ECOLOGY

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I. INTRODUCTION TO ECOLOGY

Ecology is the scientific study of the interactions that determine the distribution and abundance of organisms. Ecologists are interested in where organisms are found, how many occur there, and why they are there. An operating unit in ecology is the ecosystem, an area where organisms are linked together with each other and with their physical environment through the utilization of energy and the cycling of matter. In this introduction to the principles of ecology we will first review the conditions necessary for life. After an overview of population ecology and community organization, we will look at the structure and dynamics of ecosystems.

II. CONDITIONS FOR LIFE

Temperature is one of the major factors that limit the distribution of plants and animals. Temperature variations affect survival, reproduction and development, and may limit the distribution of organisms indirectly by affecting the ability to compete or resist disease or predation.

Organisms have various strategies for dealing with temperature fluctuations in the environment. Some of these are behavioral, such as seeking sun in order to warm their bodies or shade to avoid hot sunlight. The evaporation of sweat and panting are used to rid the body of excess heat. The metabolism rate of some animals will increase in order to raise the body temperature during cold weather. Some cold tolerant poikilotherms* (including wood frogs, spring peepers, and many insects) can resist freezing in the winter by producing glycerol (antifreeze) in their body fluids. Other winter survival strategies include hibernation and winter dormancy. During hibernation the metabolic activity of the animal is reduced to a very low level. Heart rate, breathing and body temperature are reduced and the animal becomes unconscious, unable to feel or move. Only small homeotherms hibernate, and their body temperature is actually reduced toward ambient (surrounding air) temperature. New England hibernators include the woodchuck and little brown bats. Black bears do not hibernate but enter winter sleep. Unlike true hibernators, bears are capable of coordinated movements if aroused. Female bears give birth to their cubs and nurse them in winter dens. Metabolism, however, is reduced to about half of the normal rate.

MOISTURE

Moisture availability is critical to plant functions, and influences the distribution of plants both globally and locally. Land dwelling organisms have evolved adaptations such as waterproof skin to help them conserve water. While desert-dwelling organisms are adapted to conserve water, organisms in wetlands and aquatic systems are adapted to repel or remove water from their systems.

LIGHT

Light is the essential energy that powers ecosystems through the process of photosynthesis. Plants, algae and some bacteria use solar energy to convert carbon dioxide and water into carbohydrates (sugars). Chemical bond energy in the food molecules will be used by all of the organisms in the ecosystem.

PERIODICITY

Periodicity refers to the changes that animals and plants undergo on daily and seasonal cycles. Fluctuations in the duration and intensity of light result in physiological changes within the organism that results in behavioral changes. Circadian rhythm depends on the fluctuation between light and dark over a 24-hour period. For many animals, the time of day when there is a shift between light and dark (dawn or dusk) gives a signal to begin or cease activity.

SOILS

Soils are the base for terrestrial ecosystems. It is the place where organic material is decomposed and where mineral elements are returned to the nutrient cycle. Soil provides homes for animals, anchors plants, and is the source of their water and nutrients. Soil formation begins with the weathering of rocks; its development is governed by the slope of the land, a mineral composition of the rocks. Plants growing in the soil further its development by further breaking down the rocks, bringing up minerals from underground and adding organic material as they decompose. Soil horizons or layers result from the process of soil formation. Soils and horizons differ in texture, color, structure, moisture, and chemistry. Soil erosion is a concern worldwide, as the loss of valuable topsoil reduces food production and causes extensive economic losses.

III. POPULATION ECOLOGY

A population is a group of individuals of the same kind living in the same place at the same time. The size of a population in numbers related to the area that it occupies is its density (ie. Number of animals/square mile). Factors that affect the distribution of a species are both abiotic (non-living) and biotic (other organisms). Abiotic factors include temperature, light, soil structure, space, and chemistry of the soil, air and water. Other species affect the distribution through the process of predation, parasitism, competition and disease. Some organisms, especially plants, actually poison the environment for other species by producing toxins or antibiotics. Experiments have shown that certain plants produce substances that inhibit the growth of other plants. The roots of black walnut trees, for example, produce a substance that can kill apple trees, alfalfa and tomatoes.

Population size is influenced by the number of individuals added to the group by births and immigration and by the number leaving by deaths and emigration. Populations cannot increase indefinitely. As resources become less available to an increasing number of individuals, birthrates decrease, death rates increase, and population growth slows. Conversely, if the population declines, birthrates increase, death rates slow down and the population grows. The population arrives at a regulated density. This regulation involves competition with other members of the same species over resources. If resources are limited, some individuals may be weakened and become more susceptible to disease and predation or incapable of reproducing. Overcrowding may lead to dispersal, which results in some reduction of the population in the area but more importantly leads to population expansion.

DISPERSAL

Dispersal refers to the movement of species from higher to lower density areas. Animals may migrate, and aquatic and marine organisms can be carried to new locations by water currents. Dispersal strategies by plants include the production of large numbers of seeds adapted to be carried by wind or animals. Physical barriers such as mountains and water bodies impact dispersal and therefore the global distribution patterns of organisms.
One of the most noticeable forms of dispersal is the transport of species by humans. Physical barriers are crossed and if the introduced species finds favorable conditions their numbers may explode to occupy the new area. Often, the natural limits on the population growth of the organism (predators, disease) are missing from the new location, and they

can successfully crowd out native species. These introduced species, referred to as exotic species, are of concern because their presence can reduce the biodiversity of ecosystems.

Conversely, human activity has formed barriers within areas that were previously open to the movement of organisms. Habitat fragmentation and human exploitation of the landscape has caused many species of plants and animals to be reduced to isolated or semi-isolated small populations. One impact of isolation is that the number of potential mates is reduced and inbreeding may result. The lack of genetic variability can have an impact on survival and reproductive rates. Humans interact with natural populations in other ways, including reducing nuisance populations, maintaining stability and productivity of exploited populations, and increasing or at least maintaining populations of threatened and endangered species. Exploited populations are those that are harvested by fishing, hunting and trapping.

IV. THE COMMUNITY

A community is the assemblage of populations living in an area. Not all communities contain the same number of species. Most communities consist of a few common species and many rare species. According to the 1992 United Nations Earth summit, biodiversity can be defined as "the variability among all living organisms from all sources, including, 'inter alia', terrestrial, marine and other aquatic ecosystems, and the ecological complexes if which they are part: this includes diversity within species, between species and of ecosystems. There are three main levels of diversity:

- Genetic diversity-the diversity of the genes of both individuals and populations
- Species diversity-diversity among the different species of a specific ecosystem
- Ecosystem diversity-the higher level of diversity of ecosystems across the earth

Environments that have the greatest assortment of microhabitats and available niches will support the greatest biodiversity - tropical environments support more species in almost all classification groups than do temperate and polar regions. Communities are organized by relationships among the species that make them up. Relationships may be positive or negative, and include competition, predation, herbivory, parasitism and symbiosis. An organism's niche in the community refers to its role, which for practical purposes is linked to food supply. Thus, the niche of a deer is that of an herbivore that eats certain plant parts - it is not competing with a mouse which consumes a different plant diet.

The place where two different communities meet is an edge. The area where two communities blend is an ecotone. The edge may be produced by a feature of the landscape such as a water body or soil type or it may have been created by a disturbance such as fire or agricultural use of the land. Because the ecotone supports not only some species of the adjoining communities, but also a group of opportunistic edge species, edge is high in species diversity.

Communities may change over time through the process of succession. Old fields may become forests, abandoned beaver ponds may gradually fill in and become fields. Over a period of time, one group of plant species gradually replaces another. Lichens or plants that have high reproductive and dispersal rates may first colonize disturbed soils. These pioneer plants can stabilize the soil and alter its physical and chemical properties to the point that other species will be able to succeed. The pioneers will be replaced by another community of plants and associated animal life.

Disturbances are drastic events that disrupt communities and populations. The disturbance

changes resource availability, influences species composition, initiates succession, and adds diversity to the landscape. Natural agents of disturbance are wind, moving water, drought, fire, and animal activity including insect outbreaks. Humans cause disturbance by logging, cultivation, urbanization, pollution, and mining. Human activities have the most serious impact on natural communities by eliminating or reducing habitats and ranges of plants and animals, and introducing exotic species to the detriment of native species.

Fire is a major disturbance to terrestrial ecosystems. It is both beneficial and adverse. It results in loss of soil nutrients, but also makes nutrients available. It sets into motion regeneration of fire-adapted systems by stimulating root sprouting and seed germination. It can favor fire-resistant species and eliminate fire-sensitive ones, thereby influencing composition and structure of forest systems.

Response of animals to disturbance depends on the species. Short-term impacts are the loss of food and cover. Long-term effects may be the loss of habitat for some species and the gain of habitat for others. Some species depend on disturbance for the maintenance of their habitat, especially those associated with the conditions of early succession. Other species depend on periodic fires to maintain their habitat and to provide a variety of vegetation types required in their life cycle. A few fire-dependent species would go extinct without periodic fires to maintain their habitat.

V. ECOSYSTEM DYNAMICS

A major function of ecosystems is energy flow, which supports all life on Earth. Energy flows through an ecosystem from sun to plants to consumers. Plants use solar energy to make carbohydrate molecules, transforming the energy into plant material that can then be used by other organisms in the ecosystem. Plants are the producers in the ecosystem, providing energy that passes through food chains and eventually to decomposers. The energy stored by plants is passed along through the ecosystem through a series of steps, eating and being eaten, that makes up the food chain. As energy moves through an ecosystem from sun to plants to consumers, much of it is lost as heat. The loss of energy at each step of the food chain limits the number of possible steps to four or five. Food chains can be shown diagrammatically as a series of arrows, each pointing from one species to another for which it is a source of food, for example:

Grass -> grasshopper -> sparrow -> hawk

In reality, however, the feeding relationships are not as simple as a food chain indicates. Several organisms in the ecosystem will be feeding on the grass, and the grasshopper will have more than one predator. The food chains are interlinked, and these complex interrelationships are called a food web.

Feeding on plant tissues are the plant consumers, the herbivores. They convert plant tissue into animal tissue, and in turn make energy and nutrients available for the meat eaters or carnivores. Usually we think of carnivores as animals that kill and eat prey, but in a broader sense carnivores can include any organism that feeds on another organism or on the tissue of an organism. Using this definition, parasites would be included in this category. Not all consumers fit into feeding categories, as they can eat a variety of foods. Red foxes, for example, will eat berries, small rodents and even dead animals. They are therefore herbivorous, carnivorous, and scavengers. The food habits of many animals varies with the season, with stages in its life cycle (consider tadpoles and frogs), and with the size and growth of the animal.

Scavengers are animals that eat dead plant and animal material. Among them are termites and beetles that feed on dead and decaying wood and the numerous aquatic creatures that feed on debris on the bottom of a pond. Scavengers may be herbivorous or carnivorous. Saprophytes are plants or fungi that obtain their nourishment from dead plant or animal material. Many saprophytes can live in dark places like caves or underground because they do not need sunlight as an energy source. Decomposers include bacteria and fungi that transform large organic molecules into inorganic nutrients that can be used by plants.

Materials flow from the living to the nonliving parts of the ecosystem and back in continuous cycles. These biogeochemical (life-earth-chemical) cycles make needed nutrients available for all of the organisms in the ecosystem, and are closely linked to the water cycle. Most of the earth's water is in the oceans, with free fresh water that is available for organisms, making up less that 1- percent of the total water volume. Water moves through the water cycle by precipitation, evaporation, condensation, infiltration (soaking into the soil), run off, and transpiration. Human activity greatly alters the movement of water, for example paved landscapes and buildings will obviously have an effect of the pathway that water will take.

Nitrogen, oxygen and carbon dioxide are the major constituents of the atmosphere, and the cycles involving these gases are global in nature. Oxygen is a by-product of photosynthesis and is used during cellular respiration to metabolize carbohydrates, releasing energy, carbon dioxide and water. Oxygen is very active chemically, and is found in a large number of the chemical compounds that make up the earth's crust. Carbon is a basic constituent of all organic compounds and is a major element in the process of photosynthesis. During this process, solar energy is transformed into chemical energy and stored on the carbohydrate molecules. The source of carbon in both living organisms and fossil deposits is carbon dioxide, found in the atmosphere and dissolved in water. The carbon contained in animal wastes and in the bodies of plants and animals is eventually released to the atmosphere by decomposer organisms. Carbon dioxide in the atmosphere has increased markedly since humans started burning quantities of fossil fuels during the Industrial Revolution.

Nitrogen, an element essential to the structure of protein molecules, is made available to organisms when taken into plants in the form of dissolved nitrates. The

nitrogen cycle involves several types of bacteria that process nitrogen compounds. Mineral cycling is closely linked to the water cycle, as mineral compounds enter solution and are passed through ecosystems, enter the sea, or return to the earth's crust through sedimentation. Important to mineral cycling are green plants and decomposers. The plants take up nutrients, and the decomposers release and return them to the air or water. The functioning of ecosystems relies on the internal cycling of nutrients from soil to plant and back to soil.