able to:

1Explain the measurement of population dynamics

2 Describe and explain the survival ship curve

3.0 MAIN CONTENT

3.1 Survivorship

Two kinds of information are derived from these cohort studies: survivorship curves and population growth rates. Survivorship curves show how mortality varies with age of the individuals of the cohort. Age-specific mortality, as well as age-specific fecundity, is due to changing susceptibilities and capabilities of the individual, and the variation in its environmental exposure. Depending on the age at which most of the mortality takes place, organisms can have different survivorship curves. Deevey (1947) described three types of curves (Fig. 1): Type I occurs when survival of young is high, and mortality increases drastically towards the end of the lifespan. This is typical of very protected life styles. In case of Type II survivorship curves, mortality is constant with age, as in a decay process. Most organisms have a Type III curve, where most individuals die when they are young, while older individuals are good survivors.

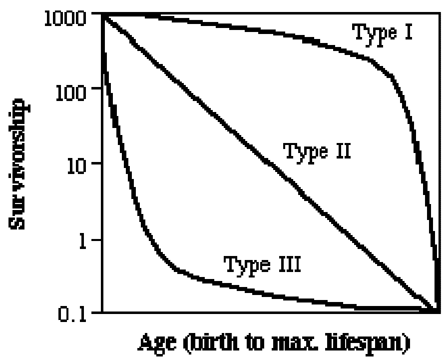

Fig.1. Three types of survivorship curves (Begon et al. 1990, Deevey 1947).

3.2 Population growth rate

Population growth rate of a cohort is defined as the basic reproductive rate R_0 for a generation over its lifetime. Using dynamic life tables is best suited for semelparous animals or monocarpic plants, especially annual organisms, as in the study on the annual plant species Phlox drummondii by Leverich and Levin (1979) (Table 2). These have a single cohort per year, and thus have no overlapping generations. Perennial iteroparous/polycarpic organisms do have overlapping generations, which makes the method less straightforward, though often still useful. Connell (1970) used this method on the long-lived barnacle Balanus glandula (Table 3). Basic reproductive rate R_0 measures the mean number of offspring that an individual of the cohort produces in its lifetime. Offspring denotes the number of individuals in the first stage of the life cycle (zygotes or young, depending on the organism).

Age interval (days) $x-x'$	Number surviving to day x a_x	Proportion of original cohort surviving to day x l_x	Proportion of original cohort dying during interval d_x	Mortality rate per day q_x	$\log_{10} l_x$	Daily killing power k_x	F_x	m_x	$l_x m_x$
0–63	996	1.000	0.329	0.005		0.003	–	–	–
63–124	668	0.671	0.375	0.009	−0.17	0.006	–	–	–
124–184	295	0.296	0.105	0.006	−0.53	0.003	–	–	–
184–215	190	0.191	0.014	0.002	−0.72	0.001	–	–	–
215–264	176	0.177	0.004	0.001	−0.75	<0.001	–	–	–
264–278	172	0.173	0.005	0.002	−0.76	0.001	–	–	–
278–292	167	0.168	0.008	0.003	−0.78	0.002	–	–	–
292–306	159	0.160	0.005	0.002	−0.80	0.001	53.0	0.33	0.05
306–320	154	0.155	0.007	0.003	−0.81	0.001	485.0	3.13	0.49
320–334	147	0.148	0.043	0.021	−0.83	0.011	802.7	5.42	0.80
334–348	105	0.105	0.083	0.057	−0.98	0.049	972.7	9.26	0.97
348–362	22	0.022	0.022	1.000	−1.66	–	94.8	4.31	0.10
362–	0	0	–			–	–	–	
							2408.2		2.41

$$R_0 = \sum l_x m_x = \frac{\sum F_x}{a_0} = 2.41.$$

Table 2. A cohort life-table for Phlox drumondii (after Leverich and Levin 1979).

Age, years x	a_x	l_x	m_x	$l_x m_x$	$x l_x m_x$
0	1 000 000	1.000	0	0	
1	62	0.0000620	4600	0.285	0.285
2	34	0.0000340	8700	0.296	0.592
3	20	0.0000200	11600	0.232	0.696
4	15.5*	0.0000155	12700	0.197	0.788
5	11	0.0000110	12700	0.140	0.700
6	6.5*	0.0000065	12700	0.082	0.492
7	2	0.0000020	12700	0.025	0.175
8	2	0.0000020	12700	0.025	0.200
				1.282	3.928

$R_0 = 1.282$

$$T_c = \frac{3.928}{1.282} = 3.1$$

$$r \approx \frac{\ln R_0}{T_c} = 0.08014\ .$$

Table 3. A cohort life-table and fecundity schedule for the barnacle Balanus glandula at Pile Point, San Juan Island, Washington (Conell 1970). (* - estimated by interpolation from the survivorship curve).

There are two ways to arrive at the basic reproductive rate. The first method is $R_0 = \sum F_x / a_0$, where $\sum F_x$, the sum of the F_x's, is the number of offspring over the life span of the cohort, and a_0 is the first stage. The ratio shows the relative change in population size/density from one generation of the cohort to the next. R_0 is also measured as $R_0 = \sum l_x m_x$, the sum of l_x, the chance of an individual surviving to age x (the time from the birth of the cohort to the census x, not necessarily in years), times m_x, the number of offspring produced during the time from age x-1 to x. The advantage of this model is, that it is explicit about the relation between overall population growth and the actual demographic processes that take place through time in the cohort. For annual organisms this sequence of processes tracks the changing of the seasons.

In cohort studies, R_0 is determined over the generation time. If the organism is an annual plant or animal, R_0 also denotes population growth rate R, defined per year: $R = R_0$. In perennial semelparous or monocarpic organisms, R_0 should be corrected for generation time T (>1 year).

Since $R_0 = R^T$, so that $\ln R = (\ln R_0)/T$.

However, for organisms with overlapping generations, it is difficult to estimate annual growth rate accurately since generation time T is in fact unknown. Instead of T, R is given by

$\ln R = (\ln R_0)/T_c$.

R_0 is corrected by T_c, the average cohort lifespan, which is the average time from the birth of an individual to the birth of one of its offspring, calculated as the sum of lengths of time of the offspring of all individuals divided by the total number of offspring:

$T_c = (\sum x.\ l_x m_x) / \sum l_x m_x = \sum x.\ l_x m_x) / R_0$.

The presence of three generations at the same time, i.e. if some individuals have produced offspring themselves while their parents are still alive, cannot be incorporated in the equation.

3.3 Static life tables

A static life table contains the age groups in a population at one particular period of time. Thus, cohorts are not followed in time, but reconstructed using one-time observations. These can be used to calculate population growth only if an assumption is made. The assumption is that the mortality experienced by the cohort at any age stays constant in time. In other words, birth rates and age-specific survivorship are assumed to be independent of the actual year in which the observations are made. Only rarely is this assumption truly justified. Therefore, the conclusions tell us how a cohort should behave, if we would have observed it and if conditions are constant between years. An example is the study of red deer by Lowe (1969) (Table 4), described in Begon et al. (1990).

A second, less problematic application of static life tables is using them in order to reconstruct past events, as Crisp and Lange (1976) did with the desert shrub Acacia burkitii (Begon et al. 1990, page 144 and 145). They were able to show, among others, the effects of grazing, because they compared two stands using one as a control.

Age (years) x	Number of individuals observed of age x a_x	l_x	d_x	q_x	Smoothed l_x	Smoothed d_x	Smoothed q_x
1	129	1.000	0.116	0.116	1.000	0.137	0.137
2	114	0.884	0.008	0.009	0.863	0.085	0.097
3	113	0.876	0.251	0.287	0.778	0.084	0.108
4	81	0.625	0.020	0.032	0.694	0.084	0.121
5	78	0.605	0.148	0.245	0.610	0.084	0.137
6	59	0.457	−0.047	—	0.526	0.084	0.159
7	65	0.504	0.078	0.155	0.442	0.085	0.190
8	55	0.426	0.232	0.545	0.357	0.176	0.502
9	25	0.194	0.124	0.639	0.181	0.122	0.672
10	9	0.070	0.008	0.114	0.059	0.008	0.141
11	8	0.062	0.008	0.129	0.051	0.009	0.165
12	7	0.054	0.038	0.704	0.042	0.008	0.198
13	2	0.016	0.008	0.500	0.034	0.009	0.247
14	1	0.080	−0.023	—	0.025	0.008	0.329
15	4	0.031	0.015	0.484	0.017	0.008	0.492
16	2	0.016	—	—	0.009	0.009	1.000

Table 4. A static life-table for red deer hinds on the island of Rhum, based on the reconstructed age-structure of the population in 1957 (After Lowe 1969).

4.0 **CONCLUSION**

In this unit you learnt, the measurement of population, survivorship curve and static life table

5.0 **SUMMARY**

The measurement of population dynamics is very important in ecological study of animals. To be able to assess the status of ecosystem there is necessity for continous measurement of the animal population, either quantitatively or qualitatively.

6.0 TUTOR-MARKED ASSIGNMENT

1 Explain the measurement of population dynamics
2 Describe and explain the survival ship curve

7.0 REFERENCES

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Unit 4: Life tables and K-factor analysis

CONTENT

1.0 INTRODUCTION

A population's growth potential has much to with how often individual members reproduce. Some species (e.g., most invertebrates) have only one reproductive event in their lifetime, while others (e.g., most birds and mammals) are capable of multiple events over an extendended portion of their lives. The former are called semelparous and the latter, iteroparous life cycles. There is a large amount of variation, however, within these broad categories. For example, some semelparous species have overlapping generations of young so that, at any one time, there may one-, two-, and three-year-old individuals present in the population. A common form of semelparity in insects of temperate regions is an annual species.

In this case, the insect overwinters as an egg or larval resting stage until spring, then grows throughout the warm months and emerges into the reproductive adult. Adults mate and lay eggs that, again, remain dormant throughout the winter. Still other semelparous species complete several generations each summer. It is easy to imagine, then, how the frequency of reproductive events, the number of young produced in each event, and the length of each generation can greatly influence how fast a population can grow.

2.0 OBJECTIVE

At the end of this unit the student should be able to:
1 Explain with examples the different type of life tables
2 State and explain life expectancy in hypothetical population
3 Explain the crieteria of k-factor analysis.

3.0 MAIN CONTENT

3.1 Life Tables

Constructing a life table is often a simple method for keeping track of births, deaths, and reproductive output in a population of interest. Basically, there are three methods of constructing such a table:
1) the cohort life table follows a group of same-aged individuals from birth (or fertilized eggs) throughout their lives,
2) a static life table is made from data collected from all ages at one particular time it assumes the age distribution is stable from generation to generation, and
3) a life table can be made from mortality data collected from a specified time period and also assumes a stable age distribution.
Note: For organisms that have separate sexes, life tables frequently follow only female individuals.

3.1.1 Examples of Life Tables are shown below:

Stage-dependent life-tables

Stage-dependent life tables are built in the cases when:

- The life-cycle is partitioned into distinct stages (e.g., eggs, larvae, pupae and adults in insects)
- Survival and reproduction depend more on organism stage rather than on calendar age
- Age distribution at particular time does not matter (e.g., there is only one generation per year)

Stage-dependent life tables are used mainly for insects and other terrestrial invertebrates.

Example1. Gypsy moth (*Lymantria dispar* L.) life table in New England (modified from Campbell 1981)

Stage	Mortality factor	Initial no. of insects	No. of deaths	Mortality (d)	Survival (s)	k-value [-ln(s)]
Egg	Predation, etc.	450.0	67.5	0.150	0.850	0.1625
Egg	Parasites	382.5	67.5	0.176	0.824	0.1942
Larvae I-III	Dispersion, etc.	315.0	157.5	0.500	0.500	0.6932
Larvae IV-VI	Predation, etc.	157.5	118.1	0.750	0.250	1.3857
Larvae IV-VI	Disease	39.4	7.9	0.201	0.799	0.2238
Larvae IV-VI	Parasites	31.5	7.9	0.251	0.749	0.2887
Prepupae	Desiccation, etc.	23.6	0.7	0.030	0.970	0.0301
Pupae	Predation	22.9	4.6	0.201	0.799	0.2242
Pupae	Other	18.3	2.3	0.126	0.874	0.1343
Adults	Sex ratio	16.0	5.6	0.350	0.650	0.4308
Adult females		10.4				
TOTAL			439.6	97.69	0.0231	3.7674

Specific features of stage-dependent life tables:

- There is no reference to calendar time. This is very convenient for the analysis of poikilothermous organisms.
- Gypsy moth development depends on temperature but the life table is relatively independent from weather.

- Mortality processes can be recorded individually and thus, this kind of life table has more biological information than age-dependent life tables.

3.1.2 **Static (Vertical) Life Table Based on Living Individuals**

Most organisms have more complex life histories than found in the above example, and while it is possible to follow a sin- gle cohort from birth to death, it often too costly or time-consuming do so. Another, less accurate, method is the static, or vertical, life table. Rather than following a single cohort, the static table compares population size from different cohorts, across the entire range of ages, at a single point in time. Static tables make two important assumptions: 1) the population has a stable age structureÑthat is, the proportion of individuals in each age class does not change from generation to gen- eration, and 2) the population size is, or nearly, stationary.

3.2.3Static (Vertical) Life Table Based on Mortality Records

Static life tables can also be made from knowing, or estimating, age at death for individuals from a population. This can be a useful technique for secretive large mammals (e.g., moose) from temperate regions where it is difficult to sample the living members. Because the highest mortality of large herbivores occurs during the winter, an early spring survey of car- casses from starvation and predator kills can yield useful information in constructing a life table. Keep in mind, however, all static tables suffer from the same two assumptions stated above.
Because we keep good birth and death records on humans, static life tables can also be used to answer questions concern-ing our populations. For instance, we know that females today have a larger mean life expectancy than men. But, was this true for our population 100 years ago? We can use data collected from cemetary grave markers to constuct a static life table and reveal interesting features of human populations from past generations. The following data were collected from a random sample of 30 females and 30 males off grave markers located in an Ann Arbor cemetary:

TABLE 2. Male and female age at death frequencies from a random sample of 60 Ann Arbor grave markers of individuals born prior to 1870. (From G. Belovsky, unpubl.).

Age at death	Females	Males
0-5	1	2
6-10	0	0
11-15	1	0
16-20	2	1
21-25	1	1
26-30	0	2
31-35	0	0
36-40	1	2
41-45	1	0
46-50	2	1
51-55	1	0
56-60	2	3
61-65	0	4
66-70	0	4
71-75	1	3
76-80	6	1

81-85	4	1
86-90	7	3
91-95	0	0
96-100	0	2

3.2 Population Features That Can Be Calculated from Life Tables:

Besides R_0, the basic reproductive rate, several other population characteristics can be determined from life tables. Some of the most common features are the cohort generation time (T_C), life expectancy (e_X), and the intrinsic growth rate (r). Cohort generation time is quite easy to obtain from our first example, a semelparous annual life cycle (T_C = 1 year), but generation time is less obvious for more complex life cycles. Generation time can be defined as the average length of time between when an individual is born and the birth of its offspring. Therefore, it can be calculated by summing all the lengths of time to offspring production for the entire cohort divided by the total offspring produced by the survivors:

Life expectancy is a useful way of expressing the probability of living (x) number of years beyond a given age. We usually encounter life expectency in newspaper articles comparing the mean length of life for individuals of various populations. However, this value is actually the life expectency at birth. One can also calculate the mean length of life beyond any given age for the population. Life expectency is a somewhat complicated calculation. Because l_X is only the proportion surviving to the beginning of a particular age class, we must Þrst calculate the average proportion alive at that age (L_X) :

$$Lx = \frac{lx + lx + 1}{2}$$

Next, the total number of living individuals at age x and beyond (T_X) is:

$$Tx = Lx + Lx + 1 +¼+ Lx + n$$

Finally, the average amount of time yet to be lived by members surviving to a particular age (e_X) is:

$$Ex = \frac{Tx}{lx}$$

The following example shows life expectency changes in a hypothetical population that experienced 50% mortality at
each age:

TABLE3. Life expectency in a hypothetical population.

Age (years)	lx	Lx	Tx	ex (years)
0	1.0	0.75	1.375	1.375
1	0.5	0.375	0.625	1.25
2	0.25	0.1875	0.25	1.0
3	0.125	0.0625	0.0625	0.5
4	0.0	-	-	-

The basic reproduction rate (R_0) converts the initial population size to the new size one generation later as:

$$N_T = N_0 \text{ x } R_0$$

If R_0 remains constant from generation to generation, then we can also use it to predict population size several generations in the future. To predict poplulation size at any future time, it is more convenient to use a parameter that already takes generation time into account. This term is Ô*r*Õ, the intrinsic rate of natural increase, and it can be calculated (or approximated for complex life cycles) by the following equation:

$$r \;@\; \frac{\ln R0}{Tc}$$

The term, *r*, is used in mathematical models of population growth discussed later.

4.0 Factor Analysis

Key-factor analysis has been applied to a variety of animal species in order to assess the role of natural enemies in population fluctuations . In general, this technique is not applicable to tropical insects because in most species the generations overlap. However, a unique feature in the life-system of *Andraca bipunctata* Walker is that it has four generations that are fairly well differentiated in a year, and it does not have a fixed seasonal peak. These features make the species amenable to analysis using life-tables.

Factor analysis is a statistical method used to describe variability among observed variables in terms of a potentially lower number of unobserved variables called **factors**. In other words, it is possible, for example, that variations in three or four observed variables mainly reflect the variations in a single unobserved variable, or in a reduced number of unobserved variables. Factor analysis searches for such joint variations in response to unobserved latent variables. The observed variables are modeled as linear combinations of the potential factors, plus "error" terms. The information gained about the interdependencies between observed variables can be used later to reduce the set of variables in a dataset. Factor analysis originated in psychometrics, and is used in behavioral sciences, social sciences, marketing, product management, operations research, and other applied sciences that deal with large quantities of data.

Factor analysis is related to principal component analysis (PCA), but the two are not identical. Because PCA performs a variance-maximizing rotation of the variable space, it takes into account all variability in the variables. In contrast, factor analysis estimates how much of the variability is due to common factors ("communality"). The two methods become essentially equivalent if the error terms in the factor analysis model (the variability not explained by common factors, see below) can be assumed to all have the same variance.

Statistical model

Definition

Suppose we have a set of *p* observable random variables, $x_1, \dots, x_p$ with means $\mu_1, \dots, \mu_p$.

Suppose for some unknown constants l_{ij} and *k* unobserved random variables F_j, where $i \in 1, \dots, p$ and $j \in 1, \dots, k$, where $k < p$, we have

$$x_i - \mu_i = l_{i1} F_1 + \cdots + l_{ik} F_k + \varepsilon_i.$$

Here, the ε_i are independently distributed error terms with zero mean and finite variance, which may not be the same for all *i*. Let $\mathrm{Var}(\varepsilon_i) = \psi_i$, so that we have

$$\mathrm{Cov}(\varepsilon) = \mathrm{Diag}(\psi_1, \dots, \psi_p) = \Psi \text{ and } \mathrm{E}(\varepsilon) = 0.$$

In matrix terms, we have

$$x - \mu = LF + \varepsilon.$$

If we have *n* observations, then we will have the dimensions $x_{p \times n}$, $L_{p \times k}$, and $F_{k \times n}$. Each column of *x* and *F* denote values for one particular observation, and matrix *L* does not vary across observations.

Also we will impose the following assumptions on *F*.

1. *F* and ε are independent.
2. E(*F*) = 0
3. Cov(*F*) = *I*

Any solution of the above set of equations following the constraints for *F* is defined as the *factors*, and *L* as the *loading matrix*.

Suppose Cov($x - \mu$) = Σ. Then note that from the conditions just imposed on F, we have

$$\mathrm{Cov}(x-\mu) = \mathrm{Cov}(LF+\varepsilon),$$

or

$$\Sigma = L\mathrm{Cov}(F)L^T + \mathrm{Cov}(\varepsilon),$$

or

$$\Sigma = LL^T + \Psi.$$

Note that for any orthogonal matrix Q if we set $L = LQ$ and $F = Q^T F$, the criteria for being factors and factor loadings still hold. Hence a set of factors and factor loadings is identical only up to orthogonal transformations.

Example

The following example is a fictionalized simplification for expository purposes, and should not be taken as being realistic. Suppose a psychologist proposes a theory that there are two kinds of intelligence, "verbal intelligence" and "mathematical intelligence", neither of which is directly observed. Evidence for the theory is sought in the examination scores from each of 10 different academic fields of 1000 students. If each student is chosen randomly from a large population, then each student's 10 scores are random variables. The psychologist's theory may say that for each of the 10 academic fields, the score averaged over the group of all students who share some common pair of values for verbal and mathematical "intelligences" is some constant times their level of verbal intelligence plus another constant times their level of mathematical intelligence, i.e., it is a linear combination of those two "factors". The numbers for a particular subject, by which the two kinds of intelligence are multiplied to obtain the expected score, are posited by the theory to be the same for all intelligence level pairs, and are called **"factor loadings"** for this subject. For example, the theory may hold that the average student's aptitude in the field of amphibiology is

{10 × the student's verbal intelligence} + {6 × the student's mathematical intelligence}.

The numbers 10 and 6 are the factor loadings associated with amphibiology. Other academic subjects may have different factor loadings.

Two students having identical degrees of verbal intelligence and identical degrees of mathematical intelligence may have different aptitudes in amphibiology because individual aptitudes differ from average aptitudes. That difference is called the "error" — a statistical term that means the amount by which an individual differs from what is average for his or her levels of intelligence (see errors and residuals in statistics).

The observable data that go into factor analysis would be 10 scores of each of the 1000 students, a total of 10,000 numbers. The factor loadings and levels of the two kinds of intelligence of each student must be inferred from the data.

Mathematical model of the same example

In the example above, for i = 1, ..., 1,000 the ith student's scores are

$$\begin{array}{ccccccccc} x_{1,i} & = & \mu_1 * 1_{1\times 1000} & + & \ell_{1,1}v_i & + & \ell_{1,2}m_i & + & \varepsilon_{1,i} \\ \vdots & & \vdots & & \vdots & & \vdots & & \vdots \\ x_{10,i} & = & \mu_{10} * 1_{1\times 1000} & + & \ell_{10,1}v_i & + & \ell_{10,2}m_i & + & \varepsilon_{10,i} \end{array}$$

where

- $x_{k,i}$ is the ith student's score for the kth subject
- μ_k is the mean of the students' scores for the kth subject (assumed to be zero, for simplicity, in the example as described above, which would amount to a simple shift of the scale used)
- v_i is the ith student's "verbal intelligence",
- m_i is the ith student's "mathematical intelligence",
- $\ell_{k,j}$ are the factor loadings for the kth subject, for j = 1, 2.
- $\varepsilon_{k,i}$ is the difference between the ith student's score in the kth subject and the average score in the kth subject of all students whose levels of verbal and mathematical intelligence are the same as those of the ith student,

In matrix notation, we have

$$X = \mu \otimes 1_{1\times N} + LF + \epsilon$$

Where:

- N is 1000 students

- X is a 10 × 1,000 matrix of *observable* random variables,
- μ is a 10 × 1 column vector of *unobservable* constants (in this case "constants" are quantities not differing from one individual student to the next; and "random variables" are those assigned to individual students; the randomness arises from the random way in which the students are chosen),
- L is a 10 × 2 matrix of factor loadings (*unobservable* constants, ten academic topics, each with two intelligence parameters that determine success in that topic),
- F is a 2 × 1,000 matrix of *unobservable* random variables (two intelligence parameters for each of 1000 students),
- ε is a 10 × 1,000 matrix of *unobservable* random variables.

Observe that by doubling the scale on which "verbal intelligence"—the first component in each column of *F*—is measured, and simultaneously halving the factor loadings for verbal intelligence makes no difference to the model. Thus, no generality is lost by assuming that the standard deviation of verbal intelligence is 1. Likewise for mathematical intelligence. Moreover, for similar reasons, no generality is lost by assuming the two factors are uncorrelated with each other. The "errors" ε are taken to be independent of each other. The variances of the "errors" associated with the 10 different subjects are not assumed to be equal.

Note that, since any rotation of a solution is also a solution, this makes interpreting the factors difficult. See disadvantages below. In this particular example, if we do not know beforehand that the two types of intelligence are uncorrelated, then we cannot interpret the two factors as the two different types of intelligence. Even if they are uncorrelated, we cannot tell which factor corresponds to verbal intelligence and which corresponds to mathematical intelligence without an outside argument.

The values of the loadings *L*, the averages μ, and the variances of the "errors" ε must be estimated given the observed data *X* and *F* (the assumption about the levels of the factors is fixed for a given *F*).

Practical implementation

4.1 Type of factor analysis

Exploratory factor analysis :*(EFA)* is used to uncover the underlying structure of a relatively large set of variables. The researcher's *a priori* assumption is that any indicator may be associated with any factor. This is the most common form of factor analysis. There is no prior theory and one uses factor loadings to intuit the factor structure of the data.

Confirmatory factor analysis: *(CFA)* seeks to determine if the number of factors and the loadings of measured (indicator) variables on them confirm to what is expected on the basis of pre-established theory. Indicator variables are selected on the basis of prior theory and factor analysis is used to see if they load as predicted on the expected number of factors. The researcher's à priori assumption is that each factor (the number and labels of which may be specified à priori) is associated with a specified subset of indicator variables. A minimum requirement of confirmatory factor analysis is that one hypothesizes beforehand the number of factors in the model, but usually also the researcher will posit expectations about which variables will load on which factors. The researcher seeks to determine, for instance, if measures created to represent a latent variable really belong together.

Types of factoring

Principal component analysis *:(PCA)*: The most common form of factor analysis, PCA seeks a linear combination of variables such that the maximum variance is extracted from the variables. It then removes this variance and seeks a second linear combination which explains the maximum proportion of the remaining variance, and so on. This is called the principal axis method and results in orthogonal (uncorrelated) factors.

Canonical factor analysis, also called Rao's canonical factoring, is a different method of computing the same model as PCA, which uses the principal axis method. CFA seeks factors which have the highest canonical correlation with the observed variables. CFA is unaffected by arbitrary rescaling of the data.

Common factor analysis, also called principal factor analysis (PFA) or principal axis factoring (PAF), seeks the least number of factors which can account for the common variance (correlation) of a set of variables.

Image factoring: based on the correlation matrix of predicted variables rather than actual variables, where each variable is predicted from the others using multiple regression.

Alpha factoring: based on maximizing the reliability of factors, assuming variables are randomly sampled from a universe of variables. All other methods assume cases to be sampled and variables fixed.

Terminology

Factor loadings: The factor loadings, also called component loadings in PCA, are the correlation coefficients between the variables (rows) and factors (columns). Analogous to Pearson's r, the squared factor loading is the percent of variance in that indicator variable explained by the factor. To get the percent of variance in all the variables accounted for by each factor, add the sum of the squared factor loadings for that factor (column) and divide by the number of variables. (Note the number of variables equals the sum of their variances as the variance of a standardized variable is 1.) This is the same as dividing the factor's eigenvalue by the number of variables.

Interpreting factor loadings*:* By one rule of thumb in confirmatory factor analysis, loadings should be .7 or higher to confirm that independent variables identified a priori are represented by a particular factor, on the rationale that the .7 level corresponds to about half of the variance in the indicator being explained by the factor. However, the .7 standard is a high one and real-life data may well not meet this criterion, which is why some researchers, particularly for exploratory purposes, will use a lower level such as .4 for the central factor and .25 for other factors call loadings above .6 "high" and those below .4 "low". In any event, factor loadings must be interpreted in the light of theory, not by arbitrary cutoff levels.

In oblique rotation, one gets both a pattern matrix and a structure matrix. The structure matrix is simply the factor loading matrix as in orthogonal rotation, representing the variance in a measured variable explained by a factor on both a unique and common contributions basis. The pattern matrix, in contrast, contains coefficients which just represent unique contributions. The more factors, the lower the pattern coefficients as a rule since there will be more common contributions to variance explained. For oblique rotation, the researcher looks at both the structure and pattern coefficients when attributing a label to a factor.

Communality (h2): The sum of the squared factor loadings for all factors for a given variable (row) is the variance in that variable accounted for by all the factors, and this is called the communality. The communality measures the percent of variance in a given variable explained by all the factors jointly and may be interpreted as the reliability of the indicator.

Spurious solutions: If the communality exceeds 1.0, there is a spurious solution, which may reflect too small a sample or the researcher has too many or too few factors.

Uniqueness of a variable: 1-h2. That is, uniqueness is the variability of a variable minus its communality.

Eigenvalues:*/Characteristic roots:* The eigenvalue for a given factor measures the variance in all the variables which is accounted for by that factor. The ratio of eigenvalues is the ratio of explanatory importance of the factors with respect to the variables. If a factor has a low eigenvalue, then it is contributing little to the explanation of variances in the variables and may be ignored as redundant with more important factors. Eigenvalues measure the amount of variation in the total sample accounted for by each factor.

Extraction sums of squared loadings: Initial eigenvalues and eigenvalues after extraction (listed by SPSS as "Extraction Sums of Squared Loadings") are the same for PCA extraction, but for other extraction methods, eigenvalues after extraction will be lower than their initial counterparts. SPSS also prints "Rotation Sums of Squared Loadings" and even for PCA, these eigenvalues will differ from initial and extraction eigenvalues, though their total will be the same.

Factor scores: Also called component scores in PCA, factor scores are the scores of each case (row) on each factor (column). To compute the factor score for a given case for a given factor, one takes the case's standardized score on each variable, multiplies by the corresponding factor loading of the variable for the given factor, and sums these products. Computing factor scores allows one to look for factor outliers. Also, factor scores may be used as variables in subsequent modeling.

4.2 Criteria for determining the number of factors

Comprehensibility: Though not a strictly mathematical criterion, there is much to be said for limiting the number of factors to those whose dimension of meaning is readily comprehensible. Often this is the first two or three. Using one or more of the methods below, the researcher determines an appropriate range of solutions to investigate. For instance, the Kaiser criterion may suggest three factors and the scree test may suggest 5, so the researcher may request 3-, 4-, and 5-factor solutions and select the solution which generates the most comprehensible factor structure.

Kaiser criterion: The Kaiser rule is to drop all components with eigenvalues under 1.0. The Kaiser criterion is the default in SPSS and most computer programs but is not recommended when used as the sole cut-off criterion for estimating the number of factors.

Scree plot: The Cattell scree test plots the components as the X axis and the corresponding eigenvalues as the Y-axis. As one moves to the right, toward later components, the eigenvalues drop. When the drop ceases and the curve makes an elbow toward less steep decline, Cattell's scree test says to drop all further components after the one starting the elbow. This rule is sometimes criticised for being amenable to researcher-controlled "fudging". That is, as picking the "elbow" can be subjective because the curve has multiple elbows or is a smooth curve, the researcher may be tempted to set the cut-off at the number of factors desired by his or her research agenda.

Horn's Parallel Analysis (PA): A Monte-Carlo based simulation method that compares the observed eigenvalues with those obtained from uncorrelated normal variables. A factor or component is retained if the associated eigenvalue is bigger than the 95th of the distribution of eigenvalues derived from the random data. PA is one of the most recommendable rules for determining the number of components to retain, but only few programs include this option.[1]

Variance explained criteria: Some researchers simply use the rule of keeping enough factors to account for 90%; (sometimes 80%) of the variation. Where the researcher's goal emphasizes parsimony (explaining variance with as few factors as possible), the criterion could be as low as 50%

Before dropping a factor below one's cut-off, however, the researcher should check its correlation with the dependent variable. A very small factor can have a large correlation with the dependent variable, in which case it should not be dropped.

Rotation methods

Rotation serves to make the output more understandable and is usually necessary to facilitate the interpretation of factors.

Varimax rotation is an orthogonal rotation of the factor axes to maximize the variance of the squared loadings of a factor (column) on all the variables (rows) in a factor matrix, which has the effect of differentiating the original variables by extracted factor. Each factor will tend to have either large or small loadings of any particular variable. A varimax solution yields results which make it as easy as possible to identify each variable with a single factor. This is the most common rotation option.

Quartimax rotation is an orthogonal alternative which minimizes the number of factors needed to explain each variable. This type of rotation often generates a general factor on which most variables are loaded to a high or medium degree. Such a factor structure is usually not helpful to the research purpose.

Equimax rotation is a compromise between Varimax and Quartimax criteria.

Direct oblimin rotation is the standard method when one wishes a non-orthogonal (oblique) solution – that is, one in which the factors are allowed to be correlated. This will result in higher eigenvalues but diminished interpretability of the factors. See below.

Promax rotation is an alternative non-orthogonal (oblique) rotation method which is computationally faster than the direct oblimin method and therefore is sometimes used for very large datasets.

4.3 K-values

K-value is just another measure of mortality. The major advantage of k-values as compared to percentages of died organisms is that k-values are additive: the k-value of a combination of independent mortality processes is equal to the sum of k-values for individual processes.

Mortality percentages are not additive. For example, if predators alone can kill 50% of the population, and diseases alone can kill 50% of the population, then the combined effect of these process will not result in 50+50 = 100% mortality. Instead, mortality will be 75%!

Survival is a probability to survive, and thus we can apply the theory of probability. In this theory, events are considered independent if the probability of the combination of two events is equal to the product of the probabilities of each individual event. In our case event is survival. If two mortality processes are present, then organism survives if it survives from each individual process. For example, an organism survives if it was simultaneously not infected by disease and not captured by a predator.

Assume that survival from one mortality source is s1 and survival from the second mortality source is s2. Then survival from both processes, s12, (if they are independent) is equal to the product of s1 and s2:

$$s_{12} = s_1 s_2$$

This is a "survival multiplication rule". If survival is replaced by 1 minus mortality [s=(1-d)], then this equation becomes:

$$d_{12} = 1 - (1 - d_1)(1 - d_2)$$

For example, if mortality due to predation is 60% and mortality due to diseases is 30%, then the combination of these two death processes results in mortality of d = 1-(1-0.6)(1-0.3)=0.72 (=72%).

Varley and Gradwell (1960) suggested to measure mortality in k-value which is the negative logarithms of survival:

k = -ln(s)

We use natural logarithms (with base e=2.718) instead of logarithms with base 10 used by

Varley and Gradwell. The advantages of using natural logarithms will be shown below.

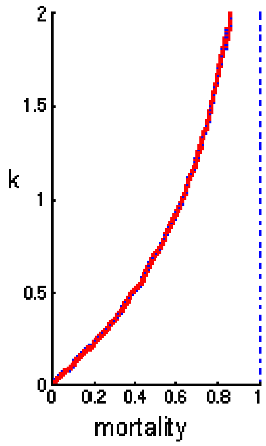
It is easy to show that k-values are additive:

$$k_{12} = -\ln(s_{12}) = -\ln(s_1 s_2) = [-\ln(s_1)] + [-\ln(s_2)] = k_1 + k_2$$

The k-values for the entire life cycle (K) can be estimated as the sum of k-values for all mortality processes:

$$K = \sum k_i$$

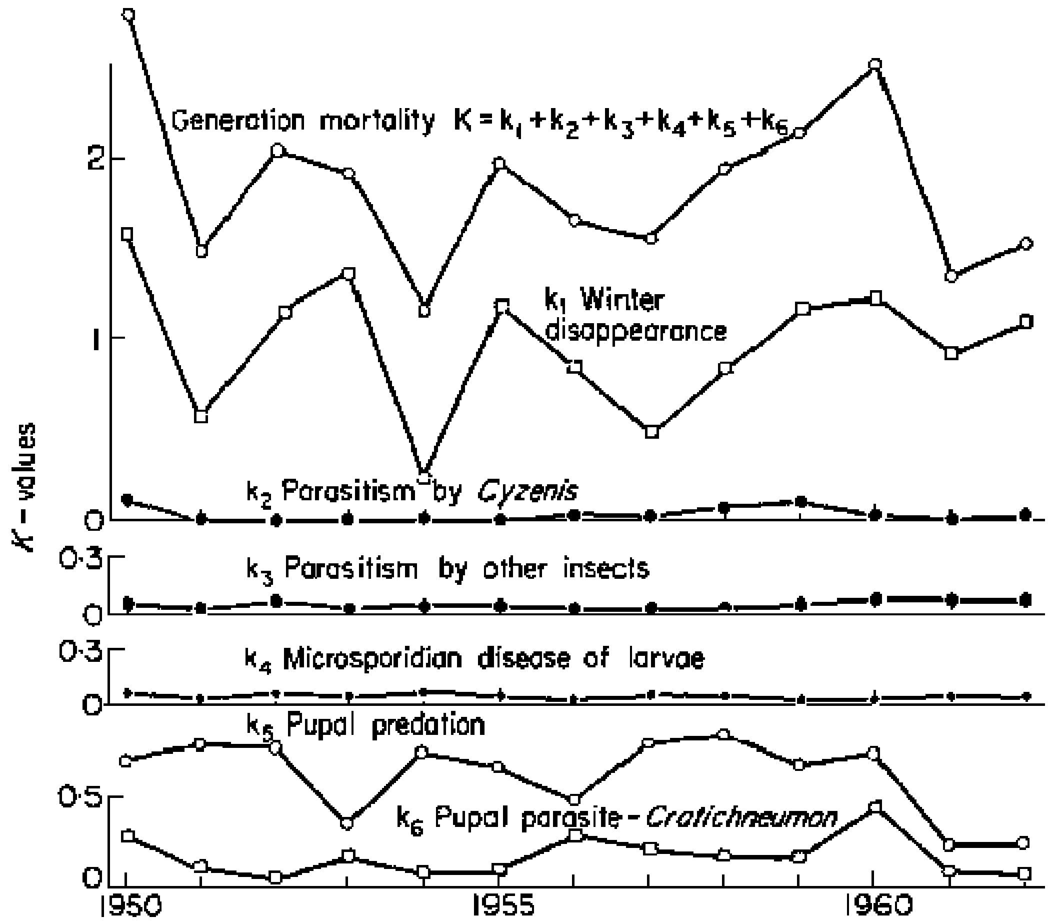
In the life table of the gypsy moth (see above), the sum of all k-values (K = 3.7674) was equal to the k-value of total mortality.



This graph shows the relationship between mortality and the k-value. When mortality is low, then the k-value is almost equal to mortality. This is the reason why the k-value can be considered as another measure of mortality. However, at high mortality, the k-value grows much faster than mortality. Mortality cannot exceed 1, while the k-value can be infinitely large.

The following example shows that the k-value represents mortality better than the percentage of dead organisms: One insecticide kills 99% of cockroaches and another insecticide kills 99.9% of cockroaches. The difference in percentages is very small (<1%). However the second insecticide is considerably better because the number of survivors is 10 times smaller. This difference is represented much better by k-values which are 4.60 and 6.91 for the first and second insecticides, respectively.

Key-factor analysis developed a method for identifying most important factors "key factors" in population dynamics. If k-values are estimated for a number of years, then the dynamics of k-values over time can be compared with the dynamics of the generation K-value. The following graph shows the dynamics of k-values for the winter moth in Great Britain.



It is seen that the dynamics of winter disappearance (k1) is most resembling the dynamics of total generation K-value. The conclusion was made that winter disappearance determines the trend in population numbers (whether the population will grow or decline), and thus, it can be considered as a "key factor". T

The key-factor analysis was often considered as a substitute for modeling. It seems so easy to compare time series of k-values and to find key-factors without the hard work of developing models of ecological processes. However, reliable predictions can be obtained only from models.

This critique does not mean that life-tables have no value. Life-tables are very important for gathering information about ecological processes which is necessary for building models. It is the key-factor analysis that has little sense.

K-value = instantaneous mortality rate multiplied by time. A population that experience constant mortality during a specific stage (e.g., larval stage of insects) change in numbers according to the exponential model with a negative rate r. We cannot call r intrinsic rate of natural increase because this term is used for the entire life cycle, and here we discuss a particular stage in the life cycle. According to the exponential model:

$$N_t = N_0 \cdot \exp(r \cdot t)$$

Population numbers decrease and thus, Nt < N0. Survival is: s = Nt/N0 . Now we can estimate the k-value:

$k = -r\ t$

.

Instantaneous mortality rate, m, is equal to the negative exponential coefficient because mortality is the only ecological process considered (there is no reproduction):

$m = -r$,

$k = m\ t$

Exponential coefficient r is negative (because population declines), and mortality rate, m, is positive.

We proved that if mortality rate is constant, then k-value is equal to the instantaneous mortality rate multiplied by time. This is analogs to physics: distance is equal to speed multiplied by time. Here, instantaneous mortality rate is like speed, and k-value is like distance. K-value shows the result of killing organisms with specific rate during a period of time. If the period of time when mortality occurs is short then the effect of this mortality on population is not large.

If instantaneous mortality rate changes with time, then the k-value is equal to its integral over time. In the same way, in physics, distance is the integral of instantaneous speed over time.

Example. Annual mortality rates of oak trees due to animal-caused bark damage are 0.08 in the first 10 years and 0.02 in the age interval of 10-20 years. We need to estimate total k-value (k) and total mortality (d) for the first 20 years of oak growth.

$k = 0.08 \times 10 + 0.02 \times 10 = 1.0$

$d = 1 - \exp(-k) = 0.63$

Thus, total mortality during 20 years is 63%.

Limitation of the k-value concept. All organisms are assumed to have equal dying probabilities. In nature, dying probabilities may vary because of spatial heterogeneity and individual variation (both inherited and non-inherited).

4.4 Estimation of k-values in natural populations.

Estimation of k-values for individual death processes is difficult because these processes often go simultaneously. The problem is to predict what mortality could be expected if there was only one death process. In order to separate death processes it is important to know the biology of the species and its interactions with natural enemies. Below you can find several examples of separation of death processes.

Example 1. Insect parasitoids oviposit on host organisms. Parasitoid larva hatches from the egg and starts feeding on host tissue. Parasitized host can be alive for a long period. Finally, it dies and parasitoid emerges from it. Insect predators usually don't distinguish between parasitized and non-parasitized prey. If an insect was killed by a predator, then it is usually impossible to detect if this insect was parasitized before. Thus, mortality due to predation is estimated as the ratio of the number of insects numbers destroyed by predators to the total number of insects, whereas mortality due to parasitism is estimated as the ratio of the number of insects killed by parasitoids to the number of insects that survived predation. In this example, predation masks the effect of parasitism, and thus, insects killed by predators are ignored in the estimation of the rate of parasitism. The effect is the same as if predation occurred before parasitism in the life cycle. Thus, in the gypsy moth life table, predation was always considered before parasitism. Diseases also mask the effect of parasitism and thus they are considered before parasitism.

Example 2. It is often possible to distinguish between organisms destroyed by different kinds of predators. For example, small mammals and birds open sawfly cocoons in a different way. Suppose, 20% of cocoons were opened by birds, 50% were opened by mammals, and remaining 30% were alive. The question is what would be the rate of predation if birds and mammals were acting alone. We assume that sawfly cocoons have no individual variation in predator attack rate, and that cocoons destroyed by one predator cannot be attacked by another predator. First, we estimate total k-value for both predator groups: $k_{12} = -\ln(0.3) = 1.204$. Second, we subdivide the total k-value into two portions proportionally to the number of cocoons destroyed by each kind of predator. Thus, for birds $k_1 = 1.204\times20/(20+50) = 0.344$, and for mammals $k_2 = 1.204\times50/(20+50) = 0.860$. The third step is to convert k-values into expected mortality if each predator was alone: for birds d1 = 1- exp(-0.344) = 0.291, and for mammals d_2 = 1- exp(-0.860) = 0.577.

5.0 CONCLUSION

In this unit you learnt, you learnt about life table and k- factor analysis in animal ecology

6.0 SUMMARY

Key-factor analysis has been applied to a variety of animal species in order to assess the role of natural enemies in population fluctuations. In general, this technique is not applicable to tropical insects because in most species the generations overlap

7.0 TUTOR-MARKED ASSIGNMENT

1 Explain with examples the different type of life tables
2 State and explain life expectancy in hypothetical population
3 Explain the criteria of k-factor analysis.
4 State the significance of using life table in animal ecology

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MODULE 3: COMPETITION IN ORGANISMS

Unit 1: COMPETITION (BIOLOGY)

Content

1.0 Introduction

Competition is an interaction between organisms or species, in which the fitness of one is lowered by the presence of another. Limited supply of at least one resource (such as food, water, and territory) used by both is required. Competition both within and between species is an important topic in ecology, especially community ecology. Competition is one of many interacting biotic and abiotic factors that affect community structure. Competition among members of the same species is known as intraspecific competition, while competition between individuals of different species is known as interspecific competition. Competition is not always straightforward, and can occur in both a direct and indirect fashion..

According to the competitive exclusion principle, species less suited to compete for resources should either adapt or die out. According to evolutionary theory, this competition within and between species for resources plays a critical role in natural selection, however, competition may play less of a role than expansion among larger groups such as families.

Sea Anemones compete for the territory in tide pools

2.0 Objectives

At the end of this unit, students should be able to:

1. Define competition?
2. List factors/resources that contribute to competition among organisms.
3. Explain the following types of competition:

   I. intraspecies competition
   II. interspecies competition
   III. interferences competition
   IV. apparent competition
   V. and exploitation competition.

4.0 Explain competitive exclusion principle

5.0 Explain evolution strategies and state the formula selection theory

3.0 Main Content

3.1Types of competition

3.1.1 By mechanism

The following terms describe mechanisms by which competition occurs, which can generally be divided into direct and indirect. These mechanisms apply equally to intraspecific and interspecific competition.

Male-male competition in red deer during rut is an example of interference competition within a species.

3.1.1.1 Interference competition

Occurs *directly* between individuals via aggression etc. when the individuals interfere with foraging, survival, reproduction of others, or by directly preventing their physical establishment in a portion of the habitat.

3.1.1.2 Exploitation competition

Occurs *indirectly* through a common limiting resource which acts as an intermediate. For example, use of resources depletes the amount available to others, or they compete for space. Also known as exploitative competition.

3.1.1.3 Apparent competition

Occurs *indirectly* between two species which are both preyed upon by the same predator. For example, species A and species B are both prey of predator C. The increase of species A will cause the decrease of species B because the increase of As would increase the number of predator Cs which in turn will hunt more of species B.

3.1.2 By species

3.1.2.1 Intraspecific competition

Intraspecific competition occurs when members of the same species vie for the same resources in an ecosystem. For example, two trees growing close together will compete for light above ground, and water and nutrients in the soil. Therefore, getting less resources, they will usually perform less well than if they grew by themselves. Although in this situation it may actually be more useful to think in terms of resource availability than competition. Adaptations to such an environment include growing taller, (where the specific prediction provided by the competition model is that all species in such a situation will grow as tall as possible). or developing a larger root system (where the specific prediction is that all species in the system will develop very deep root systems). The real question is whether these predictions are evidenced by our observations of the natural world.

3.1.2.2 Interspecific competition


Trees in this Bangladeshi forest are in interspecific competition for light.

Interspecific competition may occur when individuals of two separate species share a limiting resource in the same area. If the resource cannot support both populations, then lowered fecundity, growth, or survival may result in at least one species. Interspecific competition has the potential to alter populations, communities and the evolution of interacting species.

An example among animals could be the case of cheetahs and lions; since both species feed on similar prey, they are negatively impacted by the presence of the other because they will have less food, however they still persist together, despite the prediction that under competition one will displace the other. In fact, lions sometimes steal prey items killed by cheetahs. Potential competitors can also kill each other, and this phenomenon is called 'intraguild predation'. For example, in southern California coyotes often kill and eat gray foxes and bobcats, all three carnivores sharing the same stable prey (small mammals).

Competition has been observed between individuals, populations and species, but there is little evidence that competition has been the driving force in the evolution of large groups. For example, between reptiles and mammals. Mammals lived beside reptiles for many millions of years of time but were unable to gain a competitive edge until dinosaurs were devastated by the K-T Extinction.

3.2 Evolutionary strategies

3.2.1 r/K selection theory

In evolutionary contexts, competition is related to the concept of r/K selection theory, which relates to the selection of traits which promote success in particular environments. The theory originates from work on island biogeography by the ecologists Robert MacArthur and E. O. Wilson,1967

In r/K selection theory, selective pressures are hypothesised to drive evolution in one of two stereotyped directions: *r*- or *K*-selection. These terms, r and K, are derived from standard ecological algebra, as illustrated in the simple Verhulst equation of population dynamics:

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

where *r* is the growth rate of the population (*N*), and *K* is the carrying capacity of its local environmental setting. Typically, r-selected species exploit empty niches, and produce many offspring, each of whom has a relatively low probability of surviving to adulthood. In contrast, K-selected species are strong competitors in crowded niches, and invest more heavily in much fewer offspring, each of whom has a relatively high probability of surviving to adulthood.

4.0 Conclusion

In this unit, students had learnt so far

The meaning of competition , factors/resources that contribute to competition among organisms, types of competition and evolutionary strategies of competition

5.0 Summary

According to the competitive exclusion principle, species less suited to compete for resources should either adapt or die out. According to evolutionary theory, this competition within and between species for resources plays a critical role in natural selection, however, competition may play less of a role than expansion among larger groups such as families.

6.0 Tutor-Marked Assignments

1. What is competition?
2. List factors/resources that contribute to competition among organisms.
3. Explain the following types of competition:

   VI. intraspecies competition
   VII. interspecies competition
   VIII. interferences competition
   IX. apparent competition
   X. and exploitation competition.

4. Explain evolutionary strategies and state the formula r/K selection theory

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Unit 2 Resources contributing to competition among organisms.

1.0 Introduction

Limited supply of at least one resource (such as food, water, and territory) used by both is required. Competition both within and between species is an important topic in ecology, especially community ecology. Competition is one of many interacting biotic and abiotic factors that affect community structure. Competition among members of the same species is known as intraspecific competition, while competition between individuals of different species is known as interspecific competition. Competition is not always straightforward, and can occur in both a direct and indirect fashion

1.0 Objectives

At the end of this unit, students should be able to:

1. *List and explain resources that contribute to competition in animlas.*
2. *List physical and chemicals properties of water.*
3. *Write a formula for calculating sunlight.*
4. *Explain the following in territory: 1. spraying 2. Defence 3.Classic territories*

3.0 Main Contents

3.1.Territory (animal)

Northern Elephant Seals (Mirounga angustirostris) fighting for territory and mates.

In ethology the term **territory** refers to any sociographical area that an animal of a particular species consistently defends against conspecifics (and, occasionally, animals of other species). Animals that defend territories in this way are referred to as **territorial**.

3.1.1 Classic territories

Territorial animals defend areas that contain a nest, den or mating site and sufficient food resources for themselves and their young. Defense rarely takes the form of overt fights: more usually there is a highly noticeable display, which may be visual (as in the red breast of the robin), auditory (as in much bird song, or the calls of gibbons) or olfactory, through the deposit of scent marks. Many territorial mammals use scent-marking to signal the boundaries of their territories; the marks may be deposited by urination, by defecation, or by rubbing parts of the bodies that bear specialised scent glands against the substrate. For example, dogs and other canids scent-mark by urination and defecation, while cats scent-mark by rubbing their faces and flanks against objects, as well as by the notoriously persistently smelly spraying of urine by tomcats. Many prosimians use territorial marking; for example, the Red-bellied Lemur creates territories for groups of two to ten individuals in the rainforests of eastern Madagascar by scent marking: the male Diademed Sifaka also scent marks defended territories in some of these same rainforests. The male Western fence lizard defends a territory by posturing and combat, but less intensely after the mating season.

Invertebrates which show territorality include some ants and bees, and the owl limpet

3.1.2 Spraying

A wolf marking its territory.

Spraying (also known as **territorial marking**) is behavior used by animals to identify their territory. Most commonly, this is **scent marking**, accomplished by depositing strong-smelling chemicals such as urine at prominent locations within the territory. Often the scent contains carrier proteins, such as the major urinary proteins, to stabilize the odors and maintain them for longer.

Not only does the marking communicate to others of the same species, but it is also noted by prey species and avoided. For example felids such as leopards and jaguars mark by rubbing themselves against vegetation. Some prosimians, such as the Red-bellied Lemur, also use scent marking to establish a territory. Many ungulates, for example the Blue Wildebeest, use scent marking from two glands, the preorbital gland and a scent gland in the hoof.

3.1.3 Defence

Territories may be held by an individual, a mated pair, or a group. Territoriality is not a fixed property of a species: for example, robins defend territories as pairs during the breeding season and as individuals during the winter, while some nectarivores defend territories only during the mornings (when plants are richest in nectar). In species that do not form pair bonds, male and female territories are often independent, in the sense that males defend territories only against other males, and females only against other females; in this case, if the species is polygynous, one male territory will probably contain several female territories, while in some polyandrous species such as the Northern Jacana, this situation is reversed.

Quite often territories that only yield a single resource are defended. For example, European Blackbirds may defend feeding territories that are distant from their nest sites, and in some species that form leks, for example the Uganda kob (a grazing antelope), males defend the lek site (which is used only for mating).

Two territorial American Kestrels attacking a Red-tailed Hawk.

Territoriality is only shown by a minority of species. More commonly, an individual or a group of animals will have an area that it habitually uses but does not necessarily defend; this is called its home range. The home ranges of different groups often overlap, and in the overlap areas the groups will tend to avoid each other rather than seeking to expel each other. Within the home range there may be a *core area* that no other individual group uses, but again this is as a result of avoidance rather than defense.

Behavioural ecologists have argued that food distribution determines whether a species will be territorial or not. This however, though true as far as it goes, is too narrow a point of view. As mentioned above, there are several kinds of territoriality; for example, the defence of lek areas by kob has nothing to do with food. Many other examples of territorial defence, including fish, birds or even invertebrates, are related to competition for mates or safe lairs, rather than food. Territoriality will emerge where there is a focused resource that provides enough for the individual or group, within a boundary that is small enough to be defended without the expenditure of too much effort.

Many birds, particularly seabirds, though they nest in dense communities, are none the less territorial in that they defend their nesting site to within the distance that they can reach while brooding. This is necessary to prevent attacks on their own chicks or nesting material from neighbours. Commonly the resulting superimposition of the short-range repulsion onto the long-range attraction characteristically leads to the well-known roughly hexagonal spacing of nests. Interestingly, one gets a similar hexagonal spacing resulting from the territorial behaviour of gardening limpets such as species of Scutellastra . They vigorously defend their gardens of particular species of algae, that extend for perhaps 1–2 cm around the periphery of their shells.

Territoriality is least likely with insectivorous birds, where the food supply is plentiful but unpredictably distributed. Swifts rarely defend an area larger than the nest. Conversely, other insectivorous birds that occupy more constrained territories, such as the ground-nesting Blacksmith Lapwing may be very territorial, especially in the breeding season, where they not only threaten or attack many kinds of intruders, but have stereotyped display behaviour to deter conspecifics sharing neighbouring nesting spots.

Conversely, large solitary (or paired) carnivores, such as bears and the bigger raptors require an extensive protected area to guarantee their food supply. This territoriality will only break down when there is a glut of food, for example when Grizzly Bears are attracted to migrating salmon.

3.2 Sunlight

Sunlight shining through clouds, giving rise to crepuscular rays.

Sunlight, in the broad sense, is the total frequency spectrum of electromagnetic radiation given off by the Sun. On Earth, sunlight is filtered through the Earth's atmosphere, and **solar radiation** is obvious as daylight when the Sun is above the horizon.

When the direct solar radiation is not blocked by clouds, it is experienced as **sunshine**, a combination of bright light and radiant heat. When it is blocked by the clouds or reflects off of other objects, it is experienced as diffused light.

The World Meteorological Organization uses the term "sunshine duration" to mean the cumulative time during which an area receives direct irradiance from the Sun of at least 120 watts per square meter.

Sunlight may be recorded using a sunshine recorder, pyranometer or pyrheliometer. Sunlight takes about 8.3 minutes to reach the Earth.

Direct sunlight has a luminous efficacy of about 93 lumens per watt of radiant flux, which includes infrared, visible, and ultraviolet light. Bright sunlight provides illuminance of approximately 100,000 lux or lumens per square meter at the Earth's surface.

Sunlight is a key factor in photosynthesis, a process vital for life on Earth.

3.2.1 Calculation

To calculate the amount of sunlight reaching the ground, both the elliptical orbit of the Earth and the attenuation by the Earth's atmosphere have to be taken into account. The extraterrestrial solar illuminance (E_{ext}), corrected for the elliptical orbit by using the day number of the year (dn), is given by

$$E_{\mathrm{ext}} = E_{\mathrm{sc}} \cdot \left(1 + 0.033412 \cdot \cos\left(2\pi \frac{\mathrm{dn} - 3}{365}\right)\right),$$

where dn=1 on January 1; dn=2 on January 2; dn=32 on February 1, etc. In this formula dn-3 is used, because in modern times Earth's perihelion, the closest approach to the Sun and therefore the maximum E_{ext} occurs around January 3 each year. The value of .033412 is determined knowing that the ratio between the perihelion (0.98328989 AU) squared and the aphelion (1.01671033 AU) squared should be approximately 0.935338.

The solar illuminance constant (E_{sc}), is equal to 128×10^3 lx. The direct normal illuminance (E_{dn}), corrected for the attenuating effects of the atmosphere is given by:

$$E_{\mathrm{dn}} = E_{\mathrm{ext}}\, e^{-cm},$$

where c is the atmospheric extinction coefficient and m is the relative optical airmass.

3.2.2 Solar constant

The **solar constant**, a measure of flux density, is the amount of incoming solar electromagnetic radiation per unit area that would be incident on a plane perpendicular to the rays, at a distance of one astronomical unit (AU) (roughly the mean distance from the Sun to the Earth). The "solar constant" includes all types of solar radiation, not just the visible light. It's average value is approximately 1.366 kW/m²,[2] but this does vary slightly with solar activity.

3.2.3 Total Solar Irradiance (TSI) (upon Earth)and Spectral Solar Irradiance (SSI) (upon Earth)

Total Solar Irradiance upon Earth (TSI) was earlier measured by satellite to be roughly 1.366 kilowatts per square meter (kW/m²),[2][3][4] but most recently NASA cites TSI as "1361 W/m2 as compared to ~1366 W/m2 from earlier observations [Kopp et al., 2005]", based on regular readings from NASA's Solar Radiation and Climate Experiment(SORCE) satellite, active since 2003, noting that this "discovery is critical in examining the energy budget of the planet Earth and isolating the climate change due to human activities." Furthermore the Spectral Irradiance

Monitor (SIM) has found in the same period that spectral solar irradiance (SSI) at UV (ultraviolet) wavelength corresponds in a less clear, and probably more complicated fashion, with earth's climate responses than earlier assumed, fueling broad avenues of new research in "the connection of the Sun and stratosphere, troposphere, biosphere, ocean, and Earth’s climate".

3.2.4 Sunlight intensity in the Solar System

Different bodies of the Solar System receive light of an intensity inversely proportional to the square of their distance from Sun. A rough table comparing the amount of light received by each planet on the Solar System follows (from data in [2]):

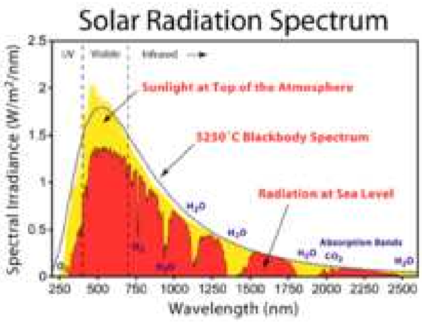
Planet	**Perihelion - Aphelion distance (AU)**	**Solar radiation maximum and minimum (W/m^2)**
Mercury	0.3075 – 0.4667	14,446 – 6,272
Venus	0.7184 – 0.7282	2,647 – 2,576
Earth	0.9833 – 1.017	1,413 – 1,321
Mars	1.382 – 1.666	715 – 492
Jupiter	4.950 – 5.458	55.8 – 45.9
Saturn	9.048 – 10.12	16.7 – 13.4
Uranus	18.38 – 20.08	4.04 – 3.39
Neptune	29.77 – 30.44	1.54 – 1.47

The actual brightness of sunlight that would be observed at the surface depends also on the presence and composition of an atmosphere. For example Venus' thick atmosphere reflects more than 60% of the solar light it receives. The actual illumination of the surface is about 14,000 lux, comparable to that on Earth "in the daytime with overcast clouds".[6]

Sunlight on Mars would be more or less like daylight on Earth wearing sunglasses, and as can be seen in the pictures taken by the rovers, there is enough diffuse sky radiation that shadows would not seem particularly dark. Thus it would give perceptions and "feel" very much like Earth daylight.

For comparison purposes, sunlight on Saturn is slightly brighter than Earth sunlight at the average sunset or sunrise (see daylight for comparison table). Even on Pluto the sunlight would still be bright enough to almost match the average living room. To see sunlight as dim as full moonlight on the Earth, a distance of about 500 AU (~69 light-hours) is needed; there are only a handful of objects in the solar system known to orbit farther than such a distance, among them 90377 Sedna and (87269) 2000 OO67

3.2.5 Composition



Solar irradiance spectrum above atmosphere and at surface
See also: Ultraviolet, Infrared, and Light

The spectrum of the Sun's solar radiation is close to that of a black body with a temperature of about 5,800 K. The Sun emits EM radiation across most of the electromagnetic spectrum. Although the Sun produces Gamma rays as a result of the Nuclear fusion process, these super high energy photons are converted to lower energy photons before they reach the Sun's surface and are emitted out into space, so the Sun doesn't give off any gamma rays to speak of. The Sun does, however, emit X-rays, ultraviolet, visible light , infrared, and even Radio waves. When ultraviolet radiation is not absorbed by the atmosphere or other protective coating, it can cause damage to the skin known as sunburn or trigger an adaptive change in human skin pigmentation.

The spectrum of electromagnetic radiation striking the Earth's atmosphere spans a range of 100 nm to about 1 mm. This can be divided into five regions in increasing order of wavelengths:

- **Ultraviolet C** or (UVC) range, which spans a range of 100 to 280 nm. The term *ultraviolet* refers to the fact that the radiation is at higher frequency than violet light (and, hence also invisible to the human eye). Owing to absorption by the atmosphere very little reaches the Earth's surface (Lithosphere). This spectrum of radiation has germicidal properties, and is used in germicidal lamps.
- **Ultraviolet B** or (UVB) range spans 280 to 315 nm. It is also greatly absorbed by the atmosphere, and along with UVC is responsible for the photochemical reaction leading to the production of the ozone layer.
- **Ultraviolet A** or (UVA) spans 315 to 400 nm. It has been traditionally held as less damaging to the DNA, and hence used in tanning and PUVA therapy for psoriasis.
- **Visible range** or **light** spans 380 to 780 nm. As the name suggests, it is this range that is visible to the naked eye.
- **Infrared** range that spans 700 nm to 10^6 nm (1 mm). It is responsible for an important part of the electromagnetic radiation that reaches the Earth. It is also divided into three types on the basis of wavelength:
    - Infrared-A: 700 nm to 1,400 nm
    - Infrared-B: 1,400 nm to 3,000 nm
    - Infrared-C: 3,000 nm to 1 mm.

3.2.6 Surface illumination

The spectrum of surface illumination depends upon solar elevation due to atmospheric effects, with the blue spectral component from atmospheric scatter dominating during twilight before and after sunrise and sunset, respectively, and red dominating during sunrise and sunset. These effects are apparent in natural light photography where the principal source of illumination is sunlight as mediated by the atmosphere.

According to Craig Bohren, "preferential absorption of sunlight by ozone over long horizon paths gives the zenith sky its blueness when the sun is near the horizon".

See diffuse sky radiation for more details.

3.2.7 Climate effects

On Earth, solar radiation is obvious as daylight when the sun is above the horizon. This is during daytime, and also in summer near the poles at night, but not at all in winter near the poles. When the direct radiation is not blocked by clouds, it is experienced as *sunshine*, combining the perception of bright white light (sunlight in the strict sense) and warming. The warming on the body, the ground and other objects depends on the absorption (electromagnetic radiation) of the electromagnetic radiation in the form of heat.

The amount of radiation intercepted by a planetary body varies inversely with the square of the distance between the star and the planet. The Earth's orbit and obliquity change with time (over thousands of years), sometimes forming a nearly perfect circle, and at other times stretching out to an orbital eccentricity of 5% (currently 1.67%). The total insolation remains almost constant due to Kepler's second law,

$$\tfrac{2A}{r^2}dt = d\theta,$$

where A is the "areal velocity" invariant. That is, the integration over the orbital period (also invariant) is a constant.

$$\int_0^T \tfrac{2A}{r^2}dt = \int_0^{2\pi} d\theta = \mathrm{constant}$$

If we assume the solar radiation power P as a constant over time and the solar irradiation given by the inverse-square law, we obtain also the average insolation as a constant.

But the seasonal and latitudinal distribution and intensity of solar radiation received at the Earth's surface also varies. For example, at latitudes of 65 degrees the change in solar energy in summer & winter can vary by more than 25% as a result of the Earth's orbital variation. Because changes in winter and summer tend to offset, the change in the annual average insolation at any given location is near zero, but the redistribution of energy between summer and winter does strongly affect the intensity of seasonal cycles. Such changes associated with the redistribution of solar energy are considered a likely cause for the coming and going of recent

3.3 Water

Water in three states: liquid, solid (ice), and (invisible) water vapor in the air. Clouds are accumulations of water droplets, condensed from vapor-saturated air.

Water is a chemical substance with the chemical formula H_2O. Its molecule contains one oxygen and two hydrogen atoms connected by covalent bonds. Water is a liquid at ambient conditions, but it often co-exists on Earth with its solid state, ice, and gaseous state (water vapor or steam). Water also exists in a liquid crystal state near hydrophilic surfaces.

Water covers 70.9% of the Earth's surface, and is vital for all known forms of life. On Earth, it is found mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapor, clouds (formed of solid and liquid water particles suspended in air), and precipitation. Oceans hold 97% of surface water, glaciers and polar ice caps 2.4%, and other land surface water such as rivers, lakes and ponds 0.6%. A very small amount of the Earth's water is contained within biological bodies and manufactured products.

Water on Earth moves continually through a cycle of evaporation or transpiration (evapotranspiration), precipitation, and runoff, usually reaching the sea. Over land, evaporation and transpiration contribute to the precipitation over land.

Clean drinking water is essential to humans and other lifeforms. Access to safe drinking water has improved steadily and substantially over the last decades in almost every part of the world. There is a clear correlation between access to safe water and GDP per capita. However, some observers have estimated that by 2025 more than half of the world population will be facing water-based vulnerability. A recent report (November 2009) suggests that by 2030, in some developing regions of the world, water demand will exceed supply by 50%. Water plays an important role in the world economy, as it functions as a solvent for a wide variety of chemical substances and facilitates industrial cooling and transportation. Approximately 70% of freshwater is consumed by agriculture.

3.3.1 Chemical and physical properties

The major chemical and physical properties of water are:

- Water is a liquid at standard temperature and pressure. It is tasteless and odorless. The intrinsic color of water and ice is a very slight blue hue, although both appear colorless in small quantities. Water vapor is essentially invisible as a gas.

- Water is transparent in the visible electromagnetic spectrum. Thus aquatic plants can live in water because sunlight can reach them. Ultra-violet and infrared light is strongly absorbed.

- Since the water molecule is not linear and the oxygen atom has a higher electronegativity than hydrogen atoms, it carries a slight negative charge, whereas the hydrogen atoms are slightly positive. As a result, water is a polar molecule with an electrical dipole moment. Water also can form an unusually large number of intermolecular hydrogen bonds (four) for a molecule of its size. These factors lead to strong attractive forces between molecules of water, giving rise to water's high surface tension and capillary forces. The capillary action refers to the tendency of water to move up a narrow tube against the force of gravity. This property is relied upon by all vascular plants, such as trees.

- Water is a good solvent and is often] referred to] as *the universal solvent*. Substances that dissolve in water, e.g., salts, sugars, acids, alkalis, and some gases – especially oxygen, carbon dioxide (carbonation) are known as *hydrophilic* (water-loving) substances, while those that do not mix well with water (e.g., fats and oils), are known as *hydrophobic* (water-fearing) substances.

- All the major components in cells (proteins, DNA and polysaccharides) are also dissolved in water.

- Pure water has a low electrical conductivity, but this increases significantly with the dissolution of a small amount of ionic material such as sodium chloride (common salt).

- The boiling point of water (and all other liquids) is dependent on the barometric pressure. For example, on the top of Mt. Everest water boils at 68 °C (154 °F), compared to 100 °C (212 °F) at sea level. Conversely, water deep in the ocean near geothermal vents can reach temperatures of hundreds of degrees and remain liquid.

- Water has the second highest molar specific heat capacity of any known substance, after ammonia, as well as a high heat of vaporization ($40.65\ kJ \cdot mol^{-1}$), both of which are a result of the extensive hydrogen bonding between its molecules. These two unusual properties allow water to moderate Earth's climate by buffering large fluctuations in temperature.

- The maximum density of water occurs at 3.98 °C (39.16 °F). It has the anomalous property of becoming less dense, not more, when it is cooled down to its solid form, ice. It expands to occupy 9% greater volume in this solid state, which accounts for the fact of ice floating on liquid water.

- Its Density is $1,000\ kg/m^3$ liquid (4 °C), and weighs 62.4 $lb/ft.^3$ ($917\ kg/m^3$, solid). It weighs 8.3454 lb/gal. (US, liquid)
- Water is miscible with many liquids, such as ethanol, in all proportions, forming a single homogeneous liquid. On the other hand, water and most oils are immiscible usually

forming layers according to increasing density from the top. As a gas, water vapor is completely miscible with air.

- Water forms an azeotrope with many other solvents.

- Water can be split by electrolysis into hydrogen and oxygen.

- As an oxide of hydrogen, water is formed when hydrogen or hydrogen-containing compounds burn or react with oxygen or oxygen-containing compounds. Water is not a fuel, it is an end-product of the combustion of hydrogen. The energy required to split water into hydrogen and oxygen by electrolysis or any other means is greater than the energy that can be collected when the hydrogen and oxygen recombine.

- Elements which are more electropositive than hydrogen such as lithium, sodium, calcium, potassium and caesium displace hydrogen from water, forming hydroxides. Being a flammable gas, the hydrogen given off is dangerous and the reaction of water with the more electropositive of these elements may be violently explosive.

3.3.2 Taste and odor

Water can dissolve many different substances, giving it varying tastes and odors. Humans and other animals have developed senses which enable them to evaluate the portability of water by avoiding water that is too salty or putrid. The taste of spring water and mineral water, often advertised in marketing of consumer products, derives from the minerals dissolved in it. However, pure H_2O is tasteless and odorless. The advertised purity of spring and mineral water refers to absence of toxins, pollutants and microbes.

3.3.3 Distribution in nature

3.3.3.1 In the universe

Much of the universe's water is produced as a byproduct of star formation. When stars are born, their birth is accompanied by a strong outward wind of gas and dust. When this outflow of material eventually impacts the surrounding gas, the shock waves that are created compress and heat the gas. The water observed is quickly produced in this warm dense gas.

Water has been detected in interstellar clouds within our galaxy, the Milky Way. Water probably exists in abundance in other galaxies, too, because its components, hydrogen and oxygen, are among the most abundant elements in the universe. Interstellar clouds eventually condense into solar nebulae and solar systems such as ours.

Water vapor is present in

- Atmosphere of Mercury: 3.4%, and large amounts of water in Mercury's exosphere
- Atmosphere of Venus: 0.002%
- Earth's atmosphere: ~0.40% over full atmosphere, typically 1–4% at surface

- Atmosphere of Mars: 0.03%
- Atmosphere of Jupiter: 0.0004%
- Atmosphere of Saturn – in ices only
- Enceladus (moon of Saturn): 91%
- exoplanets known as HD 189733 b and HD 209458 b.

Liquid water is present on

- Earth: 71% of surface

Strong evidence suggests that liquid water is present just under the surface of Saturn's moon Enceladus. Jupiter's moon Europa may have liquid water in the form as a 100 km deep subsurface ocean, which would amount to more water than is in all the Earth's oceans.

Water ice is present on

- Earth – mainly as ice sheets
- polar ice caps on Mars
- Moon
- Titan
- Europa
- Saturn's rings
- Enceladus
- Pluto and Charon
- Comets and comet source populations (Kuiper belt and Oort cloud objects).

Water ice may be present on Ceres and Tethys. Water and other volatiles probably comprise much of the internal structures of Uranus and Neptune and the water in the deeper layers may be in the form of ionic water in which the molecules break down into a soup of hydrogen and oxygen ions, and deeper down as superionic water in which the oxygen crystallises but the hydrogen ions float around freely within the oxygen lattice.

Some of the Moon's minerals contain water molecules. For instance, in 2008 a laboratory device which ejects and identifies particles found small amounts of the compound in the inside of volcanic pearls brought from Moon to Earth by the Apollo 15 crew in 1971. NASA reported the detection of water molecules by NASA's Moon Mineralogy Mapper aboard the Indian Space Research Organization's Chandrayaan-1 spacecraft in September 2009.

3.4.3.2 Water and habitable zone

The existence of liquid water, and to a lesser extent its gaseous and solid forms, on Earth are vital to the existence of life on Earth as we know it. The Earth is located in the habitable zone of the solar system; if it were slightly closer to or farther from the Sun (about 5%, or about 8 million kilometers), the conditions which allow the three forms to be present simultaneously would be far less likely to exist.

Earth's gravity allows it to hold an atmosphere. Water vapor and carbon dioxide in the atmosphere provide a temperature buffer (greenhouse effect) which helps maintain a relatively steady surface temperature. If Earth were smaller, a thinner atmosphere would allow temperature extremes, thus preventing the accumulation of water except in polar ice caps (as on Mars).

The surface temperature of Earth has been relatively constant through geologic time despite varying levels of incoming solar radiation (insolation), indicating that a dynamic process governs Earth's temperature via a combination of greenhouse gases and surface or atmospheric albedo. This proposal is known as the *Gaia hypothesis*.

The state of water on a planet depends on ambient pressure, which is determined by the planet's gravity. If a planet is sufficiently massive, the water on it may be solid even at high temperatures, because of the high pressure caused by gravity, as it was observed on exoplanets Gliese 436 b and GJ 1214 b.

4.0 Conclusion

Students have learnt the following resources that contribute to competition: Territory, water and sunlight.

5.0 **Summary**

According to the competitive exclusion principle, species less suited to compete for resources should either adapt or die out. According to evolutionary theory, this competition within and between species for resources plays a critical role in natural selection, however, competition may play less of a role than expansion among larger groups such as families.

6.0 Tutor-Marked Assignments

1. List and explain four resources that contribute to competition in animals.
2. List five physical and chemical properties of water.
3. Write a formula for calculating sunlight.
4. Explain the following in territory: 1. spraying 2. Defence 3.Classic territories

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MODULE 4 : POPULATION IN ANIMAL ECOLOGY

UNIT 1 POPULATION

Unit 1 Population

Contents

1.0 Introduction

A **population** is all the organisms that both belong to the same species and live in the same geographical area. The area that is used to define the population is such that inter-breeding is possible between any pair within the area and more probable than cross-breeding with individuals from other areas. Normally breeding is substantially more common within the area than across the border.

In sociology, population refers to a collection of human beings. Demography is a sociological discipline which entails the statistical study of human populations. This article refers mainly to human population.

2.0 Objectives:

At the end of this unit students should be able to:

1. Define population and population genetics.
2. Explain Human population control

3.0 Main Content

3.1 Population genetics

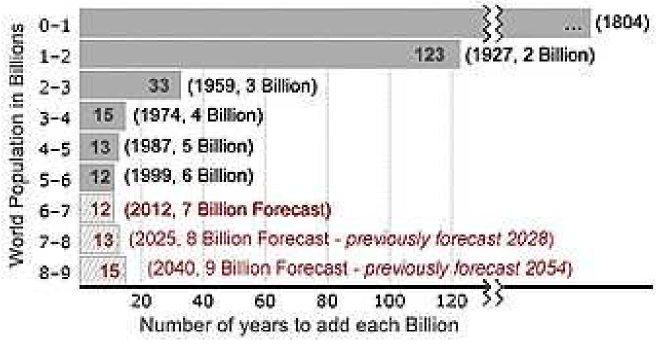
In population genetics a population is a set of organisms in which any pair of members can breed together. This implies that all members belong to the same species and live near each other.

3.2 World human population

As of 16 March 2011, the world population is estimated by the United States Census Bureau to be 6.906 billion.

According to papers published by the United States Census Bureau, the world population hit 6.5 billion (6,500,000,000) on 24 February 2006. The United Nations Population Fund designated 12 October 1999 as the approximate day on which world population reached 6 billion. This was about 12 years after world population reached 5 billion in 1987, and 6 years after world population reached 5.5 billion in 1993. The population of some countries, such as Nigeria and China is not even known to the nearest million, so there is a considerable margin of error in such estimates.

Growth



Time taken for each billion people to be added to the world's population (including future estimates). See also alt. chart

3.2.1 Population growth

Population growth increased significantly as the Industrial Revolution gathered pace from 1700 onwards. The last 50 years have seen a yet more rapid increase in the rate of population growth due to medical advances and substantial increases in agricultural productivity, particularly beginning in the 1960s, made by the Green Revolution. In 2007 the United Nations Population Division projected that the world's population will likely surpass 10 billion in 2055. In the future, world population has been expected to reach a peak of growth, from there it will decline due to economic reasons, health concerns, land exhaustion and environmental hazards. There is around an 85% chance that the world's population will stop growing before the end of the century. There is a 60% probability that the world's population will not exceed 10 billion people before 2100, and around a 15% probability that the world's population at the end of the century will be lower than it is today. For different regions, the date and size of the peak population will vary considerably.

The population pattern of less-developed regions of the world in recent years has been marked by gradually declining birth rates following an earlier sharp reduction in death rates. This transition from high birth and death rates to low birth and death rates is often referred to as the demographic transition.

3.2.2 Control

Human population control

Human population control is the practice of artificially altering the rate of growth of a human population. Historically, human population control has been implemented by limiting the population's birth rate, usually by government mandate, and has been undertaken as a response to factors including high or increasing levels of poverty, environmental concerns, religious reasons, and overpopulation. While population control can involve measures that improve people's lives by giving them greater control of their reproduction, some programs have exposed them to exploitation.

Worldwide, the population control movement was active throughout the 1960s and 1970s, driving many reproductive health and family planning programs. In the 1980s, tension grew between population control advocates and women's health activists who advanced women's reproductive rights as part of a human rights-based approach. Growing opposition to the narrow population control focus led to a significant change in population control policies in the early 1990s.

4.0 Conclusion

Students had learnt about population in general, population genetics,world population growth and human population control

5.0 Summary

According to papers published by the United States Census Bureau, the world population hit 6.5 billion (6,500,000,000) on 24 February 2006. The United Nations Population Fund designated 12 October 1999 as the approximate day on which world population reached 6 billion. This was about 12 years after world population reached 5 billion in 1987, and 6 years after world population reached 5.5 billion in 1993. The population of some countries, such as Nigeria and China is not even known to the nearest million, so there is a considerable margin of error in such estimates.

6.0 Tutor-Marked Assignment

1. Explain the following terms:

    I. Population
    II. Demodraphy.

2. Explain population genetics.
3. Explain human population control

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UNIT 2 POPULATION CYCLE

Content

1.0 Introduction

A population cycle in zoology is a phenomenon where populations rise and fall over a predictable period of time. There are some species where population numbers have reasonably predictable patterns of change although the full reasons for population cycles is one of the major unsolved ecological problems. There are a number of factors which influence population change such as availability of food, predators, diseases and climate.

2.0 Objectives

At the end of this unit,students should be able to:

1. Define population cycle.
2. List four factors that cause or contribute to population cycle.
3. Explain population cycle in some animals
4. Explain relationships between predators and prey.

3.0 Main Contents

3.1 Occurrence in mammal populations

Olaus Magnus, the Archbishop of Uppsala in central Sweden, identified that species of northern rodents had periodic peaks in population and published two reports on the subject in the middle of the 16th century.

In North America, the phenomenon was identified in populations of the snowshoe hare. In 1865, trappers with the Hudson's Bay Company were catching plenty of animals. By 1870, they were catching very few. It was finally identified that the cycle of high and low catches ran over approximately a ten year period.

The most well known example of creatures which have a population cycle is the lemming. The biologist Charles Elton first identified in 1924 that the lemming had regular cycles of population growth and decline. When their population outgrows the resources of their habitat, lemmings migrate, although contrary to popular myth, they do not jump into the sea.

3.2 Other species

While the phenomenon is often associated with rodents, it does occur in other species such as the ruffed grouse. There are other species which have irregular population explosions such as grasshoppers where overpopulation results in locust swarms in Africa and Australia.

3.3 Relationships between predators and prey

There is also an interaction between prey with periodic cycles and predators. As the population expands, there is more food available for predators. As it contracts, there is less food available for predators, putting pressure on their population numbers.

4.0 Conclusion

Students had learnt about population cycle, factor contributing to population cycle and Relationships between predators and prey

5.0 Summary

There are some species where population numbers have reasonably predictable patterns of change although the full reasons for population cycles is one of the major unsolved ecological problems.

6 Tutor-Marked Assignments

1 What is population cycle?

2 List four factors that cause or contribute to population cycle.

3 Explain population cycle in snowshoes and lemming

4 Explain relationships between predators and prey.

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UNIT 3 ANIMAL POPULATION CONTROL

Content

1.0 Introduction

2.0 Objectives

3.0 Main Contents

3. 1 Factors influencing population control

3.2 Methods for active population control

3.3 Examples

3. 4 Dynamics of Predation

3.4.1 How do predation and resource availability drive changes in natural populations?

4.0 Conclusion

5.0 Summary

6.0 Tutor-Marked Assignment

7.0 References

1.0 Introduction

Population control is the practice of artificially altering the size of any animal population besides humans. It typically refers to the act of limiting the size of an animal population so that it remains manageable, as opposed to the act of protecting a species from excessive rates of extinction, which is referred to as conservation biology.

2.0 Objectives

At the end of this unit, students should be able to :

1. Define population control in animals.
2. List and explain four biotic factors and abiotic factors that can be used to control animals population apart from humans.
3. List and discuss two active methods for population control.
4. Explain contributions of ecologists on population control.

3.0 Main Content

3.1 Factors influencing population control

Population control in animals can be influenced by a variety of factors. Humans can greatly influence the size of animal populations they directly interact with. Various humans activities (e.g. hunting, farming, fishing, industrialization and urbanization) all impact various animal populations.

Animal population control is the practice of intentionally altering the size of any animal population besides humans. It may involve culling, translocation, or manipulation of the reproductive capability. The growth of animal population may be limited by environmental factors such as food supply or predation.

The main biotic factors that effect population growth include:

- **Food-** both the quantity and the quality of food are important. Snails, for example, cannot reproduce successfully in an environment low in calcium, no matter how much food there is, because they need this mineral for shell growth.
- **Predators-** as a prey population becomes larger, it becomes easier for predators to find prey. If the number of predators suddenly falls, the prey species might increase in number extremely quickly.
- **Competitors**- other organisms may require the same resources from the environment, and so reduce growth of a population.For example all plants compete for light. Competition for territory and for mates can drastically reduce the growth of individual organisms.
- **Parasites**- These may cause disease, and slow down the growth and reproductive rate of organisms within a population.

Important Abiotic factors affecting population growth include:

- **Temperature**- Higher temperatures speed up enzyme-catalyzed reactions and increase growth.
- **Oxygen availability**- affects the rate of energy production by respiration.
- **Light availability-** for photosynthesis. light may also control breeding cycles in animals and plants.
- **Toxins and pollutants-** tissue growth can be reduced by the presence of, for example, sulphur dioxide, and reproductive success may be affected by pollutants such as estrogen like substances.

3.2 Methods for active population control

Animal euthanasia is often used as a final resort to controlling animal populations. In Tangipahoa Parish, Louisiana, the parish performed mass euthanasia on the entire animal shelter population, including 54 cats and 118 dogs that were put to death due to a widespread disease outbreak that spread among the animals.

Neutering is another option available to control animal populations. The annual Spay Day USA event was established by the Doris Day Animal League to promote the neutering of pets, especially those in animal shelters, so that the population remains controllable.

3.3 Examples

Several efforts have been made to control the population of ticks, which act as vectors of a number of diseases and therefore pose a risk to humans.

3. 4 Dynamics of Predation

3.4.1 How do predation and resource availability drive changes in natural populations?

Populations of organisms do not remain constant; the number of individuals within a population changes, sometimes dramatically, from one time period to the next. Ecologists have documented examples of such fluctuations in a wide variety of organisms, including algae, invertebrates, fish, frogs, birds, and mammals such as rodents, large herbivores, and carnivores.

Ecologists have long wondered about the factors that regulate such fluctuations, and early research suggested that resource availability plays an important role. Researchers found that when resources (food, nesting sites, or refuges) were limited, populations would decline as individuals competed for access to the limiting resources. Such bottom-up control helped to regulate the population around carrying capacity. More recently, scientists have discovered that predation can also influence the size of the prey population by acting as a top-down control. In reality, the interaction between these two forms of population control work together to drive changes in populations over time. Additional factors, such as parasites and disease can further influence population dynamics.

4.0 Conclusion

Students have learnt population control in animals, biotic and abiotic factors used in population control apart from human and other factors that can be used in population control.

5.0 Summary

Populations of organisms do not remain constant; the number of individuals within a population changes, sometimes dramatically, from one time period to the next. Ecologists have documented examples of such fluctuations in a wide variety of organisms, including algae, invertebrates, fish, frogs, birds, and mammals such as rodents, large herbivores, and carnivores.

6.0 Tutor-Marked Assignments

1. What is population control in animals?
2. List and explain four biotic factor and abiotic factors that can be used to control animals.
3. List and discuss two active method for population control apart from humans.
4. Explain contributions of ecologists on population control

7.0 References

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UNIT 4 POPULATION CYCLES IN A PREDATOR-PREY SYSTEM

Content

1.0 Introduction

There is also an interaction between prey with periodic cycles and predators. As the population expands, there is more food available for predators. As it contracts, there is less food available for predators, putting pressure on their population numbers.

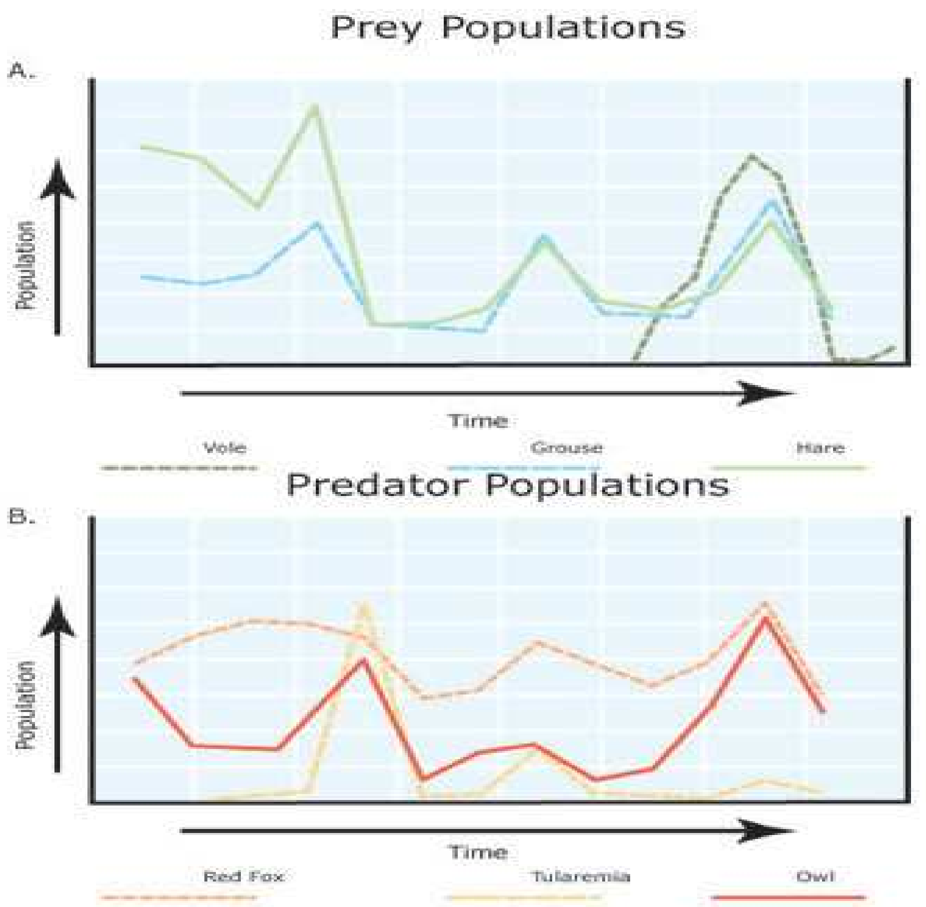

Figure 1: Population cycles in a Swedish forest community

The top figure (a) shows changes in population size for voles and small game. The striped arrows indicate years in which voles consumed tree bark as a marginal food. The bottom figure (b) illustrates how predator populations change in relation to prey abundance.

Some of the most notable examples of population changes occur in species that experience large, cyclic swings in population size. Quite often, these cycles co-occur with population cycles of other species in the same location. For example, red foxes (*Vulpes vulpes*) in northern Sweden prey on voles, grouse, and hares. Studies of these species have demonstrated linked population cycles in each of the prey species, with population peaks every 3-4 years (Figure 1). What drives these cycles?

Grouse, hares, and voles feed on vegetation, and the availability of their preferred foods will influence the population size of each. The availability of food acts as a bottom-up control that affects population size. In years when their preferred food items are abundant, populations will grow. When preferred foods are scarce, individuals must turn to less desirable foods to prevent starvation. They grow more slowly, reproduce less, and populations decline. When vole populations peak and competition for food is strongest, they turn to bark as a marginal food, and this shift in foraging behavior coincides with a population decline (Figure 1a). Grouse and hare populations cycle in a manner comparable to those of voles, which suggests that food availability plays a role in regulating populations of these herbivores.

Foxes prefer to consume voles and other small rodents, but will occasionally eat grouse and hares when voles are less abundant. We would expect that the number of foxes in the population would increase as availability of their preferred food increases, and studies have demonstrated that this does, in fact, occur (Figure 1b). Owl populations cycle in a similar manner, closely following the abundance of voles.

As predator populations increase, they put greater strain on the prey populations and act as a top-down control, pushing them toward a state of decline. Thus both availability of resources and predation pressure affect the size of prey populations. We cannot easily determine the extent to which each of these controls drives population cycles in the Swedish boreal forest, because this system is not amenable to caging experiments, but studies show that food and predation work together to regulate population sizes.

2.0 Objectives

At the end of this unit, students should be able to:

1. Explain Population cycles in a Swedish forest community
2. Explain modeling predator-prey interaction using Lotka-Volterra models
3. Explain host –parasite interaction taking the case study of bacteria (*Francisella tularensis*)
4. Discuss in full foraging behavior using Vole-fox system

3.0 Main Content

3.1 Experimental Studies of Snowshoe Hare Populations

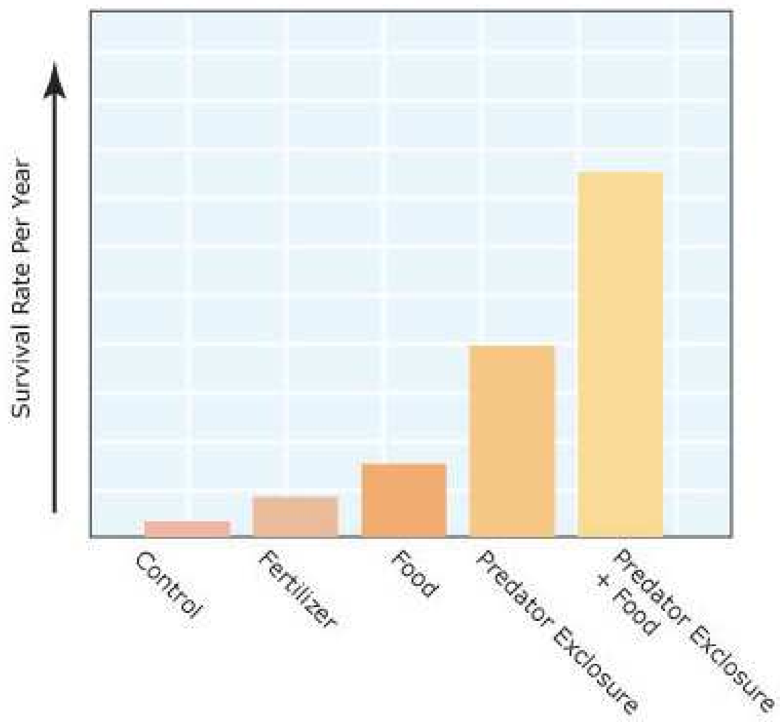

Figure 2: Outcome of the snowshoe hare field experiment

Average showshoe hare density increased under conditions of supplemental food and predator-removal. Density increased dramatically when both food and predation were modified.

Field experiments by Charles J. Krebs and colleagues have experimentally teased apart the influence of food abundance and predation on snowshoe hare (*Lepus americanus*) populations in Canada. They established nine 1 km^2 blocks in undisturbed forest. Three plots served as controls. The researchers used the remaining six to test the effects of resource availability, predation, and the interaction of both factors on snowshoe hare populations. They stocked two blocks with supplemental food for the duration of the experiment to test the effect of resource availability. To test the effect of predation pressure, they enclosed two blocks with electric fences to exclude mammalian predators (hawks and owls retained access). They treated the remaining two blocks with fertilizer to increase plant abundance. Of the two predator-exclusion blocks, one contained supplemental food to examine the influence of both resource availability and predation pressure. The food supplements provided higher-quality nutrients than did plants growing in the forest. On each of these plots, they captured, marked and released the hares twice each year: in March, before the onset of the breeding season, and in October, at the onset of winter.

Krebs and colleagues followed snowshoe hare populations on the nine plots over a course of eight years, through one population cycle in which the population peaked and declined on each study plot. At the end, they averaged the number of hares over the experiment. They found that blocks with supplemental food increased hare density three-fold, whereas fertilizer increased plant biomass on treated plots, but did not correspond to an increase in hares. These findings suggest that resource quality, rather than resource availability, acts as a bottom-up control on hare populations. The predator exclusion blocks increased the average density of hares two-fold, which supported the idea that hare populations were also controlled from the top-down through predation. The most striking finding of the study came from the plot that both excluded predators and had supplemental food supplies. This block experienced an 11-fold increase in average hare density relative to the controls (Figure 2). The researchers found that the increased density of hares was due to both higher survival and reproduction on the study plots.

3.2 Modeling Predator-Prey Interactions

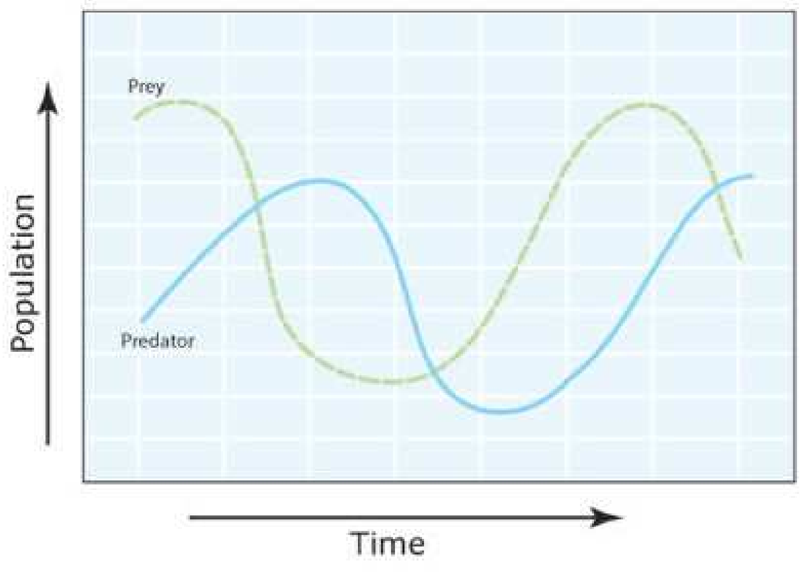

Figure 3: Graphical view of the Lotka-Volterra model

Predator and prey populations cycle through time, as predators decrease numbers of prey. Lack of food resources in turn decrease predator abundance, and the lack of predation pressure allows prey populations to rebound.

To survive and reproduce, individuals must obtain sufficient food resources while simultaneously avoiding becoming food for a predator. The snowshoe hare study demonstrates the role of both predator avoidance and food availability on population sizes. The trade-off between food intake and predator avoidance is not easily addressed in the field, and ecologists have turned to mathematical models to better understand foraging behavior and predator-prey dynamics, just as economists and atmospheric scientists do.

Lotka-Volterra models provide a useful tool to help population ecologists understand the factors that influence population dynamics. They have been particularly useful in understanding and predicting predator-prey population cycles. Although the models greatly simplify actual conditions, they demonstrate that under certain circumstances, predator and prey populations can oscillate over time (Figure 3) in a manner similar to that observed in the populations described above.

3.3 Foraging Behavior

Few systems oscillate in the cyclical manner of those described thus far. In reality, predator-prey systems are complex; they often involve multiple predators and multiple types of prey. What factors influence the type of prey an individual predator takes? What influences the foraging behavior of prey species? Under ideal circumstances, an individual will encounter high-quality food items on a regular basis. These preferred foods provide the most nutritional benefit with the fewest costs. Costs for an organism may be handling time (e.g., time required to catch prey or remove a nut from its shell) or presence of chemicals, such as tannins, that reduce the nutritional quality of the food item.

When preferred foods are scarce, organisms must switch to other, less-desirable alternatives. The point at which an organism should make this shift is not easy to predict. It depends upon many factors, including the relative abundance of each of the foods, the potential costs associated with each food, and other factors, such as the risk of exposure to predators while eating.

Consider the vole-fox system described in the first section. Field voles (*Microtus agrestis*) and bank voles (*Clethrionomys glareolus*) preferentially consume forbs and grasses, but they will turn to the bark from trees when their preferred foods become scarce. Bark contains poorer-quality nutrients than do grasses and forbs. In addition, voles must venture into the open to approach trees to feed on bark, making them more vulnerable to predation by foxes, which rely on sight to find their prey. Only when the preferred foods are very difficult to find—as occurs during times of population peaks—do voles switch to bark.

3.4 Increasing Complexity: Host-parasite Interactions

Thus far, we have focused on herbivore-plant interactions and predator-prey interactions, but parasites also play an important role in regulating populations of their hosts. The *Francisella tularensis* bacteria that cause tularemia are commonly found in both voles and hares in the Swedish boreal forest. Voles serve as a host species for *F. tularensis* and do not display symptoms of disease; however other species, such as mountain hares (*Lepus timidus*), do exhibit symptoms of tularemia when infected. Infection by these bacteria may play a role in the population cycles of these species (Figure 1b), though we currently lack data that demonstrate a causal link.

Other parasites, however, have been shown to impact the overall food web. The ectoparasite *Sarcoptes scabiei* is a mite that causes sarcoptic mange. In the late 1970s and early 1980s, mange infected red foxes in Sweden, decreasing the numbers of foxes in the community by approximately 70%. Erik R. Lindstrom and colleagues were surprised to discover that a decline in the fox population did not affect numbers of voles, which continued to oscillate as before. The fox population decline did, however, result in increased population sizes of mountain hares and grouse. *S. scabiei* reduced the strength of top-down control exerted by foxes on these prey species, which increased numbers of individuals in the prey populations and damped the 3-4 year oscillation in population size for each (Figure 4).

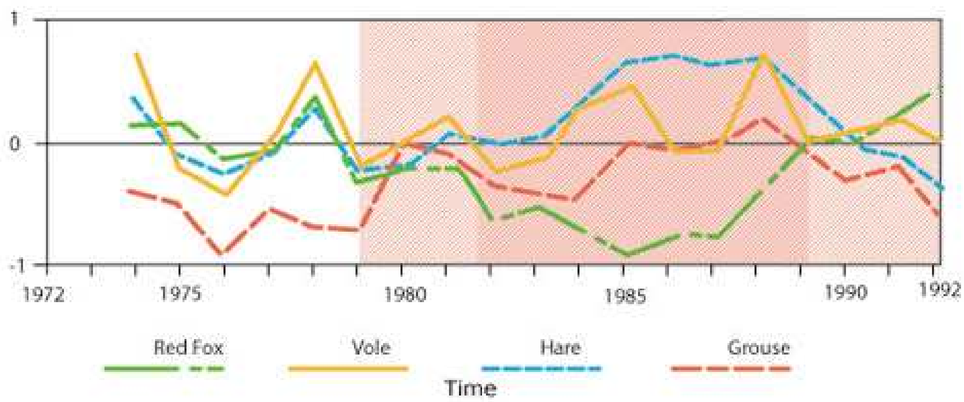

Figure 4: Population changes during a sarcoptic mange outbreak

Parasites with complex life cycles require two hosts; in some of these systems, prey function as intermediate hosts for the parasite, with predators acting as primary hosts. Parasites can manipulate the behavior of the intermediate host to make transmission to the primary host more likely. These changes typically occur when the parasite is at a stage of its life cycle when it can successfully infect the primary host. Behavioral changes that favor parasite transmission often involve unusual foraging behavior on the part of the intermediate host: foraging in locations that make the individual more susceptible to predation by the primary host. As a result, parasites can change the size of prey populations during times of heavy infestation; as the parasites infect the primary host, predator populations may also decline.

Species interactions occur on many levels, as part of a complex, dynamic system in ecological communities. Predators, prey, plants, and parasites all influence changes in population sizes over time. Simple systems may undergo large, cyclical changes, but communities with more complex food webs are likely to experience more subtle shifts in response to changes in parasite load, predation pressure, and herbivory. Consider, however, that humans have impacted many ecological communities by removing predators or reducing the availability of resources. How will such changes affect population fluctuations in the rest of the community?

3.5 Evolutionary Dynamics of Predator-Prey Systems: An Ecological Perspective

Evolution takes place in an evolutionary setting that typically involves interactions with other organisms. To describe such evolution, a structure is needed which incorporates the simultaneous evolution of interacting species. Here a formal framework for this purpose is suggested, extending from the microscopic interactions between individuals- the immediate cause of natural selection, through the mesoscopic population dynamics responsible for driving the replacement of one mutant phenotype by another, to the macroscopic process of phenotypic evolution arising from many such substitutions. The process of coevolution that results from this is illustrated in the predator-prey systems. With no more than qualitative information about the evolutionary dynamics, some basic properties of predator-prey coevolution become evident. More detailed understanding requires specification of an evolutionary dynamic; two models for this purpose are outlined, one from our own research on a stochastic process of mutation and selection and the other from quantitative genetics. Much of the interest in coevolution has been to characterize the properties of fixed points at which there is no further phenotypic evolution. Stability analysis of the fixed points of evolutionary dynamical systems is reviewed and leads to conclusions about the asymptotic states of evolution rather than different from those of game-theoretic methods. These differences become especially important when evolution involves more than one species.

4.0 Conclusion

Students have learnt so far the following:

Population cycles in a Swedish forest community .

Modeling predator-prey interactions.

Lotka-Volterra models .

Host –parasite interaction taking the case study of bacteria (*Francisella tularensis*) and foraging behavior

5.0 Summary

Species interactions occur on many levels, as part of a complex, dynamic system in ecological communities. Predators, prey, plants, and parasites all influence changes in population sizes over time. Simple systems may undergo large, cyclical changes, but communities with more complex food webs are likely to experience more subtle shifts in response to changes in parasite load, predation pressure, and herbivore. Consider, however, that humans have impacted many ecological communities by removing predators or reducing the availability of resources. How will such changes affect population fluctuations in the rest of the community?

6.0 Tutor-Marked Assignments

1. Explain Population cycles in a Swedish forest community
2. Explain modeling predator-prey interaction using Lotka-Volterra models
3. Explain host –parasite interaction taking the case study of bacteria *Francisella tularensis.*
4. Discuss in full foraging behavior using Vole-fox system

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Unit 5 DEMOGRAPHY

Content

1.0 Introduction

Demography is the statistical study of human population. It can be a very general science that can be applied to any kind of dynamic human population, that is, one that changes over time or space (see population dynamics). It encompasses the study of the size, structure and distribution of these populations, and spatial and/or temporal changes in them in response to birth, migration, aging and death.

Demographic analysis can be applied to whole societies or to groups defined by criteria such as education, nationality, religion and ethnicity. Institutionally, demography is usually considered a field of sociology, though there are a number of independent demography departments.

Formal demography limits its object of study to the measurement of populations processes, while the more broad field of social demography population studies also analyze the relationships between economic, social, cultural and biological processes influencing a population.

The term demographics is often used erroneously for demography, but refers rather to selected population characteristics as used in government, marketing or opinion research, or the demographic profiles used in such research.

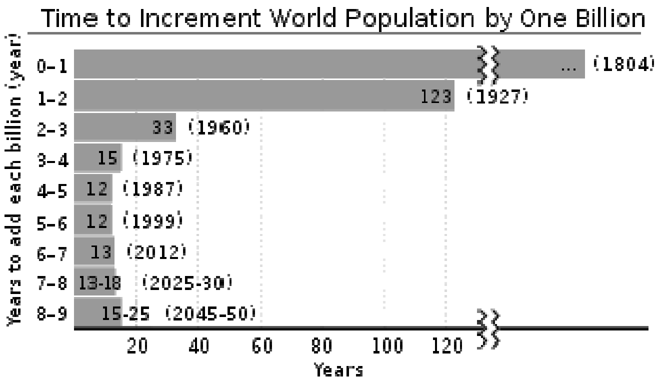
2.0 Objectives

At the end of this unit, students should be able to :

1. Explain the term demography.
2. Explain the term direct and indirect demographic
3. List and explain eight methods use in demographics.
4. List and discuss three ways by which population can be changed

3.0 Main Content

3.1 Data and methods



Rate of human population growth showing projections for later this century.

There are two methods of data collection: direct and indirect.

1. Direct data come from vital statistics registries that track all births and deaths as well as certain changes in legal status such as marriage, divorce, and migration (registration of place of residence). In developed countries with good registration systems (such as the United States and much of Europe), registry statistics are the best method for estimating the number of births and deaths.

A census is the other common direct method of collecting demographic data. A census is usually conducted by a national government and attempts to enumerate every person in a country. However, in contrast to vital statistics data, which are typically collected continuously and summarized on an annual basis, censuses typically occur only every 10 years or so, and thus are not usually the best source of data on births and deaths. Analyses are conducted after a census to estimate how much over or undercounting took place.

Censuses do more than just count people. They typically collect information about families or households, as well as about such individual characteristics as age, sex, marital status, literacy/education, employment status and occupation, and geographical location. They may also collect data on migration (or place of birth or of previous residence), language, religion, nationality (or ethnicity or race), and citizenship. In countries in which the vital registration system may be incomplete, the censuses are also used as a direct source of information about fertility and mortality; for example the censuses of the People's Republic of China gather information on births and deaths that occurred in the 18 months immediately preceding the census.

2. Indirect methods of collecting data are required in countries where full data are not available, such as is the case in much of the developing world. One of these techniques is the sister method, where survey researchers ask women how many of their sisters have died or had children and at what age. With these surveys, researchers can then indirectly estimate birth or death rates for the entire population. Other indirect methods include asking people about siblings, parents, and children.

There are a variety of demographic methods for modeling population processes. They include models of mortality (including the life table, Gompertz models, hazards models, Cox proportional hazards models, multiple decrement life tables, Brass relational logits), fertility (Hernes model, Coale-Trussell models, parity progression ratios), marriage (Singulate Mean at Marriage, Page model), disability (Sullivan's method, multistate life tables), population projections (Lee Carter, the Leslie Matrix), and population momentum (Keyfitz).

- The **crude birth rate**, the annual number of live births per 1,000 people.
- The **general fertility rate**, the annual number of live births per 1,000 women of childbearing age (often taken to be from 15 to 49 years old, but sometimes from 15 to 44).
- **age-specific fertility** rates, the annual number of live births per 1,000 women in particular age groups (usually age 15-19, 20-24 etc.)
- The **crude death rate**, the annual number of deaths per 1,000 people.
- The **infant mortality rate**, the annual number of deaths of children less than 1 year old per 1,000 live births.
- The **expectation of life** (or life expectancy), the number of years which an individual at a given age could expect to live at present mortality levels.
- The **total fertility rate**, the number of live births per woman completing her reproductive life, if her childbearing at each age reflected current age-specific fertility rates.
- The **replacement level fertility**, the average number of children a woman must have in order to replace herself with a daughter in the next generation. For example the

replacement level fertility in the US is 2.11. This means that 100 women will bear 211 children, 103 of which will be females. About 3% of the alive female infants are expected to decease before they bear children, thus producing 100 women in the next generation.

- The **gross reproduction rate**, the number of daughters who would be born to a woman completing her reproductive life at current age-specific fertility rates.
- The **net reproduction ratio** is the expected number of daughters, per newborn prospective mother, who may or may not survive to and through the ages of childbearing.
- A **stable population**, one that has had constant crude birth and death rates for such long time that the percentage of people in every age class remains constant, or equivalently, the population pyramid has an unchanging structure.
- A **stationary population**, one that is both stable and unchanging in size (the difference between crude birth rate and crude death rate is zero).

A stable population does not necessarily remain fixed in size, it can be expanding or shrinking.

Note that the crude death rate as defined above and applied to a whole population can give a misleading impression. For example, the number of deaths per 1,000 people can be higher for developed nations than in less-developed countries, despite standards of health being better in developed countries. This is because developed countries have proportionally more older people, who are more likely to die in a given year, so that the overall mortality rate can be higher even if the mortality rate at any given age is lower. A more complete picture of mortality is given by a life table which summarises mortality separately at each age. A life table is necessary to give a good estimate of life expectancy.

The fertility rates can also give a misleading impression that a population is growing faster than it in fact is, because measurement of fertility rates only involves the reproductive rate of women, and does not adjust for the sex ratio. For example, if a population has a total fertility rate of 4.0 but the sex ratio is 66/34 (twice as many men as women), this population is actually growing at a slower natural increase rate than would a population having a fertility rate of 3.0 and a sex ratio of 50/50. This distortion is greatest in India and Myanmar, and is present in China as well.

3.2 Basic equation

Suppose that a country (or other entity) contains $Population_t$ persons at time t. What is the size of the population at time $t + 1$?

$$Population_{t+1} = Population_t + Naturalincrease_t + Netmigration_t$$

Natural increase from time t to $t + 1$:

$$Naturalincrease_t = Births_t - Deaths_t$$

Net migration from time t to $t + 1$:

$$Netmigration_t = Immigration_t - Emigration_t$$

This basic equation can also be applied to subpopulations. For example, the population size of ethnic groups or nationalities within a given society or country is subject to the same sources of change. However, when dealing with ethnic groups, "net migration" might have to be subdivided into physical migration and ethnic reidentification (assimilation). Individuals who change their ethnic self-labels or whose ethnic classification in government statistics changes over time may be thought of as migrating or moving from one population subcategory to another.

More generally, while the basic demographic equation holds true by definition, in practice the recording and counting of events (births, deaths, immigration, emigration) and the enumeration of the total population size are subject to error. So allowance needs to be made for error in the underlying statistics when any accounting of population size or change is made.

3.3 History

Demographic thoughts can be traced back to antiquity, and are present in many civilisations and cultures, like Ancient Greece, Rome, India and China. In ancient Greece, this can be found in the writings of Herodotus, Thucidides, Hippocrates, Epicurus, Protagoras, Polus, Plato and Aristotle. In Rome, writers and philosophers like Cicero, Seneca , Marcus Aurelius, Epictetus, Cato and Collumella also expressed important ideas on this ground.

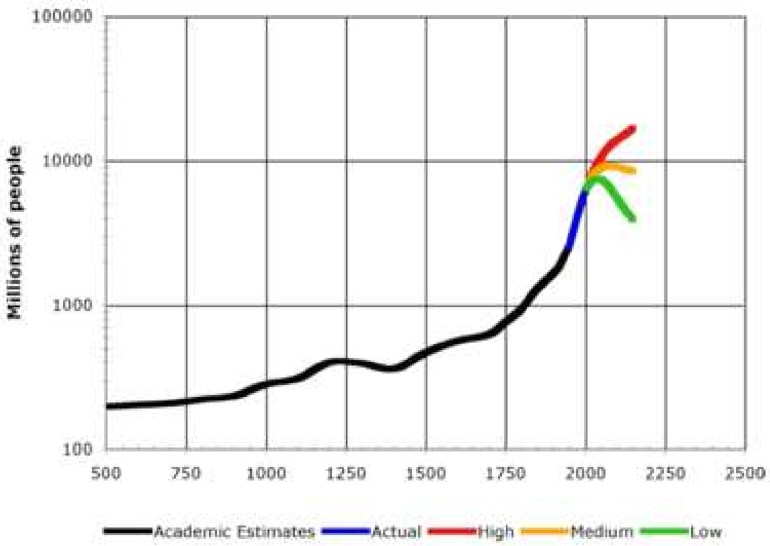
In the Middle ages, Christian thinkers devoted much time in refuting the Classical ideas on demography. Important contributors to the field were William of Conches, Bartholomew of Lucca, William of Auvergne, William of Pagula,[6] and Ibn Khaldun.

The *Natural and Political Observations ... upon the Bills of Mortality* (1662) of John Graunt contains a primitive form of life table. Mathematicians, such as Edmond Halley, developed the life table as the basis for life insurance mathematics. Richard Price was credited with the first textbook on life contingencies published in 1771, followed later by Augustus de Morgan, ‘On the Application of Probabilities to Life Contingencies’ (1838).

At the end of the 18th century, Thomas Malthus concluded that, if unchecked, populations would be subject to exponential growth. He feared that population growth would tend to outstrip growth in food production, leading to ever-increasing famine and poverty (see Malthusian catastrophe). He is seen as the intellectual father of ideas of overpopulation and the limits to growth.

The period 1860-1910 can be characterized as a period of transition wherein demography emerged from statistics as a separate field of interest. This period included a panoply of international ‘great demographers’ like Adolphe Quételet (1796–1874), William Farr (1807–1883), Louis-Adolphe Bertillon (1821–1883) and his son Jacques (1851–1922), Joseph Körösi (1844–1906), Anders Nicolas Kaier (1838–1919), Richard Böckh (1824–1907), Wilhelm Lexis (1837–1914) and Luigi Bodio (1840–1920) contributed to the development of demography and to the toolkit of methods and techniques of demographic analysis.

3.4 Transition



World population from 500CE to 2150 based on UN 2004 projections (red, orange, green) and US Census Bureau historical estimates (black). Only the section in blue is from reliable counts, not estimates or projections.

Contrary to Malthus' predictions and in line with his thoughts on moral restraint, natural population growth in most developed countries has diminished to close to zero, without being held in check by famine or lack of resources, as people in developed nations have shown a tendency to have fewer children. The fall in population growth has occurred despite large rises in life expectancy in these countries. This pattern of population growth, with slow (or no) growth in pre-industrial societies, followed by fast growth as the society develops and industrializes, followed by slow growth again as it becomes more affluent, is known as the demographic transition.

Similar trends are now becoming visible in ever more developing countries, so that far from spiraling out of control, world population growth is expected to slow markedly in this century, coming to an eventual standstill or even declining. The change is likely to be accompanied by major shifts in the proportion of world population in particular regions. The United Nations Population Division expects the absolute number of infants and toddlers in the world to begin to fall by 2015, and the number of children under 15 by 2025.

The figure in this section shows the latest (2004) UN projections of world population out to the year 2150 (red = high, orange = medium, green = low). The UN "medium" projection shows world population reaching an approximate equilibrium at 9 billion by 2075. Working independently, demographers at the International Institute for Applied Systems Analysis in Austria expect world population to peak at 9 billion by 2070. Throughout the 21st century, the average age of the population is likely to continue to rise.

3.4.1 Science of population

Populations can change through three processes: fertility, mortality, and migration.

I. Fertility involves the number of children that women have and is to be contrasted with fecundity (a woman's childbearing potential).
II. Mortality is the study of the causes, consequences, and measurement of processes affecting death to members of the population. Demographers most commonly study mortality using the Life Table, a statistical device which provides information about the mortality conditions (most notably the life expectancy) in the population.
III. Migration refers to the movement of persons from an origin place to a destination place across some pre-defined, political boundary. Migration researchers do not designate movements 'migrations' unless they are somewhat permanent. Thus demographers do not consider tourists and travelers to be migrating. While demographers who study migration typically do so through census data on place of residence, indirect sources of data including tax forms and labor force surveys are also important.

Demography is today widely taught in many universities across the world, attracting students with initial training in social sciences, statistics or health studies. Being at the crossroads of several disciplines such as sociology, economics, epidemiology, geography, anthropology and history, demography offers tools to approach a large range of population issues by combining a more technical quantitative approach that represents the core of the discipline with many other methods borrowed from social or other sciences. Demographic research is conducted in universities, in research institutes as well as in statistical departments and in several international agencies. Population institutions are part of the Cicred (International Committee for Coordination of Demographic Research) network while most individual scientists engaged in demographic research are members of the International Union for the Scientific Study of Population or, in the United States, the Population Association of America.

4.0 Conclusion

Demography is today widely taught in many universities across the world, attracting students with initial training in social sciences, statistics or health studies. Being at the crossroads of several disciplines such as sociology, economics, epidemiology, geography, anthropology and history, demography offers tools to approach a large range of population issues by combining a more technical quantitative approach that represents the core of the discipline with many other methods borrowed from social or other sciences.

5.0 Summary

Demographic research is conducted in universities, in research institutes as well as in statistical departments and in several international agencies. Population institutions are part of the Cicred (International Committee for Coordination of Demographic Research) network while most individual scientists engaged in demographic research are members of the International Union for the Scientific Study of Population or, in the United States, the Population Association of

America. A stable population does not necessarily remain fixed in size, it can be expanding or shrinking.

6.0 Tutor-Marked Assignment

1) Explain the term demography?
2) Explain the term direct and indirect demographic
3) List and explain eight methods used in demographics.
4) List and discuss three ways by which population can be changed.

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MODULE 5: BEHAVIORAL ECOLOGY OF AFRICAN MAMMALS

Unit 1 Behavioral ecology

Content

1.0 Introduction

Behavioral ecology, or **ethoecology**, is the study of the ecological and evolutionary basis for animal behavior, and the roles of behavior in enabling an animal to adapt to its environment (both intrinsic and extrinsic). Behavioral ecology emerged from ethology after Niko Tinbergen (a seminal figure in the study of animal behavior) outlined the four causes of behavior.

If an organism has a trait which provides them with a selective advantage (i.e. has an adaptive significance) in a new environment natural selection will likely favor it. Adaptive significance therefore refers to the beneficial qualities, in terms of increased survival and reproduction, a trait conveys.

For example, the behavior of flight has evolved numerous times in reptiles (Pterosaur), birds, many insects and mammals (bats) due to its adaptive significance—for many species, flight has the potential to increase an animal's ability to escape from predators and move swiftly between habitat areas, among other things, thereby increasing the organism's chances of survival and reproduction. In all instances, the organism adapting to flight had to have "pre-adaptions" to these behavioral and anatomical changes. Feathers in birds initially evolving for thermoregulation then turned to flight due to the benefits conveyed (see Origin of avian flight); insect wings evolving from enlarged gill plates used to efficiently "sail" across the water, becoming larger until capable of flight are two good examples of this. At every stage slight improvements mean higher energy acquisition, lower energy expenditure or increased mating opportunities causing the genes that convey these traits to increase within the population. If these organisms did not have the required variation for natural selection to act upon either due to phylogenetic or genetic constraints, these behaviors would not be able to evolve.

However, it is not sufficient to apply these explanations where they seem convenient. Viewing traits and creating unsubstantiated theories or "Just So Stories" as to their adaptive nature have been deeply criticized. Stephen Jay Gould and Richard Lewontin (1979) described this as the "adaptationist programme". To be rigorous, hypotheses regarding adaptations must be theoretically or experimentally tested as with any scientific theory.

The hypothesis of the evolution of insect flight for example has been tested through wing manipulation experiments. Empirical observations which adhere to the conditions prosed also provide evidence. For instance, one can suppose that when birds are not at risk of being eaten they might lose the ability to fly as the construction of functional wings are costly to produce and take away energy which could be used to increase offspring production or survival, a trend many island flightless birds such as the Kakapo, the Penguin and the now extinct Dodo demonstrate in the absence of natural predators.

2.0 Objectives

At the end of this unit, students should be able to :

1. *Understand behavior ecology.*
2. *Explain ontogenetic and mechanism under Proximate causation.*

3. *State Tinbergen's Four Questions and explain each one of them with their importance.*
4. *Explain optimization theory*
5. *Explain Evolutionarily stable strategies (ESS)*

3.0 Main Content

3.1 Proximate causation

Proximate causation is divided into two factors which are ontogenetic and mechanistic. Ontogenetic factors are the entire sum of experience throughout the lifetime of an individual from embryo to death. Hence, factors included are learning the genetic factors giving rise to behavior in individuals. Mechanistic factors, as the name implies, are the processes of the body that give rise to behavior such as the effects of hormones on behavior and neuronal basis of behavior.

3.2 Optimization theory

Behavioral ecology, along with other areas of evolutionary biology, has incorporated a number of techniques which have been borrowed from optimization theory. Optimization is a concept that stipulates strategies that offer the highest return to an animal given all the different factors and constraints facing the animal. One of the simplest ways to arrive at an optimal solution is to do a cost/benefit analysis. By considering the advantages of a behavior and the costs of a behavior, it can be seen that if the costs outweigh the benefits then a behavior will not evolve and vice versa. This is also where the concept of the trade-off becomes important. This is because it rarely pays an animal to invest maximally in any one behavior. For example, the amount of time an ectothermic animal such as a lizard spends foraging is constrained by its body temperature. The digestive efficiency of the lizard also increases with increases in body temperature. Lizards increase their body temperature by basking in the sun. However, the time spent basking decreases the amount of time available for foraging. Basking also increases the risk of being discovered by a predator. Therefore, the optimal basking time is the outcome of the time necessary to sufficiently warm itself to carry out its activities such as foraging. This example shows how foraging is constrained by the need to bask (intrinsic constraint) and predation pressure (extrinsic constraint).

A often quoted behavioural ecology hypothesis is known as Lack's brood reduction hypothesis (named after David Lack). Lack's hypothesis posits an evolutionary and ecological explanation as to why birds lay a series of eggs with an asynchronous delay leading to nestlings of mixed age and weights. According to Lack, this brood behaviour is an ecological insurance that allows the larger birds to survive in poor years and all birds to survive when food is plentiful.

3.3 Differential reproductive success

Ultimately, behavior is subject to natural selection just as with any other trait. Therefore animals that employ optimal behavioral strategies specific to their environment will generally leave greater numbers of offspring than their suboptimal conspecifics. Animals that leave a greater number of offspring than others of their own species are said to have greater fitness. However, environments change over time. What might be good behavior today might not be the best behavior in 10,000 years time or even 10 years time. The behavior of animals has and will continue to change in response to the environment. Behavioral ecology is one of the best ways to study these changes. As geneticist Theodosius Dobzhansky famously wrote, "nothing in biology makes sense except in the light of evolution."

3.4 Evolutionarily stable strategies (ESS)

The value of a social behavior depends in part on the social behavior of an animal's neighbors. For example, the more likely a rival male is to back down from a threat, the more value a male gets out of making the threat. The more likely, however, that a rival will attack if threatened, the less useful it is to threaten other males. When a population exhibits a number of interacting social behaviors such as this, it can evolve a stable pattern of behaviors known as an evolutionarily stable strategy (or ESS). This term, derived from economic game theory, became prominent after John Maynard Smith(1982), recognized the possible application of the concept of a Nash equilibrium to model the evolution of behavioral strategies.

In short, evolutionary game theory asserts that only strategies that, when common in the population, cannot be "invaded" by any alternative (mutant) strategy will be an ESSs, and thus maintained in the population. In other words, at equilibrium every player should play the best strategic response to each other. When the game is two player and symmetric each player should play the strategy which is the best response to itself.

Therefore, the ESS is considered to be the evolutionary end point subsequent to the interactions. As the fitness conveyed by a strategy is influenced by what other individuals are doing (the relative frequency of each strategy in the population), behavior can be governed not only by optimality but the frequencies of strategies adopted by others and are therefore frequency dependent (frequency dependence).Behavioral evolution is therefore influenced by both the physical environment and interactions between other individuals.

3.5 Tinbergen's Four Questions

- Most behavioral ecologists focus on answering one of the following questions in their studies. They want to know either what is the cause of the behavior; how did the behavior develop within the individual's lifetime; what function, or functions, does the behavior serve; or how did the behavior evolve? These questions are known as Tinbergen's Four Questions and are named after the behaviorist Niko Tinbergen who developed them.

3.5.1 Explanation

- Question number one deals with both environmental and internal factors that may cause behaviors, such as hormones or infringing on another animal's territory. The answers to question number two may include both genetics and the animal's past experiences, similar to the "nature versus nurture" problem in psychology. Question number three asks how the behaviors will impact the animal immediately and its ability to adapt, such as asking what will happen if an animal's territory is taken by another. Question number four concentrates on how the behaviors originated and how they have changed or will change, such as a horse's flight instinct being exacerbated by modern horse-keeping practices.

3.5.2 Importance

- There are several reasons to study behavioral ecology. Behavioral ecology can be used as a way to interpret human social problems (several ground-breaking psychological studies were based on observing animal behavior), applied to the study of neurobiology (neuroethology combines animal behavior and neuroscience) , find solutions to environmental issues (animal behavior is indicative of health of the environment), help with animal welfare (behavioral observation is necessary for deciding how to protect endangered species), and bring in new interest in biological sciences (many students find animal behavior more interesting than other science disciplines). There is also a lot of interest in animal behavior from the public. Consider all of the recent documentaries and books that have come out, and the popularity of safari trips.

3.5.3 A Behavioral Ecologist

- Dr. Jennifer Borgo, a visiting assistant professor at Coker College in Hartsville, SC, is a wildlife behavioral ecologist who has studied flying squirrels, ducks, woodpeckers, and grouse. She studies ultimate behaviors as opposed to proximate behaviors. Proximate behaviors refer to question one of Tinbergen's Four Questions, and ultimate behaviors refer to question three. Dr. Borgo focuses on interspecific interaction, which she describes as the interactions between members of different species (such as one animal hunting another).

4.0 Conclusion

Students must have learnt the following: The meaning of behavior ecology, ontogenetic and mechanism under Proximate causation, Tinbergen's Four Questions , optimization theory and evolutionarily stable strategies

5.0 Summary

Behavioral ecology emerged from ethology after Niko Tinbergen (a seminal figure in the study of animal behavior) outlined the four causes of behavior.

7 *Tutor-Marked Assignments*

1 Explain behavior ecology.
2 Explain ontogenetic and mechanism under Proximate causation.
3 State Tinbergen's Four Questions and explain each one of them.
4 4 Explain optimization theory
5 Evolutionarily stable strategies

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Unit 2 Bat as a case study of an African Mammal

Content

1.0 Introduction

Bats are flying mammals in the order **Chiroptera** (pronounced /kaɪ□rɒptərə/). The forelimbs of bats are webbed and developed as wings, making them the only mammals naturally capable of true and sustained flight. By contrast, other mammals said to fly, such as flying squirrels, gliding possums and colugos, glide rather than fly, and can only glide for short distances. Bats do not flap their entire forelimbs, as birds do, but instead flap their spread out digits, which are very long and covered with a thin membrane or patagium. *Chiroptera* comes from two Greek words, *cheir* (χείρ) "hand" and *pteron* (πτερόν) "wing."

There are about 1,100 bat species worldwide, which represent about twenty percent of all classified mammal species. About seventy percent of bats are insectivores. Most of the rest are frugivores, or fruit eaters. A few species such as the Fish-eating Bat feed from animals other than insects, with the vampire bats being the only mammalian parasite species. Bats are present throughout most of the world and perform vital ecological roles such as pollinating flowers and dispersing fruit seeds. Many tropical plant species depend entirely on bats for the distribution of their seeds.

The smallest bat is the Kitti's Hog-nosed Bat, measuring 29–34 mm (1.14–1.34 in) in length, 15 cm (5.91 in) across the wings and 2–2.6 g (0.07–0.09 oz) in mass, The largest species of bat is the Giant Golden-crowned Flying-fox, which is 336–343 mm (13.23–13.50 in) long, has a wingspan of 1.5 m (4 ft 11 in) and weighs approximately 1.1–1.2 kg (2–3 lb).

2.0 OBJECTIVES

At the end of unit, students should be able to:

explain why bat is classified as a mammal, classification and evolution of bat , behavior of bat under feeding hunting ,reproduction, habitat selection etc.

3.0 MAIN CONTENT

3.1 Classification and evolution

Giant Golden-crowned Flying-fox, *Acerodon jubatus*.

Bats are mammals. Sometimes they are mistakenly called "flying rodents" or "flying rats", and they can also be mistaken for insects and birds. There are two traditionally recognized suborders of bats:

- Megachiroptera (megabats)
- Microchiroptera (microbats/echolocating bats)

Not all megabats are larger than microbats. The major distinctions between the two suborders are:

- Microbats use echolocation: megabats do not with the exception of *Rousettus* and relatives.
- Microbats lack the claw at the second toe of the forelimb.
- The ears of microbats do not close to form a ring: the edges are separated from each other at the base of the ear.
- Microbats lack underfur: they are either naked or have guard hairs.

Megabats eat fruit, nectar or pollen while most microbats eat insects; others may feed on the blood of animals, small mammals, fish, frogs, fruit, pollen or nectar. Megabats have a well-developed visual cortex and show good visual acuity, while microbats rely on echolocation for navigation and finding prey.

The phylogenetic relationships of the different groups of bats have been the subject of much debate. The traditional subdivision between Megachiroptera and Microchiroptera reflects the view that these groups of bats have evolved independently of each other for a long time, from a common ancestor that was already capable of flight. This hypothesis recognized differences between microbats and megabats and acknowledged that flight has only evolved once in mammals. Most molecular biological evidence supports the view that bats form a single or monophyletic group.

Researchers have proposed alternate views of chiropteran phylogeny and classification, but more research is needed.

Genetic evidence indicates that megabats originated during the early Eocene and should be placed within the four major lines of microbats.

Consequently, two new suborders based on molecular data have been proposed. The new suborder Yinpterochiroptera includes the Pteropodidae or megabat family as well as the Rhinolophidae, Hipposideridae, Craseonycteridae, Megadermatidae, and Rhinopomatidae families. The new suborder Yangochiroptera includes all the remaining families of bats (all of which use laryngeal echolocation). These two new suborders are strongly supported by statistical tests. Teeling (2005) found 100% bootstrap support in all maximum likelihood analyses for the division of Chiroptera into these two modified suborders. This conclusion is further supported by a fifteen-base pair deletion in BRCA1 and a seven-base pair deletion in PLCB4 present in all Yangochiroptera and absent in all Yinpterochiroptera. The Chiropteran phylogeny based on molecular evidence is controversial because microbat paraphyly implies that one of two seemingly unlikely hypotheses occurred. The first suggests that laryngeal echolocation evolved twice in Chiroptera, once in Yangochiroptera and once in the rhinolophoids. The second proposes that laryngeal echolocation had a single origin in Chiroptera, was subsequently lost in the family Pteropodidae (all megabats), and later evolved as a system of tongue-clicking in the genus *Rousettus*.

Common Pipistrelle, *Pipistrellus pipistrellus*.

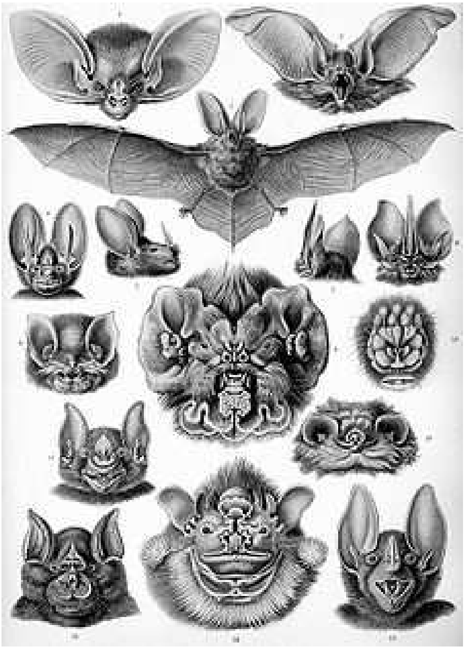
Analyses of the sequence of the "vocalization" gene, *FoxP2* was inconclusive of whether laryngeal echolocation was secondarily lost in the pteropodids or independently gained in the echolocating lineages. However, analyses of the "hearing" gene, *Prestin* seemed to favor the independent gain in echolocating species rather than a secondary loss in the pteropodids.

In addition to Yinpterochiroptera and Yangochiroptera, the names Pteropodiformes and Vespertilioniformes have also been proposed for these suborders. Under this new proposed nomenclature, the suborder Pteropodiformes includes all extant bat families more closely related to the genus *Pteropus* than the genus *Vespertilio*, while the suborder Vespertilioniformes includes all extant bat families more closely related to the genus *Vespertilio* than to the genus *Pteropus*.

In the 1980s, a hypothesis based on morphological evidence was offered that stated that the Megachiroptera evolved flight separately from the Microchiroptera. The so-called flying primates theory proposed that when adaptations to flight are removed, the Megachiroptera are allied to primates by anatomical features that are not shared with Microchiroptera. One example is that the brains of megabats show a number of advanced characteristics that link them to primates. Although recent genetic studies support the monophyly of bats, debate continues as to the meaning of available genetic and morphological evidence.

Little fossil evidence is available to help map the evolution of bats, since their small, delicate skeletons do not fossilize very well. However a Late Cretaceous tooth from South America resembles that of an early Microchiropteran bat. The oldest known definitely identified bat fossils, such as *Icaronycteris*, *Archaeonycteris*, *Palaeochiropteryx* and *Hassianycteris*, are from the early Eocene period, 52.5 million years ago. These fossil bats were already very similar to modern microbats. *Archaeopteropus*, formerly classified as the earliest known megachiropteran, is now classified as a microchiropteran.

Bats were formerly grouped in the superorder Archonta along with the treeshrews (Scandentia), colugos (Dermoptera), and the primates, because of the apparent similarities between Megachiroptera and such mammals. Genetic studies have now placed bats in the superorder Laurasiatheria along with carnivorans, pangolins, odd-toed ungulates, even-toed ungulates, and cetaceans.



"Chiroptera" from Ernst Haeckel's *Kunstformen der Natur*, 1904

The traditional classification of bats is:

- Order Chiroptera
    - Suborder Megachiroptera (megabats)
        - Pteropodidae
    - Suborder Microchiroptera (microbats)
        - Superfamily Emballonuroidea
            - Emballonuridae (Sac-winged or Sheath-tailed bats)
        - Superfamily Molossoidea
            - Antrozoidae (Pallid Bat and Van Gelder's Bat)
            - Molossidae (Free-tailed bats)
        - Superfamily Nataloidea
            - Furipteridae (Smoky bats)
            - Myzopodidae (Sucker-footed bats)
            - Natalidae (Funnel-eared bats)
            - Thyropteridae (Disk-winged bats)
        - Superfamily Noctilionoidea
            - Mormoopidae (Ghost-faced or Moustached bats)
            - Mystacinidae (New Zealand short-tailed bats)

        - Noctilionidae (Bulldog bats or Fisherman bats)
        - Phyllostomidae (Leaf-nosed bats)
    - Superfamily Rhinolophoidea
        - Megadermatidae (False vampires)
        - Nycteridae (Hollow-faced or Slit-faced bats)
        - Rhinolophidae (Horseshoe bats)
    - Superfamily Rhinopomatoidea
        - Craseonycteridae (Bumblebee Bat or Kitti's Hog-nosed Bat)
        - Rhinopomatidae (Mouse-tailed bats)
    - Superfamily Vespertilionoidea
        - Vespertilionidae (Vesper bats or Evening bats)

Megabats primarily eat fruit or nectar. In New Guinea, they are likely to have evolved for some time in the absence of microbats. This has resulted in some smaller megabats of the genus *Nyctimene* becoming (partly) insectivorous to fill the vacant microbat ecological niche. Furthermore, there is some evidence that the fruit bat genus *Pteralopex* from the Solomon Islands, and its close relative *Mirimiri* from Fiji, have evolved to fill some niches that were open because there are no nonvolant or non-flying mammals in those islands.

3.1.1Fossil bats

There are few fossilized remains of bats, as they are terrestrial and light-boned. An Eocene bat, *Onychonycteris finneyi*, was found in the fifty-two-million-year-old Green River Formation in South Dakota, United States, in 2004. It had characteristics indicating that it could fly, yet the well-preserved skeleton showed that the cochlea of the inner ear lacked development needed to support the greater hearing abilities of modern bats. This provided evidence that flight in bats developed well before echolocation. The team that found the remains of this species, named *Onychonycteris finneyi*, recognized that it lacked ear and throat features present not only in echolocating bats today, but also in other known prehistoric species. Fossil remains of another Eocene bat, *Icaronycteris*, were found in 1960.

The appearance and flight movement of bats 52.5 million years ago were different from those of bats today. *Onychonycteris* had claws on all five of its fingers, whereas modern bats have at most two claws appearing on two digits of each hand. It also had longer hind legs and shorter forearms, similar to climbing mammals that hang under branches such as sloths and gibbons. This palm-sized bat had broad, short wings suggesting that it could not fly as fast or as far as later bat species. Instead of flapping its wings continuously while flying, *Onychonycteris* likely alternated between flaps and glides while in the air. Such physical characteristics suggest that this bat did not fly as much as modern bats do, rather flying from tree to tree and spending most of its waking day climbing or hanging on the branches of trees.

3.2 Habitats

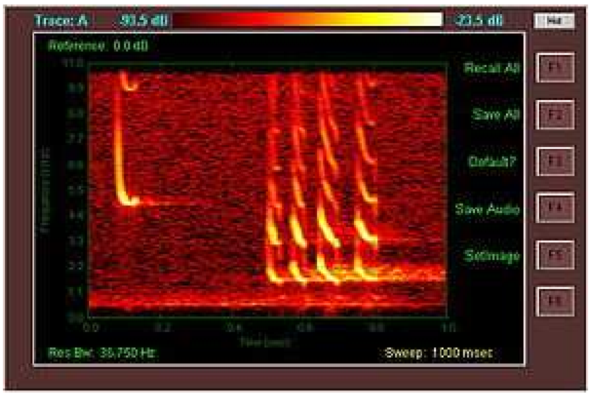
Flight has enabled bats to become one of the most widely distributed groups of mammals. Apart from the Arctic, the Antarctic and a few isolated oceanic islands, bats exists all over the world. Bats are found in almost every habitat available on Earth. Different species select different habitat during different seasons — ranging from seasides to mountains and even deserts — but bat habitats have two basic requirements: roosts, where they spend the day or hibernate, and places for foraging. Bat roosts can be found in hollows, crevices, foliage, and even human-made structures; and include "tents" that bats construct by biting leaves.

3.3 Anatomy

Skeleton of a Greater Mouse-eared Bat (*Myotis myotis*).

Scapulae, spine and ribs of *Myotis lucifugus* (Little Brown Bat).

3.3.1 Echolocation



Spectrogram of Pipistrellus Bat vocalizations. Detail is shown as the pulse duty cycle increases during a close approach to prey. The bat appears to use a hybrid pulse which combines a sharp falling frequency chirp with an extended constant frequency tail. Such a waveform may offer combined benefits of range estimation as well as Doppler shift detection. Spectrogram generated with Fatpigdog's PC based Real Time FFT Spectrum Analyzer.

Bat echolocation is a perceptual system where ultrasonic sounds are emitted specifically to produce echoes. By comparing the outgoing pulse with the returning echoes the brain and auditory nervous system can produce detailed images of the bat's surroundings. This allows bats to detect, localize and even classify their prey in complete darkness. At 130 decibels in intensity, bat calls are some of the most intense airborne animal sounds.

To clearly distinguish returning information, bats must be able to separate their calls from the echoes they receive. Microbats use two distinct approaches.

1. Low Duty Cycle Echolocation: Bats can separate their calls and returning echos by time. Bats that use this approach time their short calls to finish before echoes return. This is important because these bats contract their middle ear muscles when emitting a call so that they can avoid deafening themselves. The time interval between call and echo allows them to relax these muscles so they can clearly hear the returning echo. The delay of the returning echos provide the bat with the ability to estimate range to their prey.
2. High Duty Cycle Echolocation: Bats emit a continuous call and separate pulse and echo in frequency. The ears of these bats are sharply tuned to a specific frequency range. They emit calls outside of this range to avoid self-deafening. They then receive echoes back at the finely tuned frequency range by taking advantage of the Doppler shift of their motion in flight. The Doppler shift of the returning echos yield information relating to the motion and location of the bat's prey. These bats must deal with changes in the Doppler shift due to changes in their flight speed. They have adapted to change their pulse emission frequency in relation to their flight speed so echoes still return in the optimal hearing range.

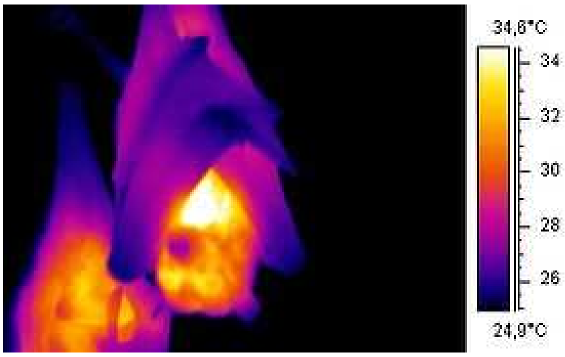
The new Yinpterochiroptera and Yangochiroptera classification of bats that are supported by molecular evidence, suggest two possibilities for the evolution of echolocation. It may have been gained once in a common ancestor of all bats and was then subsequently lost in the Old World fruit bats, only to be regained in the Horse-Shoe bats; or echolocation was evolved independent in both the Yinpterochiroptera and Yangochirpotera lineages.

Two groups of moths exploit a bat sense to echolocate: tiger moths produce ultrasonic signals to warn the bats that they (the moths) are chemically protected or aposematic. This was once thought to be the biological equivalent of "radar jamming", but this theory has yet to be confirmed. The moths Noctuidae have a hearing organ called a tympanum, which responds to an incoming bat signal by causing the moth's flight muscles to twitch erratically, sending the moth into random evasive manoeuvres.

Other senses

Although the eyes of most microbat species are small and poorly developed, leading to poor visual acuity, none of them are blind. Vision is used to navigate microbats especially for long distances when beyond the range of echolocation. It has even been discovered that some species are able to detect ultraviolet light. They also have a high quality sense of smell and hearing. Bats hunt at night to avoid competition with birds, and travel large distances at most 800 km, in their search for food.

Wings



Thermographic image of a bat using trapped air as insulation.

The finger bones of bats are much more flexible than those of other mammals. One reason is that the cartilage in their fingers lacks calcium and other minerals nearer the tips, increasing their ability to bend without splintering. The cross-section of the finger bone is also flattened compared to the circular cross section that human finger bones have, and is very flexible. The skin on their wing membranes has more elasticity and so can stretch much more than other mammals.

The wings of bats are much thinner than those of birds, so bats can maneuver more quickly and more accurately than birds. It is also delicate, ripping easily. However the tissue of the bat's membrane is able to regrow, such that small tears can heal quickly. The surface of their wings is equipped with touch-sensitive receptors on small bumps called Merkel cells, found in most mammals including humans, similarly found on our finger tips. These sensitive areas are different in bats as each bump has a tiny hair in the center, making it even more sensitive and allowing the bat to detect and collect information about the air flowing over its wings, thereby providing feedback to the bat to change its shape of its wing to fly more efficiently. An additional kind of receptor cell is found in the wing membrane of species that use their wings to catch prey. This receptor cell is sensitive to the stretching of the membrane. The cells are concentrated in areas of the membrane where insects hit the wings when the bats capture them.

Others

The teeth of microbats resemble insectivorans. They are very sharp to bite through the hardened armor of insects or the skin of fruit.

Mammals have one-way valves in veins to prevent the blood from flowing backwards, but bats also have one-way valves in arteries.

One species of bat has the longest tongue of any mammal relative to its body size. This is beneficial to them in terms of pollination and feeding. Their long narrow tongues can reach deep into the long cup shape of some flowers. When their tongue retracts, it coils up inside their rib cage.

4.0 Behaviour

Most microbats are nocturnal and are active at twilight. A large portion of bats migrate hundreds of kilometres to winter hibernation dens, some pass into torpor in cold weather, rousing and feeding when warm weather allows for insects to be active. Others retreat to caves for winter and hibernate for six months. Bats rarely fly in rain as the rain interferes with their echo location, and they are unable to locate their food.

The social structure of bats varies, with some bats leading a solitary life and others living in caves colonized by more than a million bats. The fission-fusion social structure is seen among several species of bats. The term "fusion" refers to a large numbers of bats that congregate together in one roosting area and "fission" refers to breaking up and the mixing of subgroups, with individual bats switching roosts with others and often ending up in different trees and with different roostmates.

Studies also show that bats make all kinds of sounds to communicate with others. Scientists in the field have listened to bats and have been able to identify some sounds with some behaviour bats will make after the sounds are made.

70% of bat species are insectivorous, locating their prey by means of echolocation. Of the remainder, most feed on fruits. Only three species sustain themselves with blood. Some species even prey on vertebrates: these are the leaf-nosed bats (*Phyllostomidae*) of Central America and South America, and the two bulldog bat (*Noctilionidae*) species, which feed on fish. At least two species of bat are known to feed on bats: the Spectral Bat, also known as the American False Vampire bat, and the Ghost Bat of Australia. One species, the Greater Noctule bat, catches and eats small birds in the air.

Predators of bats include bat hawks and bat falcons.

Reproduction

Newborn Common Pipistrelle, *Pipistrellus pipistrellus*.

Colony of Mouse-eared bats, *Myotis myotis*.

Most bats have a breeding season, which is in the spring for species living in a temperate climate. Bats may have one to three litters in a season, depending on the species and on environmental conditions such as the availability of food and roost sites. Females generally have one offspring at a time, which could be a result of the mother's need to fly to feed while pregnant. Female bats nurse their youngsters until they are nearly adult size; this is because a young bat cannot forage on its own until its wings are fully developed.

Female bats use a variety of strategies to control the timing of pregnancy and the birth of young, to make delivery coincide with maximum food ability and other ecological factors. Females of some species have delayed fertilization, in which sperm are stored in the reproductive tract for several months after mating. In many such cases, mating occurs in the fall, and fertilization does not occur until the following spring. Other species exhibit delayed implantation, in which the egg is fertilized after mating, but remains free in the reproductive tract until external conditions become favorable for giving birth and caring for the offspring. In yet another strategy, fertilization and implantation both occur but development of the fetus is delayed until favorable conditions prevail. All of these adaptations result in the pup being born during a time of high local production of fruit or insects.

At birth the wings are too small to be used for flight. Young microbats become independent at the age of 6 to 8 weeks, while megabats do not until they are four months old.

A single bat can live over 20 years, but the bat population growth is limited by the slow birth rate.

4.2 Hunting, feeding, and drinking

A very young bat in Tamil Nadu.

Newborn bats rely on the milk from their mother's nipples for sustenance. When they are a few weeks old, bats are expected to fly and hunt on their own. It is up to them to find and catch their prey, along with satisfying their thirst.

4.2.1 Hunting

Most bats are nocturnal creatures. Their daylight hours are spent grooming, sleeping, and resting; it is during the nighttime hours that they hunt. The means by which bats navigate while finding and catching their prey in the dark was unknown until the 1790s, when Lazzaro Spallanzani conducted a series of experiments on a group of blind bats. These bats were placed in a room submerged in total darkness, with silk threads strung across the room. Even then, the bats were able to navigate their way through the room. Spallanzani concluded that the bats were not using their eyes to fly through complete darkness, but something else.

Spallanzani decided that bats were able to catch and find their prey through the use of their ears. To prove this theory, Spallanzani plugged the ears of the bats in his experiment. To his pleasure, he found that the bats with plugged ears were not able to fly with the same amount of skill and precision that they were able to without their ears plugged.

Bats seem to use their ears to locate and catch their prey, but how they accomplish this wasn't discovered until the 1930s, by one Donald R. Griffin. Griffin, who was a biology student at Harvard College at the time, discovered that bats use echolocation to locate and catch their prey. When bats fly, they produce a constant stream of high-pitched sounds that only bats are able to hear. When the sound waves produced by these sounds hit an insect or other animal, the echoes bounce back to the bat, and guide them to the source.

4.2.2 Feeding and diet

The majority of food consumed by bats includes insects, fruits and flower nectar, vertebrates and blood. Almost three-fourths of the world's bats are insect eaters. Insects consumed by bats include both aerial insects, and ground-dwelling insects. Each bat is typically able to consume one third of its body weight in insects each night, and several hundred insects in a few hours. This means that a group of one thousand bats could eat four tons of insects each year. If bats were to become extinct, the insect population is calculated to reach an alarmingly high number.

4.2.2.1 Vitamin C

In a test of 34 bat species from six major families of bats, including major insect and fruit-eating bat families, found that bats in all tested families have lost the ability to make vitamin C, and this loss may derive from a common bat ancestor, as a single mutation.

4.2.2.2 Aerial insectivores

Watching a bat catch and eat an insect is difficult. The action is so fast that all one sees is a bat rapidly change directions, and continue on its way. Scientist Frederick A. Webster discovered how bats catch their prey. In 1960, Webster developed a high-speed camera that was able to take one thousand pictures per second. These photos revealed the fast and precise way in which bats catch insects. Occasionally, a bat will catch an insect in mid-air with its mouth, and eat it in the air. However, more often than not, a bat will use its tail membrane or wings to scoop up the insect and trap it in a sort of “bug net”. Then, the bat will take the insect back to its roost. There, the bat will proceed to eat said insect, often using its tail membrane as a kind of napkin, to prevent its meal from falling to the ground.

4.2.2.3 Forage gleaners (diet of non-flying insects)

These bats typically fly down and grasp their prey off the ground with their teeth, and take it to a nearby perch to eat it. Generally, these bats don’t use echolocation to locate their prey. Instead, they rely on the sounds produced by the insects. Some make unique sounds, and almost all make some noise while moving through the environment.

4.2.2.4 Fruits and flower nectar

A colony of Great Fruit-eating Bats

Fruit-eating, or frugivory, is a specific habit found in two families of bats. Megachiropterans and microchiropterans both include species of bat that feed on fruits. These bats feed on the juices of sweet fruits, and fulfill the needs of some seeds to be dispersed. The fruits preferred by most fruit-eating bats are fleshy and sweet, but not particularly strong smelling or colorful. To get the juice of these fruits, bats pull the fruit off the trees with their teeth, and fly back to their roost with the fruit in their mouth. There, the bat will consume the fruit in a specific way. To do this, the bats crush open the fruit and eat the parts that satisfy their hunger. The remainder of the fruit; the seeds and pulp, are spat onto the ground. These seeds take root and begin to grow into new fruit trees. “Over one hundred and fifty types of plants depend on bats in order to reproduce”.

Some bats prefer the nectar of flowers to insects or other animals. These bats have evolved specifically for this purpose. For example, these bats possess long muzzles and long extrusible tongues covered in fine bristles that aid them in feeding on particular flowers and plants. When they sip the nectar from these flowers, pollen gets stuck to their fur, and is dusted off when the bat takes flight, thus pollinating the plants below them. The rainforest is said to be the most benefitted out off all the biomes that bats live in, because of the large variety of appealing plants. Because of their specific eating habits, nectar-feeding bats are more prone to extinction than any other type of bat. However, according to a study, bats benefit from eating fruits and nectar just as much from eating insects.

4.2.2.5 Vertebrates

Although most bats are not included in this group, there is a small group of carnivorous bats which feed on other vertebrates and are considered the top carnivores of the bat world. These bats typically eat a variety of animals, but normally consume frogs, lizards, birds, and sometimes other bats. For example, one vertebrate predator, *Trachops cirrhosus*, is particularly skilled at catching frogs. These bats locate large groups of frogs by distinguishing their mating calls from other sounds around them. They follow the sounds to the source and pluck them from the surface of the water with their sharp canine teeth. Another example is the Greater Noctule bat which is believed to catch birds on the wing.

There are also several species of bat that feed on fish. These types of bats are found on almost all continents. They use echolocation to detect tiny ripples in the water’s surface to locate fish. From there, the bats swoop down low, inches from the water, and use specially enlarged claws on their hind feet to grab the fish out of the water. The bats then take the fish to a feeding roost and consume the animal.

4.2.2.6 Blood

There are a few species of bat that consume blood exclusively as their diet. This type of diet is referred to as hematophagy, and three species of bat exhibit this behavior. These species include the Common Vampire Bat, the White-winged Vampire Bat, and the Hairy-legged Vampire Bat.

The Common Vampire Bat typically consumes the blood of mammals, while the Hairy-legged and White-winged feed on the blood of birds.

4.2.3 Results of eating

Bats' dung, or guano, is so rich in nutrients, that it is mined from caves, bagged, and used by farmers to fertilize their crops. Also, guano was used in the U.S. Civil War to make gunpowder.

There comes a time in the year that some bats will not eat to supply themselves with food for the night, but for the coming months. These bats are beginning to hibernate. To do this, the bat will eat as much food as its body can contain, being as fat as possible. The bat's body then takes from the supply of fat for energy, but very slowly, because all body activities have slowed down. This supply of fat will last until the spring season arrives.

4.2.4 Drinking

Generally, bats drink water. In 1960, Frederic A. Webster discovered how bats are able to acquire this water. To do this, Webster developed a high-speed camera and flashgun that could take one thousand photos per second. Webster's camera captured the bat's method of skimming the surface of a body of water, and lowering its jaw to get just one drop of water. It then skims again to get a second drop of water, and then again to get a third, and so on, until it has had its fill of water. Its precision and control is very fine, and it almost never misses. Other bats such as the flying fox or fruit bat gently skim the water's surface, then land nearby to lick water from their chest fur.

5.0 Conservation efforts

Through conservancy efforts, such as the Organization for Bat Conservation, bats are becoming better understood and people beginning to understand the crucial role bats play in insect control and pollination.

In the United Kingdom all bats are protected under the Wildlife and Countryside Acts, and even disturbing a bat or its roost can be punished with a heavy fine.

In Sarawak, Malaysia bats are protected species under the Wildlife Protection Ordinance 1998 (see Malaysian Wildlife Law). The large Naked bat (see Mammals of Borneo) and Greater Nectar bat are consumed by the local communities.

Bats can be a tourist attraction. The Congress Avenue Bridge in Austin, Texas is the summer home to North America's largest urban bat colony, an estimated 1,500,000 Mexican free-tailed bats, which eat an estimated 10,000 to 30,000 pounds of insects each night. An estimated 100,000 tourists per year visit the bridge at twilight to watch the bats leave the roost.

5.1 Artificial roosts

Very large bat house, Tallahassee, Florida, United States.

Many people put up bat houses to attract bats just like many people put up birdhouses to attract birds. Reasons for this vary, but mostly center around the fact that bats are the primary nocturnal insectivores in most if not all ecologies. Bat houses can be made from scratch, made from kits, or bought ready made. Plans for bat houses exist on many web sites, as well as guidelines for designing a bat house. Some conservation societies are giving away free bat houses to bat enthusiasts worldwide].

A bat house constructed in 1991 at the University of Florida campus next to Lake Alice in Gainesville, Florida has a population of over 100,000 free-tailed bats.

In Britain, British hardened field defences of World War II have been converted to make roosts for bats. Pillboxes that are well dug-in and thick walled are naturally damp and provide a stable thermal environment that is required by bats that would otherwise hibernate in caves. With a few minor modifications, suitable pillboxes can be converted to artificial caves for bats.

Again in the UK, purpose-built bat houses are occasionally built when existing roosts are destroyed by developments such as new roads; one such has been built associated with bat bridges on the new (2008) A38 Dobwalls bypass.]

5.2 Threats

A little brown bat with white nose syndrome.

While conservation efforts are in place to protect bats, many threats still remain.

5.2.1White nose syndrome

Main article: White nose syndrome

White nose syndrome is a condition associated with the deaths of more than a million bats in the Northeastern United States. The disease is named after a white fungus found growing on the muzzles, ears, and wings of some afflicted bats, but it is not known if the fungus is the primary cause of the disease or is merely an opportunistic infection. Mortality rates of 90–100% have been observed in some caves. At least six species of hibernating bats are affected, including the endangered Indiana bat. Because the affected species have a long lifespan and a low birth rate of only about one offspring per year, it is not expected that populations will recover quickly.

5.2.2Barotrauma and wind turbines

Evidence suggests Barotrauma is causing bat fatalities around wind farms. The lungs of bats are typical mammalian lungs, and unlike the lungs of birds it has been hypothesized they are more sensitive to sudden air pressure changes in their immediate vicinity such as wind turbines, and are more liable to rupture them to explain their apparent higher rate of mortality rate with such devices. Bats suffer a higher death rate than birds in the neighborhood of wind turbines since there are no signs of external trauma, the cause has been hypothesized to be a greater sensitivity to sudden pressure fluctuations in the mammalian lung than in that of birds. In addition, it has been suggested that bats are attracted to these structures, perhaps seeking roosts, and thereby increasing the death rate.

5.2.3 Pathogens and role in the transmission of zoonoses

Among ectoparasites, bats occasionally carry fleas, but are one of the few mammalian orders that cannot host lice (most of the others are water animals).

Bats are natural reservoir for a large number of zoonotic pathogens[58] including rabies, severe acute respiratory syndrome (SARS), Henipavirus (i.e. Nipah virus and Hendra virus) and possibly ebola virus. Their high mobility, broad distribution, and social behaviour (communal roosting, fission-fusion social structure) make bats favourable hosts and vectors of disease. Many species also appear to have a high tolerance for harbouring pathogens and often do not develop disease while infected. However, contrary to folklore, this is not true of rabies, which is as fatal to bats as it is to all other species. However, a bat may be ill with rabies for a longer time than other mammals.

In regions where rabies is endemic, only 0.5% of bats carry the disease. However, of the few cases of rabies reported in the United States every year not caused by dogs, most are caused by bat bites. Those that are rabid may be clumsy, disoriented, and unable to fly, which makes it more likely that they will come into contact with humans. Although one should not have an unreasonable fear of bats, one should avoid handling them or having them in one's living space, as with any wild animal. If a bat is found in living quarters near a child, mentally handicapped person, intoxicated person, sleeping person, or pet, the person or pet should receive immediate medical attention for rabies. Bats have very small teeth and can bite a sleeping person without being felt. There is evidence that it is possible for the bat rabies virus to infect victims purely through airborne transmission, without direct physical contact of the victim with the bat itself.

If a bat is found in a house and the possibility of exposure cannot be ruled out, the bat should be sequestered and an animal control officer called immediately, so that the bat can be analysed. This also applies if the bat is found dead. If it is certain that nobody has been exposed to the bat, it should be removed from the house. The best way to do this is to close all the doors and windows to the room except one that opens to the outside. The bat should soon leave.

Due to the risk of rabies and also due to health problems related to their faecal droppings (guano), bats should be excluded from inhabited parts of houses. The Center for Disease Control and Prevention provides full detailed information on all aspects of bat management, including how to capture a bat, what to do in case of exposure, and how to bat-proof a house humanely. In certain countries, such as the United Kingdom, it is illegal to handle bats without a license.

Where rabies is not endemic, as throughout most of Western Europe, small bats can be considered harmless. Larger bats can give a nasty bite. They should be treated with the respect due to any wild animal

4.0 Conclusion

Students have learnt about the behavior of bat as a mammal under feeding habit , reproduction, habitats etc. They have also learnt classification and evolution of bat as mammals.

5.0 Summary

Bats are flying mammals in the order **Chiroptera** (pronounced /kaɪ □rɒptərə/). The forelimbs of bats are webbed and developed as wings, making them the only mammals naturally capable of true and sustained flight.

6.0 Tutor-Marked Assignments

Explain the behavior of bat under this heading: reproduction feeding, hunting and drinking.

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