NOTES ON ECOLOGICAL PRINCIPLES EASILY SEEN IN THE HALL OF SOUTHERN NEW ENGLAND NATURAL HISTORY

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The Biological Community or Biocoenosis

The Community Based on Plants

In every locality there is an assemblage of plants and animals which make up the biological community present at that locality. The existence of a biological community is always directly or indirectly dependent upon plants, for green plants (and a few purple and green bacteria) alone have the capacity to bring energy into the community, by converting sunlight into the chemical energy of the materials ordinarily thought of as foods. It would seem that the amount of solar radiation so captured by plants varies between zero on some deserts or snowfields up to about 0.25 per cent of the annual supply of sunlight in natural forests. In very favorable cases, with the best fertilization and cultivation, the efficiency can be raised on agricultural land to ten or more times the highest natural value. Shallow seas like Long Island Sound are more efficient as primary food factories than the average land, while the blue open water of the deep ocean is less efficient.

Plants More Abundant Than Animals

Plants are eaten by many kinds of herbivorous animals, varying in size from the most minute one-celled animals up to the elephant. On land, in modern Connecticut, the size range is from minute forms up to the deer. Most of the vegetation that is produced is, however, not eaten, and plants are nearly always the most conspicuous organisms in the landscape. As far as can be ascertained very roughly about ten per cent of the food made annually by plants is eaten directly by animals; about 30 per cent is used in the life processes of the plant and the rest is left at the fall of the leaves or the death of the plant to decay. The chief agents of decay are bacteria. This decaying plant matter is of the greatest importance in the formation of soil and also provides

Animals More Diverse Than Plants

a source of food for insects such as termites, or the grubs of beetles. The decay bacteria of the soil provide a source of food for an enormous number of animals such as earthworms, mites and minute insects. Since a single species of land plant produces many kinds of structures and products, it can give food and shelter to many kinds of animals, the latter, though less abundant than plants, are more diversified.

Food Chains

Many of the animals are eaten by other carnivorous animals, some of these carnivores are eaten by other carnivores, etc., so that in any community a series of *food chains* all starting with plants and ending with carnivorous animals can be recognized. In the sea or in fresh water lakes it is not uncommon to find food chains consisting of five or more links; on land the chains are shorter and seldom consist of more than three links. This is probably due to the fact that the carnivores on land are mainly warm-blooded and need a greater supply of food than the cold-blooded carnivorous fishes. Since most of the food produced by any set of equivalent links, or level, is not eaten, but is returned to the inorganic world by decay bacteria, long food chains are wasteful when a great quantity of energy must be consumed annually. (cf. the elimination of the middleman as a way of bringing down prices.). The largest animals, the whale-bone whales, are the terminal links of a three-link chain (microscopic plant-crustacean-whale). The slightly smaller brontosaurus downstairs fed directly on plants.

More Complex with Cold- Than Warm-Blooded Animals

Carnivores Usually Larger and Rarer Than Their Prey

In general the carnivorous members of a food chain are bigger and rarer than the herbivorous members. This is obvious when we consider that in most cases a carnivore must be bigger and stronger than its prey. It therefore needs to grow faster or longer than its prey and to use more energy in pursuit than the prey can use in flight. If the two were equally abundant the prey would soon be exterminated. The rule does not hold universally, as some carnivores become very small and tend to a parasitic habit (mosquito, flea) but it is sufficiently often true to insure that small animals should be much commoner than big ones. There are moreover many very large herbivores; these such as elephants, rhinoceros or deer, usually need patches of several different kinds of vegetation and terrain to make a satisfactory habitat. The pro-

Eltonian Pyramid of Numbers and Sizes

gressive decrease in numbers with increase in size is called the Eltonian Pyramid. In the open water of the sea the base of the pyramid embraces the minute but incredibly abundant plants, but on land the need for developing woody supporting material which is relatively inedible has enabled the plants, which must be far more abundant (in weight or volume) than animals, to escape from the size-number pyramid.

The Community in Time

Ecological Succession

If we start with any small region, left to itself, initially devoid of life but capable of being colonized from its surrounding, we shall find certain plants invading the area, and certain animals following the plants. On a bare rock, lichens will be the pioneers, on freshly broken inorganic soil (glacial till) various herbaceous weeds and grasses, in a body of water minute one-celled plants floating in the upper layers of the lake or pond. Gradually as these decay and liberate organic matter the habitat will change and more and more kinds of plants and animals will be able to colonize the area. Slowly the bare land will become a pasture and then will become covered with bushes, the rock will be hidden beneath blueberry plants, the lake will gradually fill in and become a swamp. In any climatically uniform area, the final stage of the process will in nearly all cases apparently be the same, the establishment of the climax community of the region, which in Connecticut is a hardwood forest (oak, maple, hickory) with its associated animals. This process is called ecological succession. In its simplest and most rapid form it can be seen wherever a piece of land has been cleared and then abandoned gradually, as has been the case too often throughout the whole of Connecticut.

Climax Tends to Be Same Whatever Starting Point Is Taken

Succession Easily Seen on Abandoned Farm Land

The nature of the climax is apparently primarily dependent on climate. Further north in colder climates coniferous forest prevails, further west under drier conditions the climax is grass-land. Each stage of succession is marked not only by plants but by the associated animals. The bird or insect community of abandoned farm land is conspicuously different from that of the succeeding woodland. In general it seems

Shoreline Diorama in the Hall of Southern New England: sea coast, salt marsh, and lowland farm.

Animals Most Varied Before Climax

Effect of Man is to Preserve Stages in Succession

that the *diversity* (i.e. the number of kinds that we may expect to find) of both plant and animal communities is not at a maximum in the climax forest, but at some intermediate stage in succession. In an undisturbed virgin region, practically the whole territory is covered by the climax, and earlier stages, initiated largely by accident (hurricanes, natural forest fires, landslips, etc.), are rather rare. Man, however, by disturbing the climax is apt to initiate succession on a grand scale. The whole ecology of Connecticut is determined by the continual artificial reestablishment of successional stages. Though man has exterminated some large carnivorous forms (e.g. wolf) and has introduced other species (e.g. English sparrow), his main influence on the fauna has probably been to increase greatly the abundance of species found in earlier successional stages and to reduce or eliminate those found only in the virgin climax forest.

The Relation of Individual Species to the Community (autecology; animals only treated.)

The Niche

The range of values of all environmental variables within which a species can live is called the niche of the species. Some animals have very wide niches and are likely to appear

in very different communities; others have very restricted niches and are strictly limited to single types of communities in which they may play limited and special roles. Particular interest is usually shown in species which have restricted niches but are common in the conditions under which they occur. Such species serve to define types of community, but they should not detract from the interest of other species that run through several diverse communities. Within the ranges of values constituting the limits of the niche there is an optimum value (e.g. optimum temperature within a wide range, optimum humidity, optimum composition of food, etc.) which permits the best development of a species. There is theoretical and empirical evidence that no two species co-occurring in a region ever occupy exactly the same niche. When a species that can occupy a niche, essentially identical with one already occupied, is introduced, naturally or artificially, into a region, competition occurs and the intruder either dies out or displaces the original occupant. When both old and new forms continue to co-occur, it is good evidence that the optima and limits defining the niches are not identical. The old broad niche of the original inhabitant will be split into two narrower niches if both new and old species persist.

No Two Species Occupy The Same Niche Permanently (Principle of Competitive Exclusion)

The characters of animals that enable them to occupy given niches are sometimes striking and obvious, sometimes

Adaptive Structures

very difficult to ascertain. The carnivorous dentition of the wild cat, the set of the feet of the creepers, the beautiful aerodynamic form of the swift, are obviously correlated with food habits, relation to substratum, and to the circumambient medium respectively. There is, however, nothing in the appearance of the Baltimore Oriole or the Purple Grackle to indicate that one is more social than the other, and nothing in the appearance of the Redwinged Blackbird to suggest an association with swampy ground. Further study usually shows that every species has physiological and behavioral characters appropriate to its niche, but often these can only be discovered as the result of prolonged research. In most cases we are entirely ignorant of the biological meaning of the differences that we use in classification.

Apparently Non-Adaptive Characters

Color Often Adaptive

Certain cases are known in which it appears that characters separating closely allied species are of value to their possessors. This is particularly true in the case of the colors of certain insects. Grasshoppers at rest are often remarkably difficult to detect, and certain species occupying restricted niches, such as the Ledge-locust, are colored with great accuracy to blend with their specific habitat. Some species, however, are most conspicuous when they leave the ground and take to the wing, becoming inconspicuous when they settle, so probably confusing predators as much as they do beginners in entomology.

Warning Color Hymenoptera

Other insects, notably wasps and bumble bees, are provided with stings, and their conspicuousness apparently advertises the inadvisability of attack. Other brightly colored species (monarch butterfly) may taste unpleasant. Yet other insects (wasp-like flies, viceroy butterflies) have developed the warning color without having noxious qualities; they are avoided as if noxious or unpleasant and are said to mimic the protected noxious species. The principles that have been developed to explain certain types of insect color appear however to have a very limited application in birds and mammals.

Mimicry

Life Zones and Climatic Determination of Distribution.

Zoologists have generally recognized in North America a series of climatic zones, fundamentally determined by the

heat available throughout the summer and the minimum temperature in winter. These zones are somewhat more restricted than are the great biological community types (biomes) represented by the hardwood or the coniferous forest. In Connecticut three life zones are present, namely, the Upper Austral or Carolinian Zone of the coast and of the Central Lowland of the state, the Transitional or Alleghenian Zone of the greater part of the hilly interior and the Boreal or Canadian in the highest parts of Litchfield County. At the present time it is often difficult to distinguish distributions due to these climatic zones from the effects of human disturbance which are likely to be greater in the more favorable Upper Austral Zone than in the higher northern parts of the state. The Snowshoe rabbit or Varying Hare is a typical example of a species avoiding the warmer Upper Austral Zone. One important aspect of the effect of climatic zones is shown in the development of races or subspecies within certain species, the different races differing slightly in color or size and being apparently adapted to rather different values of climatic variables. Thus in the farming district of southern Connecticut, in the Upper Austral Zone, the chipmunk is Fisher's Chipmunk, *Tamias striatus fisheri* Howell, whereas in the Transition zone of the northeast and northwest highlands of the state this is replaced by Lyster's chipmunk, *T. s. lysteri* Richardson, a paler form in which the bands on the back are gray rather than black. Other cases, dependent on skull characters and less suitable for museum display, are also known. The biological meaning of the differences between subspecies is seldom clear.

The Snowshoe Rabbit A Zonally Limited Animal

Variations of Chipmunks With Zones