NARE 211 – PRINCIPLES OF WILDLIFE MANAGEMENT (CF = 3.0; Lecture/Practical: 30/30 hours)

Course description

Wildlife and Man: Historical highlights in African wildlife conservation; wildlife laws and the land owner, role of social sciences in wildlife management, and effects of environmental pollution on fish and wildlife management. Wildlife management; Ecological background; wildlife populations; habitat factors; management techniques; natural areas and natural heritage areas. Field trip to selected area of wildlife interest.

Course objectives

The main objective of the course is to equip students with historical insights of wildlife conservation and management, the basic knowledge and understanding of wildlife ecology and principles and concepts relevant for sound conservation and management of wildlife resources, and human dimensions of wildlife conservation and management.

Learning outcomes

By the end of the course, the students will be able to:

1. Understand historical perspectives of wildlife conservation at global, continental and national scales
2. Have a good knowledge of wildlife ecology and principles relevant to wildlife conservation and management
3. Understand human dimensions of wildlife management

Teaching methods

- Lectures: 2 hours per week
- Practical: 2 hours per week
- Field trip: 2 days per semester

Methods of Evaluation

Continuous Assessment Tests		30%
CAT I	15%	
CAT II	15%	
Final Examinations	70%	

Total	100%	

Course content

TOPIC	WEEK
INTRODUCTION Relevant definitions. Historical Background of Wildlife Conservation and Management. Goals of Wildlife Management. Wildlife Management in Kenya. Wildlife Management in Protected Areas	1
BASIC ECOLOGICAL CONCEPTS Concepts pertaining to ecosystems: ecosystem, community, habitat, population, niche, energy, biogeochemical cycles, disturbance, resilience, succession, productivity, trophic interactions. Global wildlife distribution patterns.	2-3
WILDLIFE POPULATION ECOLOGY Key definitions. Population group attributes; abundance and density; growth; age distribution; fluctuations; dispersal; dispersion; aggregation; isolation and territoriality. Basic population models. Laws of population ecology. Population dynamics and wildlife management. Wildlife species interactions.	4-5
CAT I	6
COMPETITION AND ITS MANAGEMENT Definition of competition. Forms of competition. Effects of competition on wildlife populations. Applied aspects of competition. Managing competition.	7
PREDATION AND ITS MANAGEMENT Predator-prey cycles. Predator responses to prey density changes. Ecological importance of predation. Anti-predatory behaviour. Why predation control may be necessary. Predation control approaches.	8
WILDLIFE HARVEST MANAGEMENT Reasons for harvesting. Goals of harvesting. Effects of harvesting on wildlife populations. Principles of wildlife harvesting. Strategies of wildlife harvesting. Key considerations in wildlife harvesting	9
WILDLIFE HABITAT ASSESSMENT AND MANAGEMENT Definition of wildlife assessment. Wildlife-habitat relationships. Considerations in habitat assessment. Methods of habitat assessment. Habitat loss and fragmentation: causes, consequences and mitigation.	10
HUMAN DIMENSIONS OF WILDLIFE MANAGEMENT Human-wildlife conflicts and contemporary issues. Wildlife laws and policies. Wildlife conservation and the land owner. Role of social sciences in wildlife conservation and management.	11
CAT II, COURSE RECAP; COURSE EVALUATION	12
FINAL EXAMINATION	13-14

Learning materials

Key References & Texts

1. Wildlife Biology (1981). R.F. Dasmann. 1st Edition. John Wiley & Sons Inc. [SK 357.D3.C.2]
2. Wildlife Management and Conservation: Contemporary Principles and Practices (2013). P.R. Krausman . J.W. Cain III. 13-978-1-4214-0986-3 [SK 361. W55. C.3]
3. Wildlife Ecology, Conservation and Management (2006). A.R. E. Sinclair, J.M. Fryxell, G. Caughley. Blackwell Publishing. ISBN 978-1-4051-0737-211 [SK.355.S56.2006.C3]
4. Wildlife Conservation; Principles & Practises, (1979). Teague, R.D. & Decker,E. 1st Edition. The Wildlife Society. ISBN 0-933564-06-6 [SK.353.N54.C2]
5. Principles of Wildlife Management (1984). Bailey J.A. John Wiley & Sons. New York. ISBN 0-471-01649-7 [SK.355.B35.C.1]

Supplementary References & Texts

1. Sinclair, A.R.E., J.M. Fryxell and G. Caughley. 2007. Wildlife Ecology, Conservation, and Management. Second Edition. Blackwell Publishing. Malden, MA. USA.
2. Bolen, 1 E.G. and Robinson, W.L. (2003): Wildlife Ecology and Management. 5th Edition. Pearson Education, New Jersey. Pp 32-47. ISBN 0-13-066250.
3. Observing Animal Behaviour: Design and Analysis of Quantitative DataMarian Stamp Dawkins1 3: 9780198569367
4. The Wildlife Techniques Manual: Volume 1 &2: Research. Nova J. Sivy. ISBN 13-978-1-4214-0159-1 & 10-1-4214-0159-2
5. Conservation of Wildlife Populations: Demography, Genetics, and Management, 2nd Ed L. Scott Mills. ISBN 978-1-4051-2146-0 Principles of Wildlife Management James A. Bailey. ISBN 978-0-471-01649-68
6. People and Wildlife, Conflict or Co-existence? Rosie Woodroffe, Simon Thirgood and Alan Rabinowitz. ISBN 052153203512
7. Selected research papers, articles, mainstream media articles, conservation articles, popular and general media articles on wildlife management & conservation.
8. Rockwood, L.L. 2006. Introduction to Population Ecology. Blackwell Publishing, Oxford, UK
9. Gotelli, N.J. 2008. A Primer of Ecology. Sinauer Associates, Sunderland, MA, USA
10. Case, T. J. 2000. An illustrated guide to theoretical ecology. Oxford University Press

11. Odum, E.P. 1959. Fundamentals of Ecology. W. B. Saunders. Philadelphia, PA, USA.
12. Brewer, R. 1979. Principles of Ecology. W. B. Saunders. Philadelphia, PA, USA.
13. Berryman, A. A. 1999. Principles of population dynamics and their application. Stanley Thornes, UK.
14. Berryman, A. A. 2003. On principles, laws and theory in population ecology. *Oikos* 103: 695-701
15. White, P.J., J.E. Bruggeman, and R.A. Garrott. 2007. Irruptive population dynamics in Yellowstone pronghorn. 17:1598-1606.
16. http://player.slideplayer.com/24/7303514/#
17. http://slideplayer.com/slide/7110012/

INTRODUCTION

Concepts and Definitions

Wildlife

- Wildlife can be defined as all undomesticated plants and animals (vertebrates, invertebrates, microorganisms) in their natural environment (i.e. those that are outside the control of human beings)
- Note: There are legal definitions of wildlife that vary from country to country

Conservation

- Refers to the control of human use of living and non-living resources in order to yield benefits to the present generation, while maintaining their potential to meet the needs and aspirations of future generations.

Wildlife conservation

- The science of protecting and sustainably managing wildlife populations and their habitats to achieve specified human (or management) objectives

OR SIMPLY,

- The wise use of wildlife (natural resources), without wasting them.

Wildlife preservation

- Saving natural resources, but with no consumption of them. For example, outlawing hunting of endangered species
- Both preservation and conservation are necessary to sustain resources for future generations.

Two schools of thought (paradigms) regarding wildlife conservation

- **Muir School**: preservationist; nature should be protected at least partly for its own sake
    - John Muir, 1838-1914: influential American naturalist, instrumental in promoting the idea of wilderness preservation and in creating the first National Parks
- Pinchot School: nature should be protected for benefit of future humans
    - Gifford Pinchot, 1865-1946: first Chief of the United States Forest Service; promoted scientific forestry and termed conservation, “the art of producing from the forest whatever it can yield for the service of man”
- The two schools of thought are not mutually exclusive; rather, they emphasize different aspects of conservation

Wildlife management

- Was first defined by Aldo Leopold as the art of making land produce sustained annual crops of wild game for recreation use
- Can be more comprehensively defined as the application of scientific knowledge and technical skills to protect, preserve, conserve, limit, enhance, or extend the value of wildlife populations and their habitats
- Can also be defined as the application of ecological knowledge to populations of vertebrate animals and their plant and animal associates in a manner that strikes a balance between the needs of those populations and the needs of people (Bolen & Robinson 2003)

- Wildlife management can be achieved through:
    - Active Management - direct (e.g. harvesting, translocation) or indirect (e.g. habitat manipulation) population management aimed at increasing or decreasing in population
    - Passive Management or preservation - where nature is allowed to take its course without human intervention
- Wildlife management includes running parks and reserves, altering and rehabilitating wildlife habitats, pest control, protecting human life and property and managing harvests of wildlife
- Wildlife management can have local, regional, international dimensions depending on the wildlife involved; for example, management of elephants is a local concern, regional concern, and global
- Local level – effects on habitat; human-wildlife conflicts; tourism
- National level – tourism; sport hunting; poaching
- Global or trans boundary – poaching, ivory trade transboundary migration

Wildlife managers

- These are professionals who are concerned with maintaining wildlife populations that are diverse and well-balanced
- They combine research and management skills to identify human needs and to solve human-wildlife-habitat problems
- They also apply knowledge of the biology of wildlife species and the ecology of its community

Historical Background

Ancient times

- Since ancient times, human beings have (directly or indirectly) practiced wildlife management and conservation
- The Stone Age hunters and gatherers hunted only a limited number of wild animals for subsistence purposes
- They only killed mature, healthy animals but left the young ones and potential mothers.

- The ancient people only hunted certain species of animals for food
- Those animals which were believed to be sacred or taboo were left out to avoid misfortunes or bad omen.
- Certain trees and shrubs were not destroyed because they were used as shrines for prayers or medicinal purposes
- These practices made sure that some plants were protected, hence increasing food availability for wild animals.
- This was a kind of wildlife management through myth and beliefs
- It ensured growth, prosperity and survival of the wild animals and plant species and people co-existed harmoniously with the environment.
- This kind of co-existence without destruction was possible because:-
    - The human population was small compared to the available resources (plants, animals, land etc)
    - Land use practices were compatible with conservation e.g. there was no need for large scale agriculture, land for settlement, road construction and other development
    - The available resources were not exploited for commercial purposes but for subsistence only e.g. hunting for food and not for skins, tusks, horns (game trophies) and meat for sale

Present day wildlife conservation and management
Early years

- Conservation movement originated in North America in the latter part of the 19th century
- Triggered by heavy wildlife exploitation (e.g. bison reduced from 60 million to ~ 150 individuals by 1890)
- Dramatic wildlife declines fuelled growing protectionist sentiment

Era of protection

- Late 1800s to early 1930s
- Legal protection was the main tool for conservation, with science not much involved.
- Notable events during this period:
    - Supreme Court case, "Geer vs. Connecticut" (1896)
        - dealt with the transportation of wild fowl over state lines
        - established public (state) ownership of wildlife
        - allowed state governments to regulate use of wildlife

    - Yellowstone National Park, est. in 1872, became first area where wildlife species were federally protected in 1897
    - Theodore Roosevelt establishes first national wildlife refuge (1903), the Pelican Island, Florida
        - This was the first time an area was protected specifically for wildlife
    - Roosevelt pens the Antiquities Act,1906
        - This enabled presidents to proclaim historical landmarks, prehistoric structures, and other objects of historical or scientific interest as national monuments
    - Roosevelt brought the idea of wildlife "conservation through wise use" to forefront of American politics, and also pushed for more use of science in conservation

Era of game management

- Revolved around a landmark publication – Aldo Leopold's Game Management,1933
    - The publication defined the skills and techniques for managing and restoring wildlife populations
        - Premised on the idea that populations need to be studied, understood to allow for effective conservation
    - It was also used as a training guide for 'game managers'
- Game Management promoted the idea that conservation is about both legal protection and intervention (manipulation of populations based on scientific understanding)

Era of environmentalism

- 1960s to the present
- Ushered in a new paradigm in which:
    - environment is viewed holistically (as ecosystems)
    - science is used as basis for adaptive management
    - there is focus on endangered species
- Key figure: Rachel Carson,1907-1964
    - Published Silent Spring (1962) which:
        - documented detrimental effects of pesticides on the environment (particularly birds)
        - led to ban on DDT
        - galvanized public concern, interest
- • Landmark Laws
    - Wilderness Act of 1964
    - Written into law by Lyndon Johnson, originally protected > 9 million acres of federal land
        - *A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain.*

- National Environmental Policy Act, 1970
    - Introduced Environmental Impact Statements
- Marine Mammal Protection Act, 1972
    - Prohibited harvesting and importation of cetaceans, pinnipeds, sirenians
- Endangered Species Act (ESA), 1973
    - Originally species focused
    - Now protects species and habitats in the interest of conserving functioning ecosystems and natural landscapes

Goals Wildlife Management

- Wildlife populations are managed to achieve any of the following goals:-
    - To increase the populations e.g. by introduction, promotion of population growth factors e.t.c (active management)
    - To make the population decrease e.g. by culling, cropping, translocation, promotion of population reduction factors etc to meet land capacity (active management)
    - To harvest the populations on a continuing yield basis i.e. wise use (active management)
    - To leave it alone and just keep an eye on it (passive management)

Management of Wildlife Resources in Kenya

- Different states have different ways of managing wildlife resources
- In Kenya, wildlife (largely large bodied animals) are largely managed by KWS for the people of Kenya.
    - Fish are managed by Fisheries department
    - Forests by Forestry department.
- USA –US Fish and Wildlife service
- Canada - Canadian Wildlife Service managing wildlife including migratory birds whereas
- Canada- Marine fresh water fisheries are managed by the Department of Fisheries and Oceans.

History of wildlife management in Kenya

- During the construction of the Kenya – Uganda Railway, most areas of Kenya were full of wild animals

- Many pastoral communities like the Maasai felt that game meat was inferior to their traditional meals (livestock meat and blood) and would therefore not kill wild animals unless they interfere with their livestock
- The few communities that hunted wild animals for meat used simple weapons and only killed those animals they needed for their daily subsistence
- Land cultivation was minimal and there was enough room for human beings and wild animals to coexist together
- In the early 20th Century, Kenya became a paradise for hunters who came in large numbers, equipped with fast vehicles, firearms and accompanied by greedy buyers of game trophies.
- The resultant severe hunting pressure and a drastic decrease in wildlife populations caused the authorities to call the first International Conference on wildlife conservation and management in which the first laws for game conservation were passed
- The chronology of Kenya's wildlife management legislation is as follows:
    - 1900 – The E. African Game Regulations were enacted.
    - 1904, 1905 and 1906 – The Game Ordinance (rules) and amendments were enacted to strengthen the E. African Game Regulations.
    - 1907 – The Kenya Game Department was created.
    - 1909 – The Game Ordinance (rules) became law
    - The government proclaimed the Southern Game Reserve in Maasai land and the Northern Game Reserve in the Northern Frontier Province.
    - 1933 – An International Conference was held in London in which participants agreed on the principle to establish and maintain National Parks or permanent Wildlife Sanctuaries in E. Africa.
    - 1937 – An Ordinance was passed to strengthen and improve the law relating to the protection of game animals and birds in Kenya.
    - 1938 – The government appointed the Game Policy Committee to recommend where and how to establish a system of national parks.
    - 1945 – An Ordinance No. 9 or the National Parks Ordinance was enacted in which a Board of Trustees was appointed to administer the areas of land

designated as National Parks and Reserves for preservation of flora and fauna, aesthetic value (beauty), geological sites, pre-historic sites and areas of scientific interest

- Through Ordinance No. 10 of 1945, Nairobi National Park was established on 15th December 1946 and Tsavo National Park in April 1948.
- The Ordinance was later changed to become the Royal National Parks of Kenya Act which facilitated the establishment of the other National Parks and Reserves.
- The Royal National Parks of Kenya Act was later changed again to become the Wildlife Conservation and Management Act in 1976.
- This was after gazettement of Sessional Paper No. 3 which set out the wildlife conservation and management policy that is in force to date.

- By 1991, Kenya had a total of 26 National Parks, 29 National Reserves and one Game Sanctuary (Maralal).
- Four of the 26 parks are Marine National Parks and 5 of the 29 reserves are Marine National Reserves.
- The total land under protected areas in Kenya is about 44,720 Km^2 or 7.7% of the total land area of the country
- There are also a number of game ranches, private sanctuaries, conservancies and game farms in Kenya today.

- After the 1945 changes through Ordinance No. 9 and 10 two government institutions managed wildlife:
    - The Kenya National Parks Authority
    - Game Department
- The Kenya National Parks Authority administered national parks by protecting and developing them as tourist resorts
- The functions of the Game Department included:-
    - Administration and control of wild animals outside the National Parks.
    - Establishment of District Game Stations where wildlife was an important resource
    - Advising and assisting local county councils to establish game reserves where hunting was forbidden
    - Control of game hunting in the hunting blocks outside the game reserves
    - Provide financial support to local authorities to develop public utilities through

social projects to encourage communities to appreciate and participate in wildlife conservation
    - Payment of compensation for loss of life, injury or property damaged caused by wildlife.

- In 1975 Sessional Paper No. 3 was gazetted as the wildlife policy which gave the general guide and overall direction towards conservation and management of wildlife in Kenya
- In 1976 the Wildlife Conservation and Management Act was enacted by Parliament
- Through this Act the National Parks Authority and the Game Department were amalgamated (merged together) into one institution, the Wildlife Conservation and Management Department (WCMD) under the Ministry of Tourism and Wildlife.
- WCMD was in charge of conservation and management of all wildlife in Kenya, whether on state, trust and private lands and to ensure that the resource gave back the best possible returns to individuals and the nation in terms of cultural, aesthetic and economic benefits
- Licensed hunting and poaching continued to destroy wildlife in the country, precipitating a hunting ban in 1977.
- The ban led to the closure of the professional hunting companies and curio shops that dealt in game trophies
- However, this did not solve the problem for wildlife in Kenya
- Poaching was rampant and it drastically reduced the populations of certain wildlife species, particularly elephant and rhino
- By the end of 1987 it was felt that a change in wildlife conservation and management was necessary if Kenya was to save the remaining stocks of her valuable wildlife species
- This necessitated an amendment of the Wildlife Conservation and Management Act which disbanded WCMD and created KWS in 1989
- KWS is a state cooperation charged with the responsibility of conserving Kenya's wildlife (flora & fauna) for the benefit of present and future generations

- KWS is also responsible for utilizing the country‘s wildlife resources sustainably for economic development and benefit of people living near wildlife areas
- KWS has responsibility to protect people and their property against wildlife damage
- The Minister responsible for wildlife conservation is empowered by the wildlife Act to appoint a Board of Trustees to run the Kenya Wildlife Service.

Wildlife Management in Protected Areas

Emergence of wildlife protected areas around the world

- Some historians claim that areas were specifically set aside in India for the protection of natural resources over two millennia ago (Holdgate, 1999)
- In Europe, some areas were protected as hunting grounds for the rich and powerful nearly 1,000 years ago.
- The idea of protection of special places is universal: it occurs among the traditions of communities in the Pacific (―tapu‖ areas) and parts of Africa (sacred groves), for example
- Long ago, protected areas were first set aside by kings and other national rulers in Europe typically as royal hunting reserves
- Slowly these sites became open for public use, providing the basis for community involvement and tourism
- In 1870, a group of explorers in Yellowstone USA hatched the idea of a public park
- They decided that the area had natural beauty that warrants it to be made a public park or a leisure ground for the benefit and enjoyment of the people
- In 1872, the US government passed a Bill authorising such a use and the word "National Park" came into official use
- The first true national park came in 1872 with the dedication of Yellowstone by United States law ―as a public park or pleasuring ground for the benefit and enjoyment of the people
- Many other countries followed the US example:
    - In 1876, New South Wales in Australia reserved Blue Mountains National Park

- In 1879, Royal National Park was set up, also in New South Wales, in the wilds south of Sydney, so as to provide a natural recreation area for the burgeoning populations of this metropolitan area
- In 1885, Canada protected the area around the mineral hot springs at Banff which later became the Banff National Park
- In 1892, the first game reserve on the African continent was created by President Kruger (South Africa); it later became the famous Kruger National Park
- Several forest reserves were also set up in South Africa in the last years of the nineteenth century
- In 1894, Tongariro National Park was established in New Zealand by agreement with the Maori people, a place that was, and still is, important to them for spiritual reasons
- In 1895, the National Trust of Great Britain was founded to conserve places of national interest
- In 1909, the Laponia National Reserve in Sweden was established.

Characteristics of early wildlife protected areas:

- They were created by government action
- The areas set aside were generally large and contained relatively natural environments
- The parks were made available to all people; thus, from the very beginning, park visitation and tourism were central pillars of the national parks movement

Protected areas today

- By the year 2002 some 44,000 sites met the IUCN definition of a protected area; together these covered nearly 10% of the land surface of the planet

BASIC ECOLOGICAL CONCEPTS

ECOSYSTEM

- Each wildlife species participates in a vast network of life where non-living elements are brought into the tissues of living organisms and finally released into the abiotic environment
- Such a network involving interactions of biotic and abiotic components in a

manner to sustain life is called an ecosystem

- **Ecosystem can be defined as a natural system consisting of all plants, animals and microorganisms (biotic factors) in an area functioning together with all the non-living physical (abiotic) factors of the environment**
- Ecosystems have dimensions both in space (e.g. width, depth and height) and time (e.g. wet and season)
- Ecosystems are not discrete entities delineated sharply from other ecosystems
- In addition, ecosystems are interconnected
- Ecosystems can be modified by external or internal factors
- Factors that can lead to ecosystem modification include natural or anthropogenic (e.g. industrialization, creation of dams, farming, and mining).
- An ecosystem has two components:
  - **Abiotic component** – comprises basic inorganic and organic compounds of the environment (e.g. nutrients, water, litter)
  - **Biotic component** – comprises the living components of the environment (plants and animals)
- The biotic component can be subdivided into:
  - ***Autotrophic component*** –
    - A self-nourishing component where fixation of energy, use of simple inorganic substances and buildup of complex substances predominate
    - Comprises primary producers or autotrophic organisms, mainly green plants, capable of manufacturing food from simple inorganic substances
  - ***Heterotrophic component*** –
    - Predominated by utilization, rearrangement and decomposition of complex materials
    - Comprises ***Consumers*** (or macro-consumers) – heterotrophic organisms, mainly animals, which ingest other organisms or particulate organic matter
    - Also comprises ***Decomposers*** (micro-consumers, saprophytes) – heterotrophic organisms, chiefly bacteria and fungi, which break down complex compounds contained in dead organisms

- Ecosystems are generally self-sustaining but require energy from external sources

- An ecosystem can be as large as the whole biosphere or as small as a pond.

- Ecosystems usually consist of several biotic communities each having different groups of plants and animals which interact with each other and with the abiotic environment for maintenance of life

COMMUNITY

- An ecological community is an assemblage or association of actually or potentially interacting species living in the same location
- The structure, composition and distribution of a community are determined by environmental factors such as soil type, topography, climatic factors, and disturbances (both natural and anthropogenic)

HABITAT

- It is the natural environment in which a population lives, or the physical environment that surrounds (influences and is utilized by) a population
- A habitat comprises a suite of resources and environmental conditions (food, water, cover, space, mates) that determine the presence, survival and reproduction of a population
- Thus, a habitat includes both abiotic and biotic complexes
- Every species has certain habitat needs for the conditions in which it will thrive, but some are tolerant of wide variations while others are very specific in their requirements

Types of habitats

Terrestrial habitat types:

- Forests, grasslands, wetlands and deserts
- Within these broad biomes are more specific habitats with varying rainfall, temperature regimes, soils, altitudes and vegetation types
- Many of these habitats grade into each other and each one has its own typical communities of plants and animals

Freshwater habitat types:

- Rivers, streams, lakes, ponds, marshes and bogs

- Although some organisms are found across most of these habitats, the majority have more specific requirements
- For example, water velocity, temperature and oxygen saturation are important factors
    - In river systems, there are fast and slow sections, pools, bayous and backwaters which provide a range of habitats
    - Similarly, aquatic plants can be floating, semi-submerged, submerged or grow in permanently or temporarily saturated soils besides bodies of water
    - Marginal plants provide important habitat for both invertebrates and vertebrates
    - Submerged plants provide oxygenation of the water, absorb nutrients and play a part in the reduction of pollution

Marine habitats

- Include brackish (salty) water, estuaries, bays, the open sea, the intertidal zone, the sea bed, reefs and deep water zones
- Further variations include rock pools, sand banks, mudflats, brackish lagoons, sandy and pebbly beaches, and seagrass beds, all supporting their own flora and fauna
- The benthic zone or seabed provides a home for both static organisms, anchored to the substrate, and for a large range of organisms crawling on or burrowing into the surface
- Some creatures float among the waves on the surface of the water, or raft on floating debris
- Others swim at a range of depths, including organisms in the demersal zone close to the seabed, and myriads of organisms drift with the currents and form the plankton

Microhabitat and microenvironment

- The term **microhabitat** is often used to describe the small-scale physical requirements of a particular organism or population
- A microhabitat is often a smaller habitat within a larger one
- For example, a fallen log inside a forest can provide microhabitat for insects that are not found in the wider forest habitat outside such logs
- **Microenvironment** is the immediate surrounding and other physical factors of an individual plant or animal within its habitat

NICHE

- Ecological niche is the fundamental role/position/status of an organism in a community (or ecosystem) resulting from the organism's structural adaptations, physiological responses and specific behavior
- The ecological niche of an organism depends not only on where it lives but also on what it does
- Therefore, it may also be defined as the sum total of all the ecological requirements and activities of a species
- Niche-related ideas include:
    - Generalist vs. specialist
        - A generalist uses a wide range of habitats in many different ways
        - A specialist uses specific habitats in specific ways
    - Competitive exclusion principle
        - Two species with the same niche requirements cannot coexist on the same resource because one species (better adapted) will outcompete and displace the other (less adapted)
    - Ecological equivalents
        - These are species that occupy similar niches but in different habitats or locations
- The concept of ecological niche encompasses the following three aspects:
    - Spatial - distribution, habitat, physical location of an organism in an ecosystem
    - Functional – an organism's trophic level or position in a food web (e.g. predators, prey, parasites, competitors)
    - Behavioural - seasonality, diurnal patterns, movement, social organization of an organism
- If there are no other organisms in the environment (i.e. no competition), then the set of resources that an organism can utilize is referred to as **fundamental niche**
- The observed resource use in the presence of competition and other interspecific interactions referred to as **realized niche**

Importance of niche concept in wildlife management:

- The ability to match habitats to the niche requirements of a species is fundamental to wildlife management
- Damaged or altered habitats often lack some of the resources needed for niche maintenance especially if the species concerned have a narrow range of tolerance
- The concept is also important in managing introduction of exotic species (and potential impacts on native species), because two species cannot occupy the same niche

BIOGEOCHEMICAL CYCLES

(https://www.britannica.com/science/biogeochemical-cycle)

- The chemical elements, including all the essential elements of protoplasm (living part of a cell, including the cytoplasm, nucleus, and other organelles), tend to circulate in characteristic paths from the abiotic environment (lithosphere, atmosphere, hydrosphere) to organisms (biotic component) and back to the abiotic environment
- These paths are called inorganic-organic cycles or biogeochemical (biological-geological-chemical) cycles
- They include nitrogen, carbon, phosphorus, sulfur and water cycles **[GROUP ASIGGNMENT: 5 GROUPS, EACH GROUP TO DESCRIBE ONE BIOGEOCHENICAL CYCLE]**
- Useful video: https://www.youtube.com/watch?v=Bn41lXKyVWQ

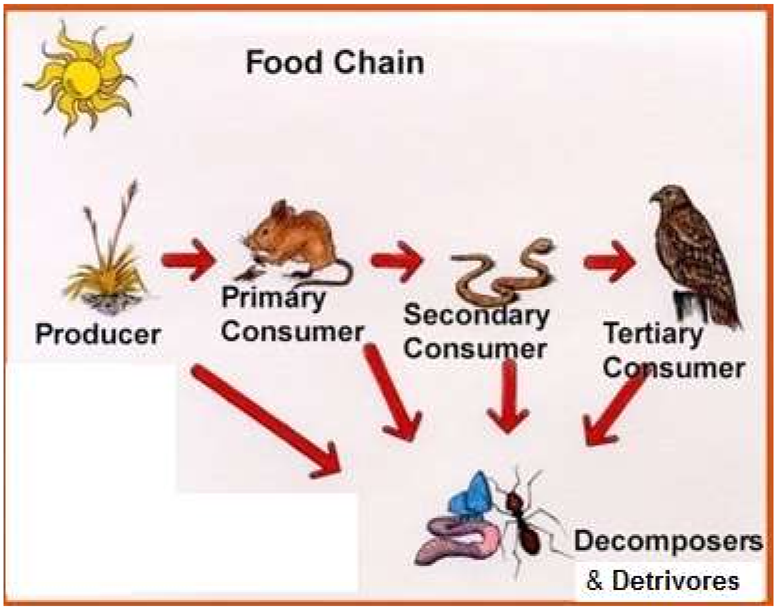
PRINCIPLES AND CONCEPTS RELATED TO ENERGY

Energy

- Defined as the ability to do work or cause change
- Energy flows through an ecosystem
- The behavior of energy is defined by the following two laws of thermodynamics:
    - ***First law***: energy can be converted from one form to another but never created or destroyed
    - ***Second law***: at each stage of energy conversion, some energy is lost in the form of heat (i.e. transformation of energy is never 100% efficient)
- These laws are relevant in understanding how solar energy flows through an ecosystem
    - For instance, only 0.1-2% of the solar energy available for photosynthesis is actually used by plants in this process

Trophic interactions

- Energy moves through an ecosystem via food chains and food webs
- A **food chain** refers to the transfer of food energy from the source in plants through a series of organisms with repeated eating and being eaten
- Energy flows from the primary producers (mainly plants) to secondary consumers to tertiary consumers, and from all these levels to detritus feeders and decomposers (see Fig. below)



- These stages of energy flow are called trophic levels

Producers

- Occupy the first trophic level and directly or indirectly support all other levels
- Derive their energy from the sun in most cases
- Able to manufacture their food from simple inorganic substances
- Include green plants, algae and other photosynthetic protists (organisms that are not animals, plants or fungi), and some bacteria
- Some tissue is not eaten by consumers and becomes food for detritivores and decomposers

Consumers

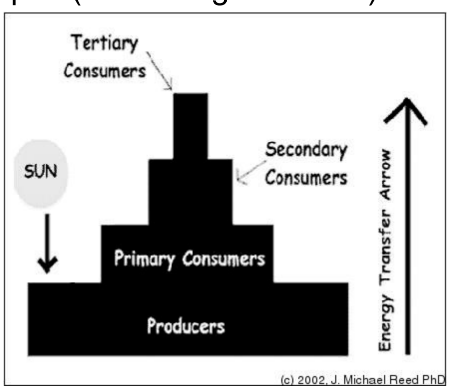
- These are organisms that feed on other organisms to obtain their energy
- They include animals (vertebrate and invertebrates), heterotrophic protists, and some bacteria
- Some tissue not eaten by consumers becomes food for detritivores and decomposers
- Consumers obtain their energy from a variety of sources: plant tissues (herbivores), animal tissues (carnivores), plant and animal tissues (omnivores), dead organic matter or detritus (detritivores and decomposers)

Energy flow

- At each transfer, a large proportion of potential energy is lost as heat
- The number of steps in a sequence is usually limited to 4 or 5
- The shorter the food chain (or the nearer the organism to the beginning of the chain), the greater the available energy which can be converted to biomass and/or dissipated by respiration
- Food chains are usually not isolated but are interconnected with one another resulting in an interlocking pattern referred to as the ***food web***
- The greater the number of alternative channels through which energy can flow, the greater the stability of the food web and ecosystem

Ecological pyramids

- Food chains and webs make up the ***trophic structure*** of an ecosystem
- Trophic structure can be shown graphically by means of ***ecological pyramids***, where the producer level forms the base and tertiary consumers the last tier or the apex (see the figure below)



- An ecological pyramid represents the distribution of energy, biomass or numbers among trophic levels, giving rise to pyramids of i) numbers, ii) biomass and iii) energy

Pyramids of numbers

- Here, the size of each tier (trophic level) is proportional to the number of individuals present at that tier
- The number of individuals supported by the ecosystem at successive trophic levels declines progressively
- This reflects the fact that the smaller biomass of top level consumers tends to be concentrated in a relatively small number of large animals
- There are some exceptions; in some forests a few producers (of a very large size) may support a larger number of consumers, and the pyramid is inverted
- This also occurs in plant/parasite food webs

Pyramids of biomass

- Each tier represents the total dry weight of organisms at each trophic level
- Dry weight is usually used as the measure of mass because the water content of organisms varies
- Organism size is taken into account so meaningful comparisons of different trophic levels are possible
- Biomass pyramids may be inverted in some systems (e.g. in some plankton communities) because the algal (producer) biomass at any one time is low, but the algae are reproducing rapidly (high productivity)

Pyramids of energy

- The size of each tier is proportional to the production (e.g. in kJ) of each trophic level
- Often very similar in appearance to pyramids of biomass
- The energy content at each trophic level is generally comparable to the biomass because similar amounts of dry biomass tend to have about the same energy content
- Notably, in general, only 5-20% (ecologists' rule of thumb 10%) of energy is transferred from one trophic level to the next because of the following factors:
    - Some energy is used for predator avoidance
    - Not all energy consumed is digestible
    - Not all energy is accessible
    - Some energy is used for maintenance (respiration, activity, thermoregulation, basal metabolism)

Productivity

Primary productivity

- This is the rate at which energy is stored by photosynthetic (or chemosynthetic) activity of producer organisms in an ecosystem
- An ecosystem's energy budget depends on primary production
- Most primary producers use light energy to synthesize energy-rich organic molecules, which can subsequently be broken down to generate ATP
- Therefore, the extent of photosynthetic production sets the spending limit for the energy budget of the entire ecosystem
- Photosynthetic output of ecosystems is limited by the amount of solar radiation reaching the surface of the globe

- Can be expressed in terms of energy per unit area per unit time ($J/m^2/yr$) or as biomass (dry weight) of vegetation added to the ecosystem per unit area per unit time ($g/m^2/yr$)
- An ecosystem's primary production should not be confused with the total biomass of photosynthetic autotrophs present at a given time, called the *standing crop*
- Although a forest has a very large standing crop biomass, its primary production may actually be less than that of some grasslands, which do not accumulate vegetation because animals consume the plants rapidly and because some of the plants are annuals

- There are two types of primary productivity:

Gross primary productivity

- The total rate of photosynthesis including organic matter used up in respiration

Net primary productivity

- The rate of storage of organic matter in plant tissues in excess of the respiratory utilization by plants
- Represents the storage of chemical energy that will be available to consumers in an ecosystem

Secondary productivity

- The rates of energy storage at consumer trophic levels are each referred to as ***secondary productivity***
- In most ecosystems, herbivores manage to eat only a small fraction of the plant material produced
- Moreover, they cannot digest all the plant material that they do eat
- Also, consumers use some energy for maintenance
- Thus, much of primary production is not used by consumers
- *Net secondary production* is the energy stored in biomass represented by growth and reproduction
- Assimilation consists of the total energy taken in and used for growth, reproduction, and maintenance

- In other words, production efficiency is the fraction of food energy that is not used for maintenance

PRINCIPLES AND CONCEPTS PERTAINING TO LIMITING FACTORS

Liebig's law of the minimum

- To live and thrive in a given situation, an organism must have essential materials which are necessary for growth and reproduction
- These basic requirements are species-specific and location-specific
- The essential material available in amounts closely approaching the critical minimum needed will tend to be the limiting one

Shelford's law of tolerance

- Organisms have their own ranges or ***limits of tolerance*** (minimum and maximum) for each of the physical and biological components of their environment
- Consequently, absence or failure of an organism can be controlled by the deficiency or excess supply of any one of several factors which may approach the limits of tolerance for that organism

Combined concept of limiting factors

- Any condition which approaches or exceeds the limits of tolerance is said to be a limiting factor or condition
- Thus organisms are controlled in nature by:
    - The quantity and variability of materials (and other components of the environment) for which there is a minimum requirement
    - The limits of tolerance of the organisms themselves to these and other components of the environment
- The limiting factors include both abiotic factors (temperature, light, water, atmospheric gases, micro- and micro-nutrients) and biotic factors (predation, competition etc)

OTHER CONCEPTS PERTAINING TO ECOSYSTEMS

Disturbance

- A disturbance is an event that causes a change in the existing condition of an ecological system
- Disturbances often act quickly and with great effect, to alter the physical structure or arrangement of biotic and abiotic elements
- Disturbances can either be anthropogenic (e.g. hunting, deforestation, prescribed burning, introduction of invasive species) or natural (e.g. wildfires, floods, drought, disease outbreaks, insect outbreaks)
- Disturbance forces can have profound immediate effects on ecosystems and can, accordingly, greatly alter the natural community
- Because of these and the impacts on populations, these effects can continue for an extended period of time

Ecological importance of disturbance

- Biological diversity is dependent on natural disturbance
- The success of a wide range of species from all taxonomic groups is closely tied to natural disturbance events such as fire, flooding, and windstorm
- As an example, many shade-intolerant plant species rely on disturbances for successful establishment and to limit competition
- Without this perpetual thinning, diversity of forest flora can decline, affecting animals dependent on those plants as well.
    - *A good example of this role of disturbance is in ponderosa pine (Pinus ponderosa) forests in the western United States, where surface fires frequently thin existing vegetation allowing for new growth. If fire is suppressed, Douglas fir (Pesudotsuga menziesii), a shade tolerant species, eventually replaces the pines. Douglas firs, having dense crowns, severely limit the amount of sunlight reaching the forest floor. Without sufficient light new growth is severely limited*
- As the diversity of surface plants decreases, animal species that rely on them diminish as well
- Fire, in this case, is important not only to the species directly affected but also to many other organisms whose survival depends on those key plants
- In addition, herbivores thrive on post-fire vegetation regrowth

Management implications of disturbance

- Limiting the impact that a natural disturbance will have on an ecosystem is difficult because the timing of the disturbance, its location, its intensity, and its spatial patterning are unpredictable
- However, a future disturbance event may be forecast based on time series data (i.e., records of past occurrences) and the event's probability of occurrence across a long interval
- For example, geologists have assigned probabilities to earthquake occurrences along the Pacific Ring of Fire, and meteorologists have attempted to calculate the probability of a 100-year snow event (an uncommonly large snowfall that has a 1 percent probability of occurring in any given year)
- In contrast, large disturbances of biological origin are much more difficult to predict, because of the vast numbers of species and species' interactions involved
- In fact, the most-devastating biological disturbances are caused by poorly known or unknown microorganisms
- Large, long-lasting ecological disturbances that stress natural ecosystems on a global (rather than local) scale pose significant challenges to management and restoration efforts
- For example, the global impact on marine ecosystems of ocean acidification, which stems from the absorption of carbon dioxide by seawater, is not well understood
- Likewise, while the rise of average global near-surface air temperatures (i.e., global warming) has been found to increase drought frequency and severity, thereby modifying patterns of ecosystem productivity and the geographic ranges of many species, how these changes could impact ecosystems globally remains uncertain
- In the case of overfishing, which is a persistent global problem—in 2010, for example, 53 percent of the world's fish stocks were fully exploited (i.e., operating at maximum sustainable yield) and another 17 percent were overexploited—marine ecologists have documented changes in the structure of fish populations and that of their prey that ultimately could change the structure of the ecosystems they inhabit
- The consequences of the trophic cascades that are likely to follow such changes are yet to be fully explored

Ecological resilience

- Ecosystems are dynamic and adaptive systems capable of changing from one state to another in response to a changing environment
- Ecological resilience is the ability of an ecosystem to cope with disturbance and stress and return to a stable state

- Such disturbances can include stochastic events such as fires, flooding, windstorms, insect population explosions, and human activities such as deforestation, fracking of the ground for oil extraction, pesticide sprayed in soil, and the introduction of exotic plant or animal species
- Resilience measures the amount of stress or disturbance required to change an ecosystem from one state to another
- A resilient ecosystem can better withstand shocks and rebuild itself without transforming into a different state
- Disturbances of sufficient magnitude or duration can profoundly affect an ecosystem and may force an ecosystem to reach a threshold beyond which a different regime of processes and structures predominates
- Human activities that adversely affect ecosystem resilience such as reduction of biodiversity, exploitation of natural resources, pollution, land-use, and anthropogenic climate change are increasingly causing regime shifts in ecosystems, often to less desirable and degraded conditions

Ecological succession

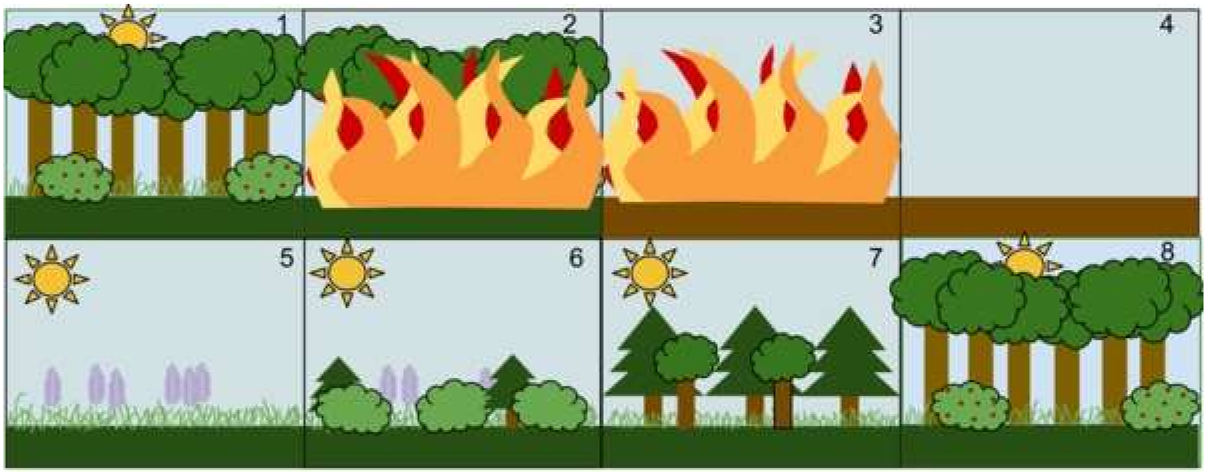
- This is the process of change in the species structure of an ecological community over time
- Involves replacement of one community of organisms by another in an orderly and predictable manner
- Succession ends at the climax community, a relatively stable community that reaches a dynamic equilibrium
- Each of the communities preceding the climax community is called a seral community (or sere)
- Two basic types of succession (primary and secondary):

Primary succession

- This is succession that begins with colonization of an area that has not been previously occupied by an ecological community, such as newly exposed rock or sand surfaces, lava flows, newly exposed glacial tills
- The stages of primary succession include pioneer plant community (lichens [fungus + algae] and mosses), grassy stage, smaller shrubs, and trees
- Animals begin to return when there is food there for them to eat
- When it is a fully functioning ecosystem, it has reached the climax community stage.

Secondary succession

- Follows severe disturbance (or removal of a pre-existing community), which moves the ecosystem back to an earlier successional stage
- Dynamics in secondary succession are strongly influenced by pre-disturbance conditions, including soil development, seed banks, remaining organic matter, and residual living organisms
- Because of residual fertility and pre-existing organisms, community change in early stages of secondary succession can be relatively rapid
- Commonly observed following natural disturbances such as fire, flood, and severe winds, and human-caused disturbances such as logging and agriculture
- *An example of Secondary Succession by stages (See Fig. below)*:



1. A stable deciduous forest community
2. A disturbance, such as a wild fire, destroys the forest
3. The fire burns the forest to the ground
4. The fire leaves behind empty, but not destroyed, soil
5. Grasses and other herbaceous plants grow back first
6. Small bushes and trees begin to colonize the area
7. Fast growing evergreen trees develop to their fullest, while shade-tolerant trees develop in the understory
8. The short-lived and shade intolerant evergreen trees die as the larger deciduous trees overtop them; the ecosystem is now back to a similar state to where it began.

Mechanisms of succession

According to Clements (1961), succession is a process involving several phases:

- *Nudation*: Succession begins with the development of a bare site, called nudation

(disturbance)

- *Migration*: It refers to arrival of propagules
- *Ecesis*: It involves establishment and initial growth of vegetation
- *Competition*: As vegetation becomes well established, grow, and spread, various species begin to compete for space, light and nutrients
- *Reaction*: During this phase autogenic changes such as the buildup of humus affect the habitat, and one plant community replaces another
- *Stabilization*: A supposedly stable climax community forms.

Succession of animal communities

- Animal communities also exhibit changes with changing plant communities
- In lichen stage the fauna is sparse, and comprises few mites, ants and spiders living in the cracks and crevices
- The fauna undergoes a qualitative increase during herb grass stage
- The animals found during this stage include nematodes, insects larvae, ants, spiders, mites, etc
- The animal community increases and diversifies with the development of forest climax community
- At climax, the animal community may comprise invertebrates like slugs, snails, worms, millipedes, centipedes, ants, bugs; and vertebrates such as squirrels, foxes, mice, moles, snakes, various birds, salamanders and frogs

Microsuccession (serule)

- This is the succession of micro-organisms including fungi and bacteria occurring within a microhabitat
- This type of succession occurs in recently disturbed communities or newly available habitat, for example in recently dead trees, animal droppings, exposed glacial till, etc
- Microbial communities may also change due to products secreted by the bacteria present
- Changes of pH in a habitat could provide ideal conditions for a new species to inhabit the area
- In some cases the new species may outcompete the present ones for nutrients leading to the primary species demise
- Changes can also occur by microbial succession with variations in water availability and temperature

Succession and wildlife management

- All wildlife species have adapted features that allow them to exploit unique parts of an environment and plant community
- Each species acquires energetic and nutritional resources by foraging on specific foods that are available in a particular successional stage of one or more plant communities.
- As a plant community's composition and structure change, so do the food and cover resources it provides
- Therefore, the wildlife community that a tract of land supports changes as ecological succession progresses
- Wildlife management success is achieved by manipulating the natural processes that determine the type of plant community that exists in an area
- One important objective for managing habitats is to create the specific type of plant community that provides the energetic, nutritional and cover requirements of wildlife throughout the year
- Landowners can affect the plant community or successional stage by manipulating the frequency, timing and intensity of disturbances
- Practices such as planting shrubs, fertilizing a food plot or flooding a crop field will increase the rate of plant succession
- Practices such as prescribed fires, disking, mowing, herbicide applications, timber stand improvements and tree harvests will set back plant succession
- Effective wildlife management depends on recognizing the successional stages to which a species has adapted and conducting appropriate habitat management practices to create and maintain those specific plant communities throughout the year

Global wildlife distribution patterns

- Species are not uniformly spread among Earth's biomes
- Tropical areas generally have more plant and animal biodiversity than high latitudes, measured in species richness (the total number of species present)
- This pattern, known as the latitudinal biodiversity gradient, exists in marine, freshwater, and terrestrial ecosystems in both hemispheres
- Why is biodiversity distributed in this way? Ecologists have proposed a number of explanations:
    - Higher productivity in the tropics allows for more species;

- The tropics were not severely affected by glaciation and thus have had more time for species to develop and adapt;
- Environments are more stable and predictable in the tropics, with fairly constant temperatures and rainfall levels year-round;
- More predators and pathogens limit competition in the tropics, which allows more species to coexist; and
- Disturbances occur in the tropics at frequencies that promote high successional diversity.

- Of these hypotheses, evidence is strongest for the proposition that a stable, predictable environment over time tends to produce larger numbers of species
- For example, both tropical ecosystems on land and deep sea marine ecosystems—which are subject to much less physical fluctuation than other marine ecosystems, such as estuaries—have high species diversity
- Predators that seek out specific target species may also play a role in maintaining species richness in the tropics.
- It is well known that trends in the distribution of species follow some patterns.
  - Primates and their relatives are generally found in tropical areas, and kangaroos are limited to Australia and some nearby islands.
  - Elephants occur in Africa and parts of southern Asia,
  - Polar bears and walrus are found only in Arctic areas of northern North America and Asia.

- Based on the distribution of species and groups of species, we can perceive the world as consisting of a series of biological regions, or biomes
- Biomes are largely defined in terms of climatic patterns
- Understanding the factors that produce the major biomes of the world can provide important insights into the factors that have led to the incredible diversity of life that surrounds us.
- Two general classes of factors have led to the observed distribution of life.

1. **Historical factors** include such events as the advance and retreat of glaciers, the lifting of mountains, formation of islands, and the slow but inexorable shifting of the continents across the surface of the globe.

2. **Ecological factors**, and include such things as the timing and distribution of rainfall, annual (and extreme) temperatures, the influence of latitude, and proximity to oceans or other large water bodies, and
    - Wild animal species geographical ranges are restricted by: both **physical factors and biotic factors.**
        - The most important physical factors that affect wild animal distribution are rainfall and temperatures
        - Important biotic factors are;
            - Predation – predator distribution is influenced by prey population and vis vasa.
            - Competition – mainly interspecific – recall the concept of competitive exclusion
        - Intraspecific competition affects habitat selection

3.0 WILDLIFE POPULATION ECOLOGY

DEFINITIONS

Species

- A group of closely related organisms that are very similar to each other and are usually capable of interbreeding and producing fertile offspring

Population

- A collective group of individuals of the same species occupying the same geographic area at the same time and have the potential to reproduce with one another

Population ecology

- A sub-field of ecology concerned with populations and how they interact with their environment

POPULATION GROUP ATTRIBUTES

- A population has biological attributes which it shares with its component organisms/individuals (e.g. growth, differentiation, self-maintenance, organization structure)

- Importantly, however, a population also has group attributes (e.g. density, birth rate, death rate, age or stage structure, sex ratio, etc.) unique to the group and not shared with component individuals

POPULATION DENSITY AND ABUNDANCE

- Population density is population size relative to some unit of space (number of individuals or population biomass per unit area or volume)
- It is important to distinguish between **crude density** (the number per unit of total space or area) and **specific** or **ecological density** (number per unit of habitat space or area)
- **Population abundance** is the total number of individuals in a population
- Because population abundance may change very rapidly or may be difficult to measure directly, indices of relative abundance may be useful (e.g. number of birds seen per hour, or percentage of sample plots occupied by a given species)
- As with other population attributes, population density or abundance can be quite variable, often within definite upper and lower limits

POPULATION GROWTH RATES

- Often, we are interested not only in the change in population size, but also the rate of this change
- A rate is obtained by dividing the change by the period of time corresponding to that change
- ***Absolute growth rate*** = change in the number of organisms per unit time
- ***Specific growth rate*** = absolute growth rate divided by the total population size

NATALITY

- This is the birth rate of a population
- Two types:
    - ***Maximum natality*** = theoretical maximum production of new individuals under ideal conditions (no ecological limiting factors, reproduction being limited only by physiological factors; It is constant for a given population
    - ***Ecological or realized natality*** (or just ***natality***) = population increase under an actual or specific environmental condition; It is not constant for a population but may vary depending on population size, composition and physical environmental conditions

- Can be expressed as:
  - ***Absolute natality rate*** by dividing the number of new individuals produced by time
  - ***Specific*** or ***percent natality rate*** by dividing the number of new individuals per unit of time per unit of population size, N
- N may represent the total population or only the reproductive part of the population
- For vertebrates, it is customary to express natality rate per female (thus N = number of females)
- Natality rate can never be less than zero

MORTALITY

- Refers to the death rate of individuals in a population
- Two types:
  - ***Minimum mortality*** = the loss under ideal or non-limiting conditions; Constant for a given population
  - ***Ecological or realized mortality*** = the loss of individuals under a given environmental condition; Varies with population size and environmental conditions
- Can be expressed in two ways:
  - ***Absolute mortality rate*** = the number of individuals dying per unit time
  - ***Specific*** or ***percent mortality rate*** = the number of individuals dying per unit time divided by the total population size

POPULATION AGE DISTRIBUTION

- This is the distribution of individuals across different age classes in a population
- Age distribution strongly influences population processes (especially natality and mortality) of most vertebrate species
- In terms of natality:
  - Reproduction is usually limited to certain age groups (usually middle age groups)
  - In ungulates, birth rate are generally lower in the youngest and oldest reproductive age classes; under less favorable environmental conditions, reproductive rates decline most in these age classes (see Tables below)
- In terms of mortality:
  - Mortality varies with age except under Type II survivourship

- Generally, high birth rate or high mortality rate (if probability of death increases with age) shifts population toward a younger population

- Consequently, the ratio of the various age groups in a population determines the current reproductive status of the population and indicates future patterns
- Usually, a rapidly expanding population will contain a large proportion of young individuals and vice versa
- Populations have "normal" or **stable age distribution** toward which actual age distributions tend
- A population is said to have a stable age distribution if the proportion of each age class in the population remains constant through time
- A special kind of stable age distribution is the **stationary age distribution** which occurs when both the relative and absolute numbers in each age class remain constant
- Thus, stable age distribution occurs:
    - In populations increasing or decreasing at a *constant* rate, i.e., constant birth and death rates in each age class
    - In stationary populations where the difference between births and deaths equals zero (stationary age distribution)
- Once a stable age distribution is achieved, unusual changes in natality or mortality result in temporary changes only, with spontaneous return to the stable situation
- Age structure can be represented graphically with a population pyramid (see Fig below)

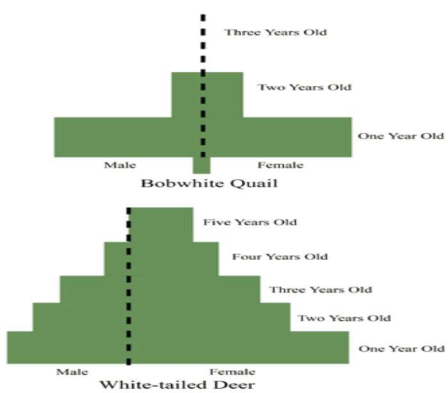


Figure. Age pyramids for bobwhite quail and white-tailed deer.

- As evident from the Fig. above, most populations generally have younger cohorts that are larger in number than older cohorts

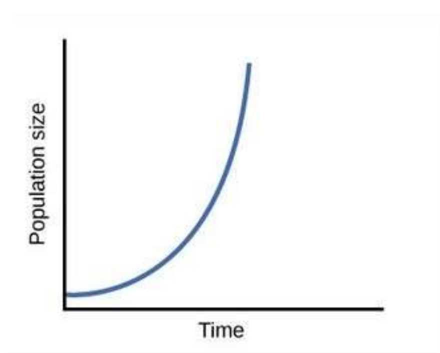
- The overall population specific growth rate (***r***) under unlimited environmental conditions depends on the age composition and the specific growth rates due to reproduction of component age groups
- When a stable age distribution exists, the specific growth rate under unlimited environment is called the ***intrinsic rate of natural increase*** (or ***biotic potential*** or ***reproductive potential*****)**
- The difference between biotic potential and the rate of increase which occurs in an actual field condition is called ***environmental resistance*** (the sum total of environmental limiting factors which prevent the biotic potential from being realized)

POPULATION GROWTH FORMS

- Population growth forms (or curves) are characteristic patterns of rate of change in population size
- The type of population growth form may give a hint as to the underlying processes controlling population changes
- In general, there are two idealized patterns of population growth: the ***J-shaped growth form*** and the ***S-shaped*** or ***sigmoid growth form***

J-shaped growth form

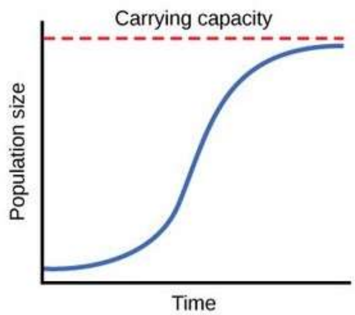
- Here, population density increases first slowly as the population establishes itself and individuals adapt to the new environment (LAG PHASE) then rapidly in exponential or geometric fashion (EXPONENTIAL PHASE) and then stops and crashes abruptly when environmental resistance (e.g. drought) sets in suddenly (See Fig below)



- This type of population growth is termed ‘density-independent’

S-shaped or ***sigmoid growth form***

- Here, population density increases slowly at first as the population establishes itself and individuals adapt to the new environment (LAG PHASE), then rapidly under minimal environmental resistance (EXPONENTIAL PHASE), but soon starts to increase at a decreasing rate as the environmental resistance increases (DECELERATION PHASE), culminating into a more or less equilibrium level called the carrying capacity (STATIONARY PHASE) (see Fig below)



- The upper level beyond which no major increase in population size can occur is called the ***carrying capacity***
- The carrying capacity is determined by the biotic potential of a population and environmental resistance
- This type of population growth is termed 'density-dependent' since growth rate depends on the numbers present in the population

DENSITY-INDEPENDENT AND DENSITY-DEPENDENT FACTORS

- ***Density-dependent*** factors affect the population depending on its size or density
    - Often direct, beginning to act well below the carrying capacity and intensify as the upper limit is approached
    - Examples include competition, predation, parasites, diseases
    - Considered one of the chief agents preventing over-population
- ***Density-independent*** factors affect the population regardless of the density or size of the population
    - Include climatic factors
- Density-independent factors tend to bring about variations in population size that cause a shifting of carrying capacity levels (population limitation), while density dependent factors tend to maintain a population in a steady state or to hasten the return to such a level (population regulation)

WILDLIFE POPULATION FLUCTUATIONS

- Wildlife populations do not grow indefinitely because density dependence tends to push them towards the carrying capacity, *K*
- However, populations do not often rest at *K*, but tend to fluctuate around it
- Such fluctuations can be of varying magnitudes (mild to dramatic) depending on the species and environmental conditions

Types of population fluctuations

- In general, the following four types of fluctuations can be discerned in wildlife populations:
  - Stable
  - Irruptive
  - Irregular
  - Cyclic

Stable

- Population size fluctuates mildly around the carrying capacity
- Characteristic of species living under fairly constant environmental conditions (e.g. undisturbed tropical rainforests)

Irruptive

- Population is normally fairly stable, but occasionally explodes (*irrupts)* to peak then crashes to a lower stable level below the carrying capacity
- Driven by environmental factors that temporarily increase carrying capacity
- Typical of rapidly reproducing species
- Examples of vertebrates: raccoon, house mouse, Yellowstone pronghorn (see White et al. 2007 abstract below)

Irregular

- Chaotic behavior in population size (no apparent recurring pattern)

- Often due to variation in density-independent environmental factors that have a large, immediate impact on population size (e.g. fires, catastrophes)

Cyclic

- Populations exhibiting periodic cycles hit peaks and valleys in abundance at regular time intervals (generally a multiple year cycle)

POPULATION DISPERSAL

- This is the movement of individuals into or out of the population or population area
- Through dispersal, young animals leave their natal home ranges and wonder to new locations hoping to establish their own
- Distances moved vary between species from less than one km in rodents to hundreds of km in carnivores
- Dispersal complements natality and mortality in shaping population growth form and density
- Dispersal is usually associated with high mortality rates as the dispersing animals are young and inexperienced and the environment unknown, often inhospitable and dangerous
- Dispersal is influenced by barriers and the inherent power of movement of individuals (vagility)
- The barriers include mountains, deserts, rivers, predators, oceans, highways Importance
- Importance of dispersal:
    - Dispersal complements natality and mortality in shaping population growth form and density
    - Maintenance of genetic variability within a species – avoidance of inbreeding which can lead to genetic depression
    - Repopulation of depleted areas
    - Colonization of new habitats as they become available.
- The effect of dispersal on a population depends on:
    - The status of the growth form of the population (how far it is from the carrying capacity level or whether it is actively growing or declining)
        - Dispersal will have more pronounced effect if the population is well below or above the carrying capacity
            - For example, immigration may speed up population growth or, in case of extreme reduction, prevent extinction
        - However, if the population is close to the carrying capacity, dispersal will have minimal effect

            - Here, dispersal gains or losses result in compensating changes in natality and mortality
    - The rate of dispersal
        - Rapid or large scale immigrations or emigrations are more likely to result in pronounced effects than are gradual or small scale dispersal movements
- Three forms of dispersal: ***emigration*** (one-way outward movement), ***immigration*** (one-way inward movement) and ***migration*** (periodic departure and return)

Migration

- Migration is a special form of dispersal which often involves the mass movement of the entire population
- In modern usage the term is usually restricted to regular, periodic movements of populations away from and back to their place of origin
- A single round trip may take the entire lifetime of an individual, as in some fish species or an individual may make the same trip repeatedly, as with many of the migratory birds and mammals
- The animals may travel in groups along well-defined routes; or individuals may travel separately, congregating for breeding.

Importance of migration

- Makes possible occupation of regions which would be unfavourable in the absence of migration
- Enables animals to maintain a higher average density and activity rate even during unfavourable periods

Why migrate?

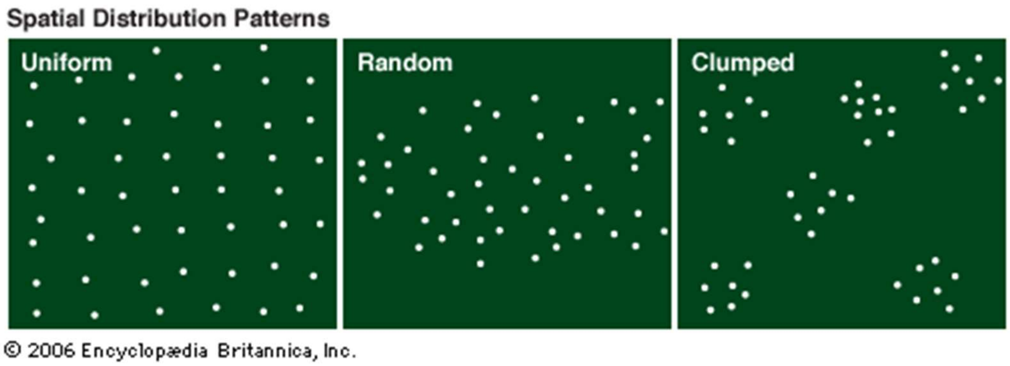
    - Seasonal migrations occur in many species of insects, birds, marine mammals, and large herbivorous mammals
        - These migrations often provide the animals with more favorable conditions of temperature, food, or water

    - Many birds and a few bats of cold and temperate regions migrate to warmer areas during the winter
    - Herbivores of cold regions have summer and winter ranges; many herbivores of warm regions, such as the African antelopes, migrate seasonally to avoid drought
- In many cases the chief function of migration is to provide a suitable place for reproduction, which may not be the place most suitable for the feeding and other daily activities of adults. For example:
    - Hundreds of thousands of gnus (wildebeests) of E Africa take part in annual migrations to calving grounds
    - Many fishes migrate to spawning grounds, and in some cases this involves a change from saltwater to freshwater (e.g., salmon) or vice versa (e.g., freshwater eels)
    - Sea turtles seals, and many sea birds come ashore to breed, and most amphibians gather near water at the breeding season
    - Fur seals and many whales make ocean voyages of thousands of miles to their breeding grounds, the former coming ashore on islands
    - Such migration is seriously affected by the increasing rate of destruction of natural habitats
- Animals also migrate to areas that may be safer for the young because of fewer predators or more shelter from predators

POPULATION SPATIAL STRUCTURE

Internal distribution patterns (dispersion)

- This is the way a population is spaced across an area
- Driven largely by the supply of food and other resources
- Three broad patterns of spatial distribution of individuals within a population:



- **Random**
  - Individuals are scattered randomly across a landscape without any particular pattern.
  - In other words, each individual is equally likely to occur anywhere within the population
  - Occurs where resources are distributed evenly/uniformly or sporadically
  - No strong effects of competition or environment on the distribution
  - Very rare in nature
- **Uniform**
  - Organisms spread out in a fairly regular pattern
  - Occurs where competition between individuals is severe or where there is antagonism that promotes even spacing
  - Additionally, may be due to some regularity in the distribution of resources
- **Clumped**
  - In a clumped distribution, individuals occur in high density patches, separated by areas with few, if any, individuals
  - Found in places where resources are patchy
  - For example in drylands, mammals have a clumped distribution because of the patchy distribution of waterholes
  - Can also be due to mutual attraction among individuals
  - The most common pattern in nature
  - While the distribution of individuals within a population may be clumped, the distribution of the clumps may be random, aggregated or uniform

- Determination of the type of distribution is necessary if population density is to be measured correctly
- Thus sample methods and statistical analyses which would be applied for random or uniform distribution may be inadequate for strongly clumped distributions

Aggregation

- Clumping is the result of aggregation of individuals driven by the following factors:
    - Local habitat differences
    - Daily and seasonal weather changes
    - Reproductive processes
    - Social attractions
- Therefore, the degree of aggregation found in a given population depends on the strength of these factors
- Aggregation may increase competition between individuals, but this can be counterbalanced by increased survival of the group (e.g. reduced predation, modification of the microclimate)
- The degree of aggregation, as well as the overall density which results in optimum population growth and survival varies with species and conditions
- Therefore, based on ***Allee's principle***, undercrowding (absence of aggregation), as well as overcrowding, may be limiting

Isolation and territoriality

- In wildlife populations, certain forces may bring about isolation or spacing of individuals, pairs or small groups in a population
- Isolation is usually the result of:
    - Inter-individual competition – nearby individuals are eliminated by the most vigorous
    - Actual directed antagonism – individuals avoid or are driven out of the immediate area already occupied
- Both cases may result in random or uniform distribution
- Individuals, pairs, or family groups of vertebrates commonly restrict their activities to a definite area called the ***home range*** (or ***territory*** if actively defended)
- Territoriality is most pronounced in vertebrates with complicated reproductive behavior patterns involving net building, egg laying and parental care)
- Territorial behavior is mostly restricted to breading season
- It results in reduced competition, conservation of energy during critical periods, prevention of overcrowding and exhaustion of food supply

READING ASSIGNMENT

Laws of population ecology

POPULATION DYNAMICS AND WIDLIFE MANAGEMENT

DEFINITION AND IMPORTANCE

- Population dynamics is concerned with spatial and temporal changes in population attributes (e.g. abundance, density, age class distribution, death rates, birth rates, spatial distribution and sex ratio) and the biological and environmental processes that influence those changes
- Population dynamics is an important tool for **Wildlife Conservation and Management** as it allows us to:
    - Identify the relative importance of environmental or biological factors affecting a population, including the impacts of invasive or introduced species
    - Understand how human activities impact wildlife populations
    - Assess the status of endangered or threatened wildlife species and their likelihood of extinction
    - Control of populations of problem wildlife
    - Ensure sustainable wildlife harvesting

REASONS FOR POPULATION DECLINE

- Adverse habitat change
- Competition from other species
- Excessive hunting and predation
- Disease

ANALYSIS OF FACTORS UNDERLYING POPULATION DECLINE

- We can achieve this by comparing a healthy and a declining population of the same species
- This can reveal if hunting, diseases, human settlements, habitat degradation, competing species, predation are having a role

- If no obvious reasons emerge, then detailed work is necessary to determine age-specific birth rates and death rates
- If habitat change is the reason, we would expect to find high rates of juvenile mortality and low birth rates in the first mature age group
- If birth and mortality rates are both high, predation or hunting could be the problem.

POPULATION CONTROL

- Control implies the reduction of animal populations to some predetermined levels
- In rare cases it can imply elimination of a species from an area
- Control can be done directly on the animals themselves e.g. culling, or by manipulating the animal‘s habitat

Culling

- Examples of when control may be necessary:
    - Culling of individuals infected with a disease
    - Overpopulation (e.g. elephants in Shimba Hills national Park)
- To stabilize a population at an arbitrarily level, a constant proportion of individuals are removed

Habitat manipulation

- Can be achieved via:
    - Controlled burning
    - Cutting vegetation
    - Fencing
    - Application of fertilizers

ANALYSIS OF POPULATION DYNAMICS

- Controlling wildlife populations requires analysis of population dynamics
- This analysis requires data such as birth and death rates
- Sometimes, modelling may be necessary to predict future trends in population size
- A population model can be regarded as a book keeping system for keeping track of the four components of population change (births, deaths, immigration, emigration)
- Notably, population models have limitations (see below), necessitating combining

modelling with ecological monitoring

Basic equations for open and closed populations

- For 'open' populations, the general population model can be expressed mathematically as:

  $N_{t+1} = N_t + B_t - D_t + I_t – E_t$

  Where:
  N_t = the size of a population at some arbitrary time t
  N_{t+1} = population size one arbitrary time unit later
  B_t, D_t, I_t and E_t = total number of births, deaths, immigrations and emigrations, respectively, within the time interval from t to $t + 1$.

- In terms of change,

  $N_{t+1} - N_t = B_t - D_t + I_t – E_t$

- For 'closed' populations:

  $N_{t+1} = N_t + B_t - D_t,$ with change being expressed as $N_{t+1} - N_t = B_t - D_t$

Modelling density independent population growth
Thomas Malthus (1978) recognized that populations have an intrinsic tendency toward exponential growth

- Assumptions:
  - Population growth or decline follows an exponential curve
  - Per capita growth rates are constant
  - No underlying genetic variation between individuals with regard to reproduction and survival
  - No age, stage or size structure – There are no differences in survival and reproduction among individuals due to their age, stage or size
- Typical exponential growth situations:
  - Where a species has naturally colonized or has been introduced by humans into a new and acceptable geographic area
  - Where a species has been greatly depressed by human activities and such activities cease
- The growth of such populations can be calculated either as a discrete process using the geometric model or as a continuous process using the exponential model

Geometric model

- Relies on the use of the difference equation
- Applicable to populations with discrete or non-overlapping generations
- These include populations of many mammals in seasonal environments, like most big game species which tend to have birth/death pulses at defined times of the year
- In such species, all young are born within a few weeks of one another during a particular season
- Two general equations can be used:

  $N_t = \lambda^t N_0$ OR $N_t = N_0 (1 + R)^t$
  Where $R = b - d$, and is called the **discrete growth factor** (sometimes called **geometric rate of increase**); b = per capita birth rate and d = per capita death rate
- Also:

  $$\frac{\Delta N_t}{N_t} = R$$
- The quantity (1 + R) is often given its own symbol, λ (lambda), and is called the **finite rate of increase**

Exponential model

- Applicable to populations with overlapping generations (i.e. continuous reproduction)
- For example, humans (and many great apes) have overlapping generations as do many small mammals (rodents) and many invertebrates in non-seasonal environments
- Relies on the use of the differential equation:

  $N_t = N_0 e^{rt}$

- The symbol r is called the **instantaneous rate of increase,** the **intrinsic rate of increase** or the **Malthusian parameter**
- Notably, r is a *per capita* rate (an average rate taken over all individuals in the population)
- Its units are *individuals per individual per unit time*
- *When* $r < 0$, population decreases, $r = 0$, population stable and $r > 0$, population increases
- Also:

  $$\frac{(dN/dt)}{N} = r$$

Modelling density dependent population growth

- Population growth can follow the exponential model only under special circumstances and for short periods of time
- In most cases, according to Verhulst's Law:
  - As N increases, resources become limited and intraspecific competition becomes important
  - As N increases, density-dependent factors adversely affect the population's vital rates (mortality, survival , and/or birth rates), leading to a decrease in population growth rate

- When population sizes are small, competitive pressures are released and growth rate increases
- Therefore, per capita population growth rate is not constant, but depends on population size (i.e, density dependent)
- A population growing according to the logistic pattern would have slow growth when N is small, grow most rapidly when N is of intermediate abundance, and grow slowly again as N approaches carrying capacity

Characteristics of the logistic growth pattern

- An S-shaped curve results when population size is plotted against time
- The curve has an upper asymptote called the carrying capacity (K), the maximum population size at which the growth rate = 0
- Deceleration in population growth is smooth as it approaches K; thus, when the curve is cut in half, the upper and lower halves are mirror images
- The point at which curve could be cut in half is called the inflection point, which occurs at $K/2$, the steepest point on the curve
- The maximum population growth rate (i.e. the maximum sustainable yield) occurs at $N = K/2$

Assumptions of the logistic growth model

- Because the logistic model is derived from the exponential model, it shares the assumptions of no genetic variation or age structure in the population
- But because resources are limited in the logistic model, the following additional assumptions apply*:*

1. The carrying capacity is a constant;
2. Birth and death rates change linearly with population size (it is assumed that birth rates and survivorship rates both decrease with density, and that these changes follow a linear trajectory);
3. The interaction between the population and the carrying capacity of the environment is instantaneous: that is, the population is "sensitive" to the carrying capacity with no time lags;
4. Abiotic, density-independent factors do not affect birth and death rates (no environmental stochasticity);
5. Crowding affects all members of the population equally.

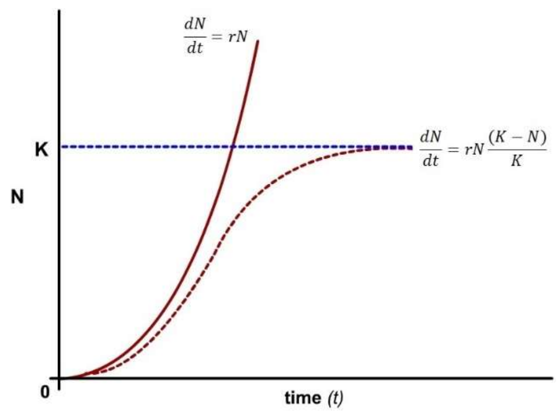
Discrete time

- The difference equation for logistic growth is given by the logistic equation: $N_{t+1} = N_t + rN_t(1-N_t/K) = N_t[1+r(1-N_t/K)]$, where r is the intrinsic rate of increase for an infinitesimally small population and K is the carrying capacity

- When the rate of increase has slowed to the point that births equal deaths, then the population has reached its carrying capacity *K*
- The parameters *r* and *K* dictate how fast the population recovers from any perturbation

Continuous time

- Use the differential equation:
  $dN/dt = rN(1-N/K)$, where r is the intrinsic rate of increase



- Through integration, this equation becomes:

  $N_t = K/[1+ (K/N_0-1)e^{-rt}]$

Importance of using population models

- Population models can be used to predict the result of some management action; such as banning consumptive use of wildlife or change in harvesting strategy
  - Would the population increase after such an intervention?
  - Would change in harvesting result in a larger harvest or a sustainable population?

Limitations of using models

- Assumptions in models may be inaccurate
- Environment may at times be unpredictable

WILDLIFE SPECIES INTERACTIONS AND RELATIONSHIPS

- No organism exists in isolation; each participates in interactions with other organisms and with the abiotic components of the environment
- Species interactions may involve only occasional or indirect contact (predation or competition) or they may involve a close association between species
- Such interactions can lead to various outcomes:
  - Beneficial to both as in mutualism
  - Beneficial to one and harmful/detrimental to the other
  - Beneficial to one and neutral to the other
  - Detrimental to both

ASSIGNMENT

Describe six various types of ecological interaction between species, giving at least two relevant examples in each case.

COMPETITION AND ITS MANAGEMENT

What is competition?

- Ecological competition is the struggle between two organisms for the same resources within an environment
- Competition can occur among individuals of the same species (intraspecific) or among individuals belonging to different species (interspecific).

Forms of competition

Exploitation

- Exploitation competition occurs when individuals use a resource so that less of it is available to others

- It includes both removal of resource (consumptive use) when food is consumed and occupation of a resource (pre-emptive use) when resources such as nesting sites are used

Interference

- Interference competition involves the direct interaction of individuals through various types of behavior
- For instance the exclusion of some individuals from territories or the displacement of subordinate individuals by dominants in a behavioural hierarchy

Conditions for competition

The following conditions must be met for competition to be considered to be occurring:

1) Fitness of competing individuals must be affected – i.e. resource shortage must affect reproduction, growth or survival and hence the ability of individuals to pass their genes to the next generation
2) Competition cannot occur unless the shared resource is in short supply or access to that resource by one organism is impaired by another
3) The amount of resource available to each individual must be affected by what is consumed by other individuals. Thus, two species cannot compete if they are unable to influence the amount of resource available to the other species, or to interfere with that species obtaining the resource.

Interspecific competition

- Here, individuals of one species suffer reduction in fecundity, survivorship, or growth as a result of exploitation of resources or interference by individuals from another species.
- Interspecific competition can take place between closely related species as they compete for the same resources that are limited - for example, competition between Grevy's zebra and plains zebra
- However, it can also occur between unrelated species – for example, in certain shallow lakes of South America, the visiting flamingoes and native fishes compete for the same zooplankton as their food
- Usually, competition occurs when resources are limited, but in some cases, resources need not be limiting for competition to occur. Specifically, the feeding efficiency of one species might be reduced due to the interfering and inhibitory presence of the other species, even if the resources are in plenty. For example, Abingdon tortoise in Galapagos Island became extinct within a decade after goats were introduced into the island due to the fact that the goats had greater browsing efficiency than the tortoise

Resource partitioning and coexistence

- Gause's Competitive Exclusion Principle states that two closely related species competing for the same limited resources cannot exist together because the competitively inferior will be eliminated
- Consequently there is usually resource partitioning, a mechanism meant for co-existence of species

- According to the principle of resource partitioning, if two species compete for the same resource, they could avoid competition by choosing different parts of that resource.

Interspecific competition models

- Competition can be modelled using Lotka-Volterra models. These models examine changes in abundance of one species while in competition with another species.
- Based on these models the predicted outcome of competition between the two species can be as follows:
  1) Species 1 is stronger competitor, so 1 wins (Figure a below)

  2) Species 2 is stronger competitor, so 2 wins (Figure b)

  3) Both species are stronger competitors on each other than on themselves, so may exist in unstable coexistence (Figure c)

  4) Both species are weak competitors, so exist in stable coexistence (Figure d).

Apparent competition

- This is a form of competition between a species or group of organisms indirectly competing with another species or group of organisms, which both of them serve as prey of a predator
- This competition occurs when the first species increases in number. This, in turn, results in the increase in number of predators in the area. With the increase in the number of predators, this also means that there are more predators hunting for the other species in the area

- It is termed apparent competition because it produces the same changes in prey populations as would be expected from intra-specific exploitation competition.
- Examples of apparent competition include:
    1) In Kruger National Park, predators are causing the demise of secondary prey, the roan antelope
    2) Wildebeest in Lake Manyara National Park because of high abundance of buffalo, the primary prey.
- If two prey species live in the same habitat as in the wildebeest and buffalo example, then at high intensities of predation coexistence is unlikely. Conversely, coexistence is promoted if the two species select different habitats (niche partitioning).
- Another version of apparent competition can occur through shared parasites; one species can be a superior competitor if it supports a parasite which it transmits to a more vulnerable species. For example, when gray squirrels were introduced to Britain, they brought a parapox virus that reduced the competitive ability of the indigenous red squirrel.

Applied aspects of competition

Conservation of endangered species

Where we have to protect an endangered species from competition with another (common) species, it is important to detect the presence, form and source of competition. For example, dwindling population of roan antelope (rare species) in KNP was erroneously associated with competition with wildebeests leading to culling of wildebeest. However, it was later discovered that roan population was actually being suppressed by predators supported by an abundant zebra population (apparent competition). The following lessons can be learnt from this:

1) Simple measures of resource overlap or changes in resource overlap may not be sufficient indicators of competition
2) Observations that an increase in a common species is correlated with a decrease in the rare species does not mean that direct competition is the cause; apparent competition could be.

Therefore, in addition to these measurements, we need to measure:

1) Resource requirement
2) Availability of limiting resources and demonstration that one is in short supply
3) Predation rates on both the target species and alternative prey.

Managed systems

For instance, rangelands and forests where there could be competition between domestic spp. and wildlife

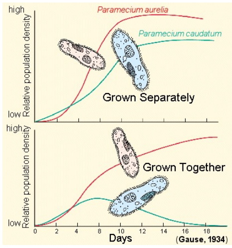
Species introductions

If we want to introduce a new species to a system, e.g., a new game bird for hunting and there could be competition from other resident species

Measuring interspecific competition

Laboratory experiments

- These involve simple, controlled environments where competing species are grown together and separately (Figure below) and their performance (e.g. growth) is measured and compared between the two treatments.

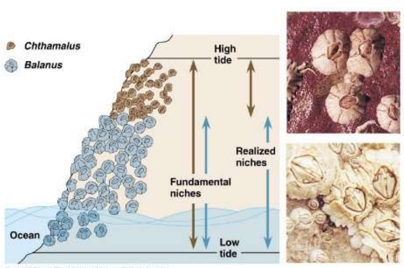


Manipulative field experiments

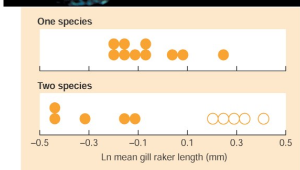
- Here, the density of one species is reduced and then the response of the other species is measured. In is suitable for sessile organisms.

Natural experiments

Competition can be evidenced by competitive release, a phenomenon in which a species whose distribution is restricted to a small geographical area due to presence of a competitively superior species, expands its distributional range when the competing species is experimentally removed. In other words, competitive release results in expansion of a species' niche in absence of competitor compared to niche size in presence of competitor (Figure below).



Competition can also be evidenced through character displacement - morphological difference between allopatric (species alone) and sympatric (species together) populations (Figure below).



Problems with food supply measurement

- The information required to determine whether competition for resources such as food is the cause of population regulation include the type of food eaten, how much food is required and how much food is available
- However, nutrient requirements are unknown for most wildlife species, and approximations from other, often domestic, species are often used. But these approximations are often inaccurate because nutrient requirements for domestic species are believed to be far much different from those of wildlife species. In addition, the actual amount of food available to animals is difficult to assess because most animals forage selectively. As such, indirect assessment of competition through the use of indicators such as body condition may be preferable.

Effects of competition on a population

Competition causes mortality and influences birth rates through starvation, increased vulnerability to disease, etc. These effects become more severe with increasing population and this moves the population towards K.

Managing competition

Can be achieved by adjusting animal numbers, kinds/classes and manipulating the habitat.

Adjusting animal numbers- If the population density is low relative to forage availability, it is expected that both intra- and inter-specific competition will be minimized. Animal numbers can be managed in a variety of ways including hunting/harvesting, grazing exclusion, etc.

Kinds/classes of animals - Because of resource partitioning between species, having the right kind of animals i.e. animal species with little or no resource overlap may be key in controlling competition. In particular, non-native species are known to compete more intensely with native species, and this should be taken into account before introducing such species

Habitat management - Managing habitat to increase its carrying capacity is another way of minimizing competition within and between species. Some habitat management techniques include grazing management, fire, re-seeding, bush control.

PREDATION AND ITS MANAGEMENT

What is predation?

Predation is an interspecific interaction, where one animal (predator) kills and consumes whole or part of the other animal (prey). The term predation therefore excludes scavengers or detritivores which eat dead material. Broadly, herbivores are the predators for plants; the problem of predation is more severe for plants than animals because plants cannot move.

Ecological importance of predation

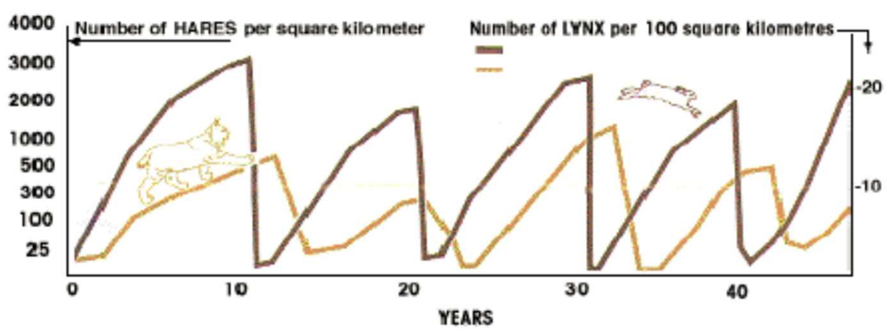
Predation serves various ecological functions including:

1) Predation is a way to transfer the energy from one animal to other; thus, predators are important in an ecosystem as they act as ‘conduits’ for energy transfer to higher trophic levels
2) Predators keep the prey population under control, which otherwise reach very high population density and cause imbalance in the ecosystem
3) Predators help in maintaining species diversity in a community by reducing the intensity of competition among the competing prey species
4) Sometimes predators can be used as biological control for pests

Predator-Prey Relationships

Predator-Prey Cycles

Interaction between predators and their prey change in cycles. The cycles are characterized by sharp increases in numbers followed by seemingly periodic crashes. Classic example snowshoe hare (prey) and Canadian lynx (predator) - See Fig below



Predator-prey cycles can be explained by two hypotheses:

1) Top-down control hypothesis (example):
   - Cycle controlled by the predator at the top
   - Lynx prey on hare, reducing hare population
   - Fewer hares support fewer lynxes

- Causes periodic reduction in lynx population
- Lag-time, offset from hare reduction
- Reduced numbers of predators (lynx) allows population of prey (hare) to recover and increase
- Increased numbers of prey (hare) support increased numbers of predators and lynx population increases
- Cycle continues
- Doubt has been cast on this explanation because snowshoe hares have been found to exhibit similar 10-year "boom-or-bust" cycles on islands where lynx are absent

2) Bottom-up control hypothesis (example):
    - Rather than cycle being driven by predator at top, it might be driven by food source of prey (hare) at the bottom
    - Reduction in quantity or quality of food source (plants) of hare leads to crash of hare population
    - Fewer hare support fewer predators and lynx population crashes
    - Reduction in hare population gives plant population time to recover
    - Increased plant population supports more hares and hare population increases
    - Increased hare population supports more lynx and lynx population increases
    - Cycle continues, driven by plant availability
    - Genuine examples of both top-down and bottom-up control exist in nature

Consumer-resource networks

Predator-prey interaction can be represented graphically as consumer-resource interaction networks (See Figures below).

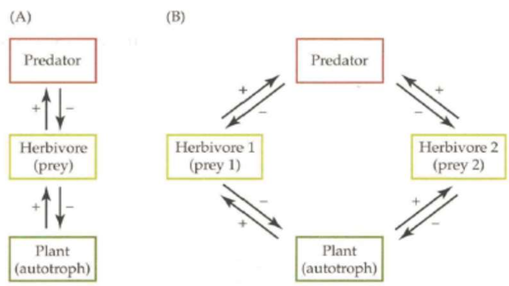


Figure 5.1 Simple consumer–resource interaction networks: a food chain (A) and a food web (B). Consumer–resource links (represented by arrows) are the building blocks of these networks. Plus signs next to the arrows indicate positive effects on consumer species from eating a resource species; minus signs indicate negative effects on the resource species being consumed.

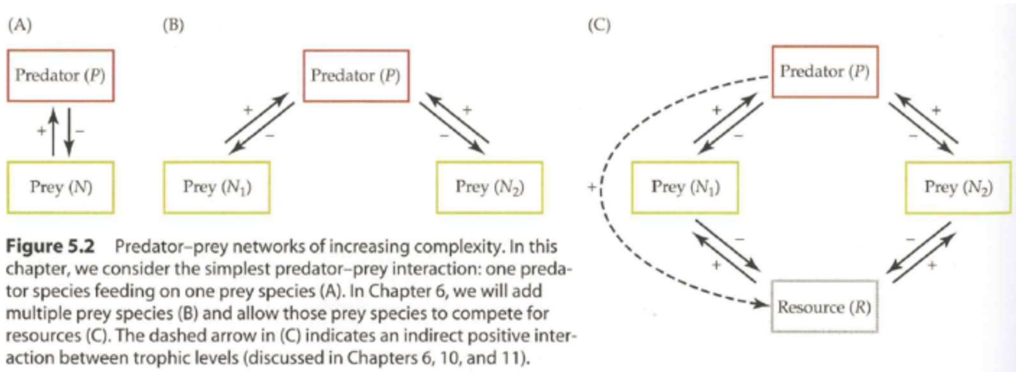


Figure 5.2 Predator–prey networks of increasing complexity. In this chapter, we consider the simplest predator–prey interaction: one predator species feeding on one prey species (A). In Chapter 6, we will add multiple prey species (B) and allow those prey species to compete for resources (C). The dashed arrow in (C) indicates an indirect positive interaction between trophic levels (discussed in Chapters 6, 10, and 11).

Response of predators to changes in prey density

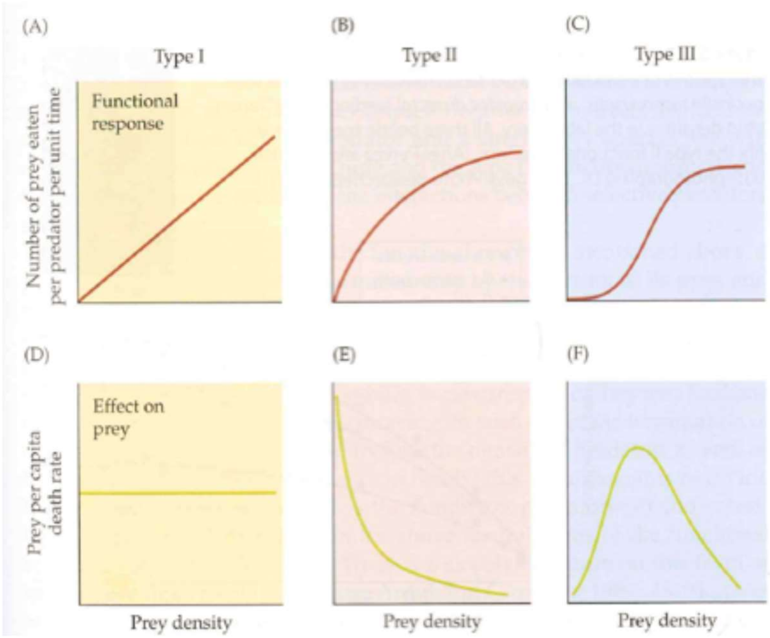
The response of predators to prey density depends on:

1) The feeding behavior of individual predators, which is called the functional response

2) The response of the predator population through reproduction, immigration, and emigration, which is called the numerical response

Functional response

The concept was developed by Holling 1959. There are three types of functional response – Type I, Type II and Type III



Type I

- Here, the number of prey caught by a predator will increase directly with prey density (Fig A above)
- Assumes that a predator 1) searches randomly for its prey; 2) has an unlimited appetite; and 3) spends a constant amount of time searching for its prey.
- Under Type I response, the proportion of prey population eaten remains constant irrespective of prey density (Fig D above).
- This type of response may be unrealistic (except for lower ranges of prey density) because: 1) No animal has an unlimited appetite
  2) A constant search time is unlikely as the predator will spend increased handling time at the expense of search time with increasing prey density.

Type II

- Here, the number of prey eaten per predator increases to an asymptote as prey density increases (Figure B above).
- Under this response, the proportion of the prey population eaten declines with increasing prey density (Figure E above).

Type III

- Here, the number of prey caught per predator per unit time increases slowly at low prey densities, but fast at intermediate prey densities before leveling off at high densities, producing a sigmoid curve (Figure C above).
- When the number of prey eaten is expressed as a proportion of the live population, the proportion consumed increases first, then declines (Figure F above).

Numerical response

- Numerical response is defined as the trend of predator numbers against prey density**.**
- As prey density increases, more predators survive and reproduce, resulting in an increase in predator population, which in turn eats more prey
- However, this increase becomes asymptotic (see Fig 10.6 below) because of interference behavior, such as territoriality, within the predator population**.** Territoriality results in dispersal so that resident numbers stabilize

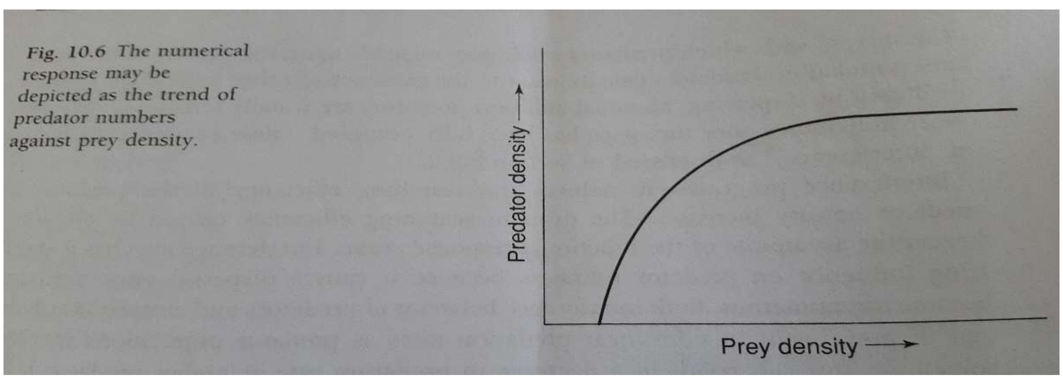


Fig. 10.6 The numerical response may be depicted as the trend of predator numbers against prey density.

Behavioural responses of prey to predation

Migration

Prey population can reduce predation by migrating to areas beyond the range of its main predators. This may work because unlike their prey (e.g. ungulates), predators with slow-growing, non-preccocial young are obliged to stay within their range to breed.

Herding

Animals can reduce the risk of predation by forming groups/herds/flocks, and group sizes should increase with increasing predator densities. The benefit of living in groups is however counteracted by the cost of intraspecific competition within the group. Therefore, there is normally a group size where the benefit-cost ratio is optimized.

Spacing

This is exhibited by female ungulates (e.g. impalas) when they give birth; they become solitary. This behaviour relies on predators spending most of their search time in high prey density areas, so solitary prey at low density experience a partial refuge and hence lower predation rates.

Birth synchrony

Prey species synchronize their reproduction to lower predation rate on their young, a behaviour called predator swamping.

4.4. Factors Affecting Predation

The effect of predation on wildlife varies temporally and is influenced both by anthropogenic and natural factors.

Short-term overabundance followed by sharp decline of a primary prey species

This can occur if the density of a primary prey species increases dramatically then declines suddenly and sharply**.** Hungry predators will then move to other (secondary) prey

Changes in habitat

This can cause prey to concentrate in certain areas, making them easy to catch. Example – large scale bush clearance (manmade) or drought-induced reduction of nesting cover (natural).

Unnatural prey concentrations

Such concentrations might occur around supplemental feeding areas or artificial water sources. This may attract predators who might find it easy to catch prey.

Population structure

Distorted population structure (e.g. sex and age ratios) of prey and predators may lead to increased predation.

4.5. Predation Management

Relevance: why should we worry about predation?

- For rare prey species, the presence of a predator can determine whether such species will survive or become extinct, especially if the predator is an introduced species. This is particularly important on small islands or isolated larger land areas like Australia and New Zealand.
- Where prey are pests (problem animals), predation may be useful as biological control agents. However, introduction of predators should be done with caution because it can lead to unintended ecological problems. For example, the small Indian mongoose and the stoat were introduced to Hawaii and New Zealand, respectively, to control animals considered as pests. However, these predators found the indigenous birds and small marsupial mammals easier to catch, making the predators a major problem.
- Finally, where harvesting of a prey species is the objective, the offtake of natural predators must be taken into account if the risks of overharvesting and decimation of the prey population are to be avoided.

Theories relevant to predation management

Two general schools of thought inform predation management of wildlife populations; top-down (predator-driven) and bottom-up (prey-driven) theories.

Top-down (predator-driven) theory

If predators are removed, prey (game) density will increase. This theory is relevant in implementing predator control measures.

Bottom-up (prey-driven) theory

According to this theory, prey track food availability and predators track prey density. It is relevant in implementing habitat manipulation to enhance prey density. The advantage of this approach over the top-down approach is that a predator may be a keystone species, and its removal may affect other species in the ecosystem.

Predator management methods

Non-lethal methods

Habitat enhancement

Involves manipulating the habitat to favour the prey species. This may range from strategic bush control (especially to improve the carrying capacity of large game), improving water supply to changes in grazing management. The goal is to improve habitability of the landscape for the prey species. This would enable the species to use the entire site to escape from the predator. To improve the habitat, it is imperative to understand the needs of the target prey species.

Predator translocation

Predators can be trapped using live traps and translocated to other areas

Fencing

Predator-proof fencing can ameliorate protection of prey species. However, this technique is not applicable to wild prey, especially where they are free-ranging.

Lethal methods

- These are methods that involve killing of predators
- Human-predator conflict (especially with regard to livestock depredation) usually results in lethal and illegal control of the predators, including poisoning, shooting and trapping
- Retaliatory killing of predators by livestock owners is common in most wildlife areas
- In some cases, there is pre-emptive killing of predators because of the perceived potential economic losses that can be caused by the predators
- Wildlife conservation authorities are forced to kill predators in response to complaint

from land owners.

- These methods are unethical and not recommended especially considering that most large carnivore species are experiencing human-driven global declines
- In Africa, several carnivore species listed as threatened by the World Conservation Union including:
    - Ethiopian wolf [*Canis simensis*], critically endangered;
    - African wild dog [*Lycaon pictus*], endangered;
    - African lion [*Panthera leo*], vulnerable;
    - Cheetah [*Acinonyx jubatus*], vulnerable;
- Conflict between people and large carnivores undermines the viability of populations that are nominally protected and those living outside reserves.
- Thus, shooting, poisoning, accidental snaring, and road accidents—occur mostly on or outside the borders of unfenced reserves and are particularly common where reserves are surrounded by areas supporting high densities of people
- This mortality creates population sinks around protected areas;

Mitigating these conflicts

- Habitat manipulation techniques
- Predator translocation
- Improved livestock husbandry:
    - Use of dogs as guards
    - Keeping livestock in secure enclosures at night e.g. use of predator-proof bomas
- Creating barriers/fences
- Relocation of human settlements
- Waste management to discourage overlap with wild animals
- Other strategies:
    - Compensation schemes
    - Insurance programs
    - Incentive programs
    - Community based NRM schemes

WILDLIFE HARVEST MANAGEMENT

6.1 What is wildlife harvesting?

Wildlife harvesting can be defined as the removal of wild animals from a population by humans. There are various forms of harvesting, including regulated sport hunting, trapping of animals, subsistence hunting, commercial harvesting, and collection of animals for pet trade.

6.2 Reasons for wildlife harvesting

Nutrition

Subsistence hunting provides substantial nutrients to humans, especially proteins. Here, the goal is to provide sustainable harvest to meet these nutritional needs

Economics

To subsistence hunters, harvested wild meat represents a source of food that would otherwise have to be purchased. Harvest for sale/profits, ranging from subsistence to commercial. Sport hunting produces benefits from license sales and taxes.

Recreation

Hunting provides recreational opportunities (i.e., opportunities for enjoyment, amusement of pleasure).

Culture

Hunting can be part of a society's cultural heritage. Hunting can garner respect for the hunter and produce culturally significant adornments (e.g. feathers) and trophies. In addition, cultural rituals and celebrations may centre on hunting. The goal here is to ensure sustainable harvest to sustain these cultural needs.

Management

Harvesting can be used as a tool to preserve populations and mitigate effects of human activities. Harvesting can be effectively used to reduce populations of overabundant wildlife, reduce human-wildlife conflicts, and control problem animals and eliminate invasive/exotic species. For example, predator removal can be used to enhance the growth of a prey population.

6.3. Management goals for wildlife harvesting

From a management perspective, there can be three goals of wildlife harvesting, namely, sustainable harvesting, population control and elimination of invasive/alien species.

Sustainable harvesting

Here, the goal is to maintain a positive growth rate so that there is a surplus available to harvest. After harvest, the goal is to sustain a relatively constant population size ($r = 0$ or $\lambda = 1$)

Wildlife population control

Sometimes the goal may be to reduce population size. This is often done with invasive or overabundant wildlife to reduce negative ecological effects, or reduce human-wildlife conflicts.

Elimination of invasive or alien species

Here, the goal is to harvest unsustainably to eliminate the population. In this case, the goal would be a decreasing population growth rate ($r < 0$ or $\lambda < 1$). Feral hogs in the southeastern U.S. and California provide good examples of elimination management programs.

6.4. Effects of harvesting on wildlife

Harvesting can have a variety of effects of wildlife, often detrimental, but sometimes beneficial from the population perspective. These effects are summarized below.

Mortality impacts

Harvesting results in reduced population density (this may not be necessarily a bad thing if a species is overabundant), reduced population growth rate, and population extinction.

Disturbance of unharvested animals

Harvesting can alter the behavior of non-harvested animals in many ways including:

1) These animals are forced to flee and abandon their preferred foraging sites
2) They also burn valuable calories in the process
3) They can also shift their activity patterns, use alternative routes, and avoid certain habitats, sometimes to their detriment

Alteration of sex ratios

Harvests can lead to unfavourable sex ratios, resulting in decreased reproduction.

Alteration of the genetic structure of population

Harvesting can operate as a powerful selective force that alters the genetic structure of a population.

Incidental take

Harvesting can negatively impact on the populations of non-target wildlife species.

Alteration of predator-prey relationships

Species that feed on the harvested population may decrease because of decreased prey availability. Also, removal of predators through harvest may impact on non-target prey populations.

6.5. Characteristics of species/populations that are amenable to sustainable harvesting

1) Should contain harvest ages with low reproductive value to minimize harvest impact on annual recruitment
2) Species have the potential to increase productivity with active management
3) Should have high reproductive rates
4) Should have life cycles that are completed within the management area which facilitates control over all sources of mortality and potentially illegal harvest.

6.6. Ecological concepts/principles relevant to wildlife harvesting

Compensatory vs. additive mortality

Harvest always results in mortality or removal animals from the population. Compensatory mortality occurs when increased survival, reproduction, or movement into the population offset the numerical effects of harvest mortality. Additive mortality occurs when the harvest mortality is additional to (i.e., over and above) the normal mortality in the absence of harvest. An example of the potential relationships between hunting mortality rate and realized annual survival is shown in the Figure below:

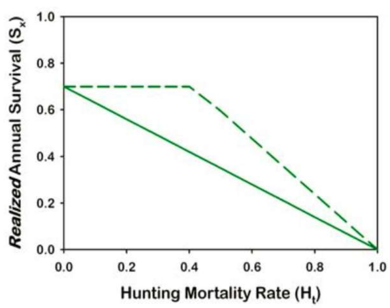


Figure. Realized annual survival as a function of hunting mortality rate under compensatory (the flat part of the dashed line) and additive (solid line) conditions.

Note that in this population (Figure above), the background (or unharvested) survival rate is 0.70 (or 70%). Hunting is additive when each additional mortality due to hunting decreases survival rate (solid line in the Figure). Hunting is compensatory when the realized annual survival rate does not change even when hunting mortality takes place (see the flat part of the dashed line in the Figure above). In this example, hunting is compensatory up to a hunting mortality of 40%, beyond which it is additive.

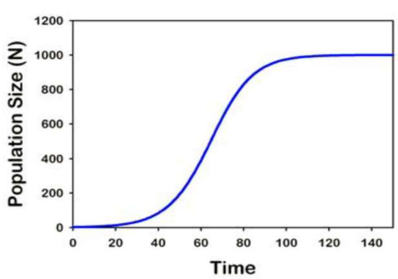
When harvest mortality is compensatory, then realized survival rate, S_t = background survival rate, S_0, irrespective of harvest mortality rate. When harvest mortality is additive, the relationship between realized survival rate and hunting mortality can be expressed as: $S_t = S_0\ (1.0 - H_t)$, where H_t is harvest mortality rate. For example, assume a harvest mortality of 0.4 and a background survival of 0.7; the realized survival rate would be: 0.7 (1.0 – 0.4) = 0.42.

Logistic population growth

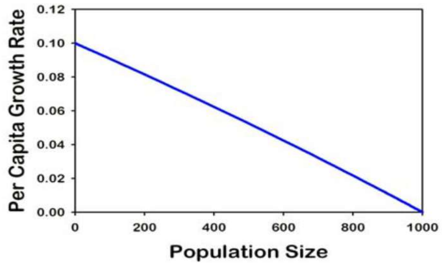
The logistic growth equation is a modification of the exponential growth equation (*dN/dt* = *rN*). The logistic equation includes a density-dependent feedback through a "carrying capacity" term (K) that slows population growth at high population densities by acting as part of a multiplier to the exponential growth equation as shown below:

dN/dt = rN([K-N]/K), where r = intrinsic rate of increase, N = population size and K = carrying capacity

Notice that the multiplier approaches 1 when population size approaches 0 (i.e., if N is nearly 0, then K/K must be nearly 1). As population size increases (i.e., N gets larger), K-N gets closer to 0 and the multiplier approaches 0. This relationship produces a sigmoid curve as shown below.



Under logistic growth, the relationship between per capita growth rate and population size is linear as shown below



As population size (N) nears carrying capacity (K), the multiplier ((K-N)/K) gets increasingly smaller, so the per capita growth rate is also smaller. This accounts for the density-dependent growth rates of populations that are limited by intrinsic forces like competition for food or space.

Maximum sustainable yield

An important aspect of the logistic growth model for harvesting populations is recruitment, or number of individuals added to the population. Notice the number of individuals added to the population (absolute recruitment) first increases, peaks, and then decreases (see Fig Below). The population size at which recruitment peaks is critical because this is where the highest number of individuals can be sustainably harvested.

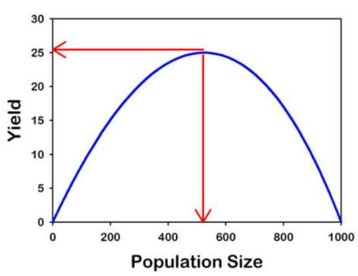


Figure. Yield (recruitment) vs. population size from the logistic equation.

The population size corresponding to the top of the recruitment curve (see Fig above) is the population size at which the maximum sustainable yield (MSY) is possible. The MSY is the highest number of individuals that can be removed from a population sustainably. In the Figure above, the MSY is about 25 individuals and the population size at which this can be accomplished is about 525. This is approximately ½ carrying capacity (K/2), meaning the MSY point corresponds to the inflection point in the logistic curve. Notice that at population sizes smaller than or larger than 525, fewer individuals can be sustainably harvested. This is because of the relationship between growth rate and population size:

- At < K/2, per capita growth rates are high, but the population is small, so few individuals are actually added (absolute recruitment is low)
- At > K/2, the population is large, but the per capita growth rates are small, so few individuals are actually added (absolute recruitment is low).

An important principle from this analysis of MSY is that maintaining a moderate-sized population will permit a greater harvest over time than maintaining larger population sizes

Additional principles of yield curves

Caughley (1976:227) provided the following additional principles about yield curves:

- If a population is stable in size (i.e., at carrying capacity), it must be reduced below that level to generate a harvestable surplus
- For each size to which a population is reduced, there is an appropriate sustained yield
- For each sustained yield other than the MSY, there are two population sizes from which it can be harvested

- There is only one population size at which an MSY can be harvested

Assumptions in using yield curves

Holt and Talbot (1978) provide assumptions in using yield curves:

- The population is more or less self-contained
- The population has attained, before exploitation began, a steady state at carrying capacity;
- There are no significant shifts in the carrying capacity during the period of exploitation
- Any time lags in the response of the population to exploitation are not such as to cause fluctuations of large amplitude in the population
- The process of reducing the initial population by exploitation is reversible

Carrying capacity

There are several different concepts of carrying capacity as highlighted below.

Ecological (K) carrying capacity

Ecological carrying capacity (K) is the maximum number of individuals of a given population that the resources of the environment can support sustainably. It is the equilibrium a population tends towards through density-dependent effects from lack of food, space, cover and other resources, and is represented by the asymptote of the logistic regression curve. A long-term environmental change can affect resources which in turn alters K.

I-carrying capacity

This is the population size that yields the maximum sustainable yield (MSY) and that occurs at the inflection point of the logistic curve.

Minimum impact carrying capacity

This is the population size that minimizes impact on other wildlife species (without eliminating the population). This definition includes a distinct value component: what is considered an impact relates to societal (human) objections.

Optimum carrying capacity

This is the population size that best satisfies human interests and expectations. Most of the time, populations are managed for optimum yield (or optimum carrying capacity) rather than maximum sustainable yield. This carrying capacity can be anywhere along the curve depending on the human interest to be maximized. When MSY is the goal, then optimum carrying capacity = I-carrying capacity. If the goal to be maximized is population size (say for an endangered or recovering species), then optimum carrying capacity = K-carrying capacity.

Economic carrying capacity

This is the population size that offers maximum economic returns and is determined by the economic objectives of the producers (i.e., by their definition of 'productivity').

Population explosion, crash and decimation

Any exploitation of an animal population reduces its abundance. Below a certain exploitation level, animal populations may be resilient, increasing their survival and/or growth rates and production rates to compensate for the individuals removed. Where populations are regulated primarily through density-dependent processes, exploitation rates (up to the maximum sustained yield) will tend to increase productivity and reduce natural mortality of the remaining individuals. Exploitation rates can reach a point at which extinction/decimation of the population will occur if continued

Harvesting may be used to prevent population explosion (the situation where herd size grows at an increasingly faster rate) from occurring. Population explosion is often followed by a dramatic drop in herd size, called a population crash, which is the ultimate disaster for any herd owner. Somewhere between no exploitation and excessive exploitation there lies a level at which the maximum sustained yield can be obtained. The maximum exploitation rate is at least partially a function of the biotic potential or production rate of the species.

Age structure

The age composition and the number of animals remaining after exploitation are key factors in the dynamics of exploited animal populations. Obviously, if exploitation tends to reduce the most fecund segment of the population, its effects on reproduction and survival of young will not be compensatory

Population and environment

Significant trends in carrying capacity are often related to changes in habitats, illustrating the intimate tie between population and environment. This implies that attempts to assess population response to exploitation without assessment of critical habitat factors will often be only partially valid.

6.7 Wildlife harvest strategies

Fixed-quota harvesting

This involves harvesting a constant number of individuals each year. This results in 2 “equilibrium points”, or population sizes at which the quota could be harvested; these two points are called sustained yield pair. In the Fig below, the Y-axis represents the number of individuals added to the population (recruitment) at a particular population size.

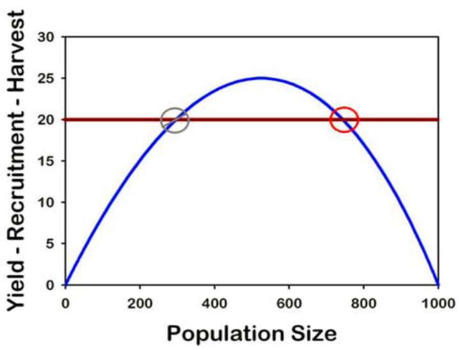


Fig. Recruitment curve for fixed quota strategy.

The lower density point is to be avoided because:

- More effort is required to harvest than at the higher density; and
- Any reduction in density below the lower point is an overharvest, and could lead to extinction of the population
- It is unstable because any decrease in density results in decreasing recruitment.

Merits of quotas

- There is a direct link between prescription (quota) and result (harvest), and this has an intuitive appeal to managers
- If quotas happen to be sustainable, then the enterprise profitability is likely to increase.

Demerits of quotas

- If quotas exceed MSY, populations would decline to extinction
- Quotas must be established based on knowledge of current carrying capacity. If this information does not exist, then the quotas would often lead to over harvesting and possibly extinction. Thus, long-term data (many years) about population dynamics help to reduce uncertainty about the true values of both carrying capacity and maximum sustained yield
- Harvesting a constant number of individuals (quotas) is inefficient when there are fluctuations in recruitment or population density. For safety, harvest quotas must be set low enough to match the lowest predicted recruitment
- Alternatively, managers must predict the population size for the upcoming year (to set quotas) using information from monitoring and census efforts; this can be both expensive and uncertain depending on the quality of the monitoring data.

Fixed-proportion harvesting

Here, a fixed percentage of the population is harvested each year. Thus, the actual number of individuals harvested each year will vary as the population size varies (see the Fig below).

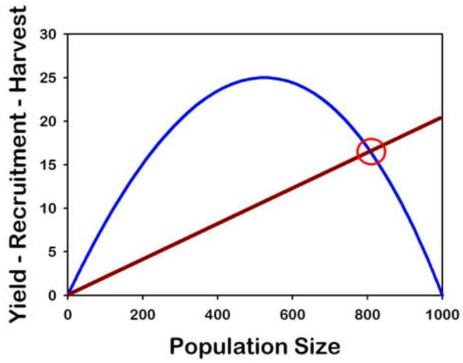


Figure. Recruitment curve for fixed proportion harvest strategy.

Advantage

- A key advantage of this strategy is that it generates sustained yield even with variation in environmental conditions (carrying capacity). When population sizes are high, a high absolute number of individuals are harvested; however, if population size decreases (perhaps due to a harsh winter), the absolute number of animals harvested decreases (even though the proportion harvested stays the same), and this allows the population to recover

Disadvantage

- Fixed-proportion strategies require accurate estimates of annual recruitment and population size each year. In the absence of this information, the risk of overharvesting is high

Constant-effort harvesting

Constant-effort strategies indirectly regulate the harvest by regulating hunter effort. The assumption is that hunter effort is related to harvest by the relationship: $H = qEN$, where H = Harvest, N = Population size, q = catchability coefficient, E = Hunter effort.

Effort is usually measured in person-days (or gun-days) or another similar measure. Catchability coefficient: for example, if one hunter covers 1% of the available habitat and 'captures' all the individuals encountered, then the catchability coefficient (or efficiency) would be 0.01. Notably, the size of the harvest should increase both with effort and population size.

With a large population (N = 1,000), the total harvest given 25 person-days of effort would be: $(0.01) \times (25) \times (1{,}000) = 250$ animals harvested. Now, assume the population declines because of unfavorable weather conditions (e.g., a drought, an unusually cold, snowy winter) to N = 400: $(0.01) \times (25) \times (400) = 100$ animals harvested.

Notice that the number of animals harvested changes in response to a smaller population size, even though hunting effort has not changed. Effort can be controlled through licenses (to limit number of people harvesting), restricted hunting seasons (limited time period for hunting), and spatial restrictions.

Advantage

- A key advantage of constant-effort strategies is that there is a built-in safety mechanism; when animal numbers are low, harvest levels drop automatically simply because the harvest becomes more difficult.

Fixed-escapement harvesting

Here, animals are harvested only when the population (or recruitment) exceeds some predetermined threshold (see Fig below).

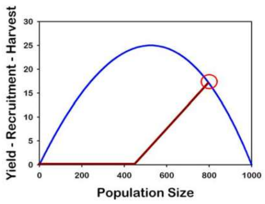


Figure. Recruitment curve for fixed escapement harvest strategy.

Excess individuals above this target threshold are termed escapement. The aim will be to remove the escapement and insure minimum level of population.

Advantage

Conservation, rather than harvest, is the primary goal (Sinclair et al. 2006) because this is, by far, the safest strategy for ensuring the persistence of the population.

Disadvantages

- It requires knowledge about annual recruitment or population size, which may be difficult to estimate accurately
- It may result in variable harvest sizes, leading to cash flow fluctuations

Spatial harvest strategy

This is an attempt to control effort by restricting hunting in some areas (management units) and allowing it in others. One approach to implementing this strategy may involve dividing the total area of interest into grid cells, each cell being a management unit. Alternatively, management units may be biological (e.g., physiographic regions, drainages, and watersheds that reflect more or less discrete animal populations), political, (e.g., counties), or a combination (e.g., a grouping of counties that closely match a biological unit).

Hunter effort (and harvest) can be controlled by varying the number of management units open to hunting

Advantages

- The key advantage of this harvest strategy is that as long as the unharvested areas contain a viable population, a sustainable harvest is practically guaranteed even if MSY is occasionally exceeded
- This strategy requires little specific information on recruitment

Disadvantage

- Requires information about harvest, habitat quality and general population dynamics (e.g. annual rate of increase), especially in unharvested areas, which may be difficult to obtain.

Adaptive harvest management

This is an approach that treats harvest strategies as a form of experiment, where the results of management are measured, compared against objectives and models, and then modified for improved management. This approach recognizes that there are several sources of uncertainty in any harvest management strategy. Its implementation involves the following five steps:

1) Objectives for harvest management must be identified. Examples of objectives include: ensuring population persistence, reducing human-wildlife conflicts, and providing a given number of hunting opportunities
2) Develop predictive population models to evaluate the potential outcomes of the different harvest options
3) Implement the harvest strategy favoured by the population models

4) Monitor the response of the population to the harvest strategy, and evaluate the strategy by comparing how well the predictions from the population model fit the monitoring data. In other words, assess how well the harvest strategy achieved the original objectives
5) Using the monitoring data, reassess the objectives (in 1 above), update and then improve the population models (in 2 above). The updated model is then used to evaluate modified harvest strategies, and the process continues.

6.8. Key considerations in wildlife harvesting

Age-Specific Harvest Considerations

Hunters often preferentially harvest certain age classes; for example recreational hunting typically favors mature adults (i.e., the bigger animals). However, different age classes have different survival probabilities, and make different contributions to the annual recruitment. Therefore, preferential selection of a given age class (or age classes) for harvesting may have implications on the future recruitment into the population. For example, harvesting very old individuals that are no longer fecund (and thus have low reproductive values) does not impact the future recruitment into the population. Also, harvesting very young individuals does not result in large impacts because such individuals have low reproductive values given that many of them would not survive to reproductive age ("numerical compensation"). In contrast, individuals in the early adult age classes have high reproductive values, and harvesting can result in large impacts on future recruitment. The high reproductive value of such individuals is because:

1) They have survived to adulthood and the probability of surviving to reproduce is now high
2) They are young and have completed very little of their lifetime reproduction

Thus, most of the future recruitment would come from these animals.

Sex-Specific Harvest Considerations

Sex of the individuals harvested is also an important consideration in harvest strategies. Harvests are often biased toward males because:

1) Males typically are larger in many hunted species (especially large mammals) and have the large antlers, tusks, horns, etc. that are the trophies sought by hunters
2) In some harvested species (those that are polygynous, like lek-breeding birds and many large mammals), one male can fertilize many females, thus a population that is skewed toward females can be favorable

Preferential harvesting of males provides for an increased harvest without impacting the reproductive capability of the population. For example, if a population is 80% female, then up to 80% of the population could potentially be bearing offspring. However, populations with sex ratios that are too strongly skewed can cause the following problems:

1) There may be too few males to successfully mate all females, and sometimes, if the number of males drops too low, then females engage in competition for the remaining few males, increasing female mortality and decreasing reproductive output

2) The few males remaining are often smaller because of selection for "trophy" characteristics. These characteristics may also be the ones that females use to select mates. The remaining small males may, therefore, be less likely to mate.
3) If there are only a few males, these must be protected (not harvested) to ensure adequate reproduction. However, males are often the most "profitable" component of the population to be harvested, because they are the trophies that hunters often value most. A female-skewed sex ratio may thus devalue the population.

WILDLIFE HABITAT ASSESSMENT AND MANAGEMENT

7.1 What is wildlife habitat assessment?

An organism's ability to survive depends in large part on the resources (e.g., food, water, and cover) available to it; these resources are provided by the habitat in which organisms live. Therefore, assessments of wildlife habitat are predicated on the basic assumption that at some level wildlife is controlled by its habitat.

Habitat assessment is the evaluation of the relative habitat conditions available to a focal group of wildlife. Habitat conditions are often used as a surrogate to make inferences about the presence, abundance, fitness, or productivity of wildlife populations, species, or communities.

7.2 Wildlife-Habitat Relationships

Each species is associated with or adapted to a fairly unique set of habitat conditions. Associations between wildlife species and their preferred habitats are often referred to as *wildlife-habitat relationships*. The range of habitat conditions that are acceptable varies considerably among species. Species that occur only in a narrow range of conditions are habitat specialists, whereas those that tolerate a broader range are habitat generalists. It tends to be easier to assess or predict the habitat relations of specialists than of generalists.

Habitat quality vs. species abundance

The assumption that the presence or abundance of a species reflects the quality of a given location as habitat is not always valid. An important aspect of habitat quality is the contribution of the habitat to the reproductive fitness of the population, and hence its ability to persist through time. In this regard, habitat quality may not be very well correlated with density. For example, in birds, territoriality may limit the number of breeding individuals that can occur in a particular forest stand, even one of optimal quality, and relegate non-breeding individuals to areas of lesser quality. Density may actually be higher in the low quality stand where no reproduction occurs. Likewise, areas of potentially optimal quality may be completely unoccupied by species that are rare, simply because of a lack of individuals to fill available habitat. These considerations notwithstanding, as long as managers are alert to this possibility, the assessment of habitat conditions based on density still can be a useful tool in evaluating and understanding the impacts of habitat alteration.

7.3 Purposes of Wildlife Habitat Assessment

1) A manager may simply want to assess the capability or likelihood that a given tract can support certain wildlife species

2) When declines in the abundance of a focal species are noted, wildlife managers may assess habitat conditions to determine if some degradation in quality may be responsible
3) Often, it is desirable to be able to predict in advance the impact of proposed land management activities, such as timber harvest or prescribed burning, on the quality of wildlife habitat.

7.4. Considerations in habitat assessment

Habitat Features

Before undertaking any assessment of habitat, it is essential to understand the habitat features are important to the focal species. A review of the literature or consultation with experts familiar with the species often is sufficient to determine these features. Assessment of these features can provide insights into the relative quality of habitat for wildlife. Habitat features can be considered as either macro or micro variables, roughly corresponding to the scale or perspective of measurement.

Macro Features

These are characteristics of habitats that are described across relatively large areas or within a landscape context. They can (and sometimes must) be assessed remotely via the use of tools such as geographic information systems (GIS), satellite imagery, or aerial photography. Examples of such variables include stand or patch size, shape, and age, amount of edge, vegetation cover type, and distance to other important features such as water, roads, cliffs, caves, or neighboring nesting/roosting sites.

Micro Features

These are habitat features that describe more site-specific conditions and must be directly assessed on-site. They most often include measures of vegetation structure and composition, though soil and topographic conditions are also critical to some species. In forested habitats, vegetative conditions are usually the most important habitat components for wildlife. Vegetation structure includes both vertical and horizontal aspects of density (e.g., stem density, foliage volume), and particular preferred plant species may need to be considered. Other specific features like snag (dead or dying standing tree) size and density (for cavity nesting birds and small mammals), burrows (for small mammals, reptiles, amphibians, and invertebrates), or the availability and quality of preferred browse plants (for browsers) may be measured.

7.4 Methods of habitat assessment

A wide variety of methods have been developed for vegetation sampling, from plot- or transect-based designs to plotless methods. The sampling method must be carefully adapted to the objective of the study. See Higgins et al. (2005) for a review of vegetation sampling methods applicable to wildlife habitats.

HUMAN-WILDLIFE INTERACTIONS AND CONTEMPORARY ISSUES

POACHING

Poaching is the illegal taking of wild plants or animals contrary to local and international conservation and wildlife management laws. Violations of hunting laws and regulations are normally punishable by law and, collectively, such violations are known as **poaching**.

“poaching” means illegal hunting, illegal capturing and illegal harvesting of any wild animal

In Kenya, all hunting is illegal as there is no legal hunting in Kenya. ―Hunting for the purposes of subsistence or facilitating the trade in wildlife products, particularly the bush-meat trade, is prohibited and any person engaging in such activity will be committing an offence and is liable on conviction to a fine or to imprisonment or to both such fine and imprisonment ‖ Wildlife Bill 2011.

Also ―sport hunting or any other recreational hunting will be committing an offence and is liable on conviction to a fine or to imprisonment or to both such fine and imprisonment‖

However in some countries that hunting is allowed e.g. Tanzania, South Africa e.t.c In modern times poaching may be illegal and in violation because;

- The game or fish is not in season; usually the breeding season is declared as the closed season when wildlife species are protected by law.
- The poacher doesn't *own* the land he is poaching on and/or hasn't got *permission* to hunt on that land
- The poacher does not possess a valid permit.
- The poacher is illegally selling the animal, animal parts or plant for a profit.
- The animal is being hunted outside of legal hours.
- The hunter used an illegal weapon for that animal.
- The animal or plant is on restricted land.
- The right to hunt this animal is claimed by somebody.
- The type of bait is inhumane. (e.g. food unsuitable for an animal's health)
- The means used are illegal (for example, baiting a field while hunting quail or other animals, using spotlights to stun or paralyze deer, or hunting from a moving vehicle, watercraft, or aircraft).
- The animal or plant is protected by law or that it has been listed endangered or in Appendix 1 of

  CITES
- The animal or plant has been tagged by a researcher.

Methods of Controlling Poaching.

- The military option Enforcement
- Alternative protein option _ to control subsistence hunting.
- International lobbying
  - to uplift legal protection
  - International trade : remove market : Appendix system of CITES

- Creation of protected areas
- Creating ownership at local level - Community conservancies
- Legislative provisions
    - Uplifting protection status
    - Laws
    - International conventions
- Discuss any other feasible

Human Wildlife Conflict Mitigation Measures

Causes of human - wildlife conflict;

- Lack of a country land use policy, which leads to incompatible land uses
- Increase in population therefore encroachment onto historical wildlife areas, corridors, dispersal/breeding zones and buffer areas

Types of human-wildlife conflict;

- Human Injury
- Human death
- Crop damage
- Property damage
- Livestock predation
- Human threats

Human-Wildlife Conflict Management

Human wildlife conflict continues to pose a big management challenge to KWS.

- This is largely due to the increased human population and the lack of a national land use policy.
- In the current draft wildlife policy and legislation KWS is encouraging community participation and collaboration in managing wildlife resources through devolved structures. An important aspect in developing a positive value of wildlife resource is to reduce the negative aspects of wildlife on human activities. Wildlife can be compatible to a greater or lesser degree with some form of land use, particularly pastoralism and ranching. However, densely settled areas & agricultural land are not compatible with many kinds of wildlife.
- In response to this, KWS has deployed the following management tools to avert the negative consequences of conserving wildlife or living with wildlife resources.
    - Erection of electric fences and otherand other forms of wildlife proof barriers This

barriers are erected where they serve as appropriate solution to persistent problem of damage to agricultural crops to or to property or other threats to people's livelihoods.

- KWS has erected fences along the perimeter of certain parks and reserves in order to minimize human wildlife conflicts. For example lake Nakuru National Park, Northern part of Nairobi National Park, Mt. Kenya National Park and Aberdare National Park. KWS has constructed and maintains a total of **1225 km of electrical fences** nationally with **888 km within protected areas and 337 km outside protected** areas.
- KWS also works closely with the provincial administration in dealing with the human wildlife conflict cases. Erecting and maintaining electric fences is an expensive venture. These are erected in consultation with the affected communities and funding support from the government and prospective donors. KWS also encourages communities to employ alternative methods of dealing with human wildlife conflict. Such as building of moats, trenches, natural fences using kay

apple, pilipili etc KWS - Community based initiatives
include: -

1. **Education and Awareness Creation :**

   There are many extension approaches/ mechanism adopted by KWS to stimulate local people to participate and benefit from wildlife conservation. This includes direct visit by community officers to the target individuals, short training courses/ workshops to sensitize and educate local people, preparation and presentation of specific wildlife related messages at Baraza's, organize exchange visits of the target groups to various wildlife areas, use of mass media in community education and sensitization programs and building capacity of local institutions and local communities to instill a sense of ownership and responsibility of the wildlife resource. This is a continuous process bearing in mind the emerging issues in Natural Resources Management.

2. **Social support programs**

   The principle is to give incentives to the local people who live in wildlife areas (dispersal area, & corridors) and who tolerate wildlife and, bear the cost of wildlife conservation. The cost borne may be in form of damage caused by wildlife or of — opportunity costs‖ lost such as not cultivating, not fencing or practice incompatible land use systems.

- To some stakeholders fences represent a physical and psychological barrier to their use of resources behind the fence. To others they represent a solution to the conflict between people and animals.

  Fencing projects must reconcile these differing views if they are to be successful.

- To some stakeholders - Elephants are too valuable to be destroyed as crop raiders because their full value cannot be realized when shot as crop raiders.
- Although the capital cost of a fencing project is very high compared to the damage caused by problem animals, fencing projects should not be judged solely by the success they have in reducing crop raiding.
- In the long term, they also have an important role to play in saving human lives and valuable animals, while maintaining the wild lands

How effective is an electric fence in reducing crop losses?

In most cases birds and insects cause as much loss to crops as wild animals do.

Elephants

Elephants are the most serious problem animals but can be deterred by a good electric fence. However certain individuals may repeatedly test a fence, resulting in regular breaks but infrequent penetration into the enclosed area. A 1.9m high fence appears to be successful in keeping elephants out.

Buffaloes

Buffaloes can break fences but usually cause little crop damage. They may _blunder' into a fence but retreat on being shocked. A buffalo is probably more of a threat to people than to crops.

Hippos

Hippos usually stay close to one site and are easily controlled with low electric fences. Hippos may however enter a fenced area at a river crossing.

Antelopes

An antelope such as a kudu may break a fence in the course of jumping over it. \

Bushpigs, baboons, lions and leopards

Electric fences are not very effective against bushpigs since they may dig under them. Similarly, small carnivores may dig under, or climb and squeeze through small gaps even in a fence where the wires are closely spaced. Baboons and monkeys can easily use trees to climb over the fence. Carnivores do not cause crop damage and primates can be chased away by watchful people during the day, bush pigs are often responsible for extensive crop damage, especially at night.

Problems of using electric fences

- Are expensive to construct at least US$ 20 per m. KWS 1225km- = about Ksh. 24, 500,000/= Require maintenance to be effective

Some members of community destroy fences in order to access resources e.g. pastures and watering points.