THE IMPENDING EMERGENCE OF ECOLOGICAL THOUGHT

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Prologue

Ecology as an autonomous science has existed about as long as genetics, but ecologists have been exceedingly timid about becoming involved in public affairs. Individually, they have lent support to conservation groups in protesting the destruction of natural areas and some of the more flagrant cases of environmental pollution. But only rarely have they shown signs of genuine outrage as many did over some of the programs of predator control in the West.

For the most part, we have gone on learning more and more in the field and laboratory and ivory tower while adopting a somewhat detached and sometimes bemused attitude toward the activities of an ill-informed public. It is not a matter of any great import if people want to believe that the songbirds are protecting us from insect pests, and we do not begrudge a livelihood to those 'exterminators' who make their living by harvesting rats. There is even something amusing about 'sportsmen's' groups doing their civic duty by shooting crows or planting fishes, as though the female bass' 10,000 eggs per spawning or the pike's 100,000 is somehow inadequate — it conjures up a picture of someone importing acorns to scatter among the oaks.

But, in recent years, things have been happening that make the widespread ignorance of ecology seem more alarming than amusing. The human population of the world has entered a potentially disastrous cycle of growth; we are polluting the environment at an unprecedented rate, and with biologically active materials such as pesticides and radioisotopes to which the earth's biota has never before had to adapt; and, in one way or another — through erosion or paving or poisoning, we are removing vast areas from the cycle of photosynthetic productivity. Worst of all, our policy makers are seeking and obtaining advice on these problems from groups of scientists who do not even recognize the existence of ecology. Those of us who have spent our professional lives trying to understand the intricate mechanisms that regulate population size and the composition of biotic communities are not amused when chemists can obtain space in reputable scientific journals to assert that their employer's product is what regulates population size and community composition.

It will take volumes to bring even the scientific public up to date with what ecologists have learned that should be considered in seeking solutions to the crises facing mankind. But permit me to use the minuscule space allotted to me here to indulge in ecological meditation about one little problem — our current fascination with residual pesticides.

A Parable

In a small town where as a boy I spent several summers, there lived an old gentleman who professed the belief that a high concentration of ethyl alcohol in the blood would protect him from infectious diseases. The old man was ahead of his time; he was the first person of my acquaintance to advocate what we now call systemic pesticides.

A few years later, "wonder drugs," in the shape of the sulfas, appeared and showed much greater antibacterial activity than alcohol; then a great many physicians and veterinarians endorsed the old man's hypothesis that an animal body loaded with such chemicals would be protected from an assortment of important diseases. The chemicals became ingredients of such diverse products as foot powders and animal foods. Soon it was learned that sulfas might have side-effects even more undesirable than those of alcohol, but this was not too discouraging because, by this time, penicillin had appeared and seemed to be about as toxic as physiological saline to vertebrates. But there is no need here to review the history of chemoprophylaxis.

The old man's hypothesis is with us now in a slightly different form, represented by the intensive search for systemic insecticides. The rationale, of course, is to grow plants that will kill insects that touch them or bite them, and, for example, cattle that will cause bot flies to drop dead before they can damage the cowhide. It is argued that, even if people do not want to eat protected organisms, the approach can still be valuable for protecting ornamental plants, species producing fiber and lumber, and dogs, cats, and horses. A

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Fire . . . .

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poisonous soil or atmosphere can be regarded as sort of a systemic pesticide for the biotic community or superorganism so, in effect, our present practices are simply the analog of a clinical technique that has been tried and quite generally abandoned.

If the chemical defenses had lived up to expectations, a number of the most important infectious diseases would already have moved from the textbooks to the history books, but I am not aware that even one disease has done so as a result of all these efforts. What went wrong? Even in those pioneer days when penicillin was a novelty almost unavailable to civilians, a few geneticists were predicting (though not very loudly) that the bacteria would evolve resistant strains. But, to the best of my knowledge, ecologists were completely reticent about saying that these prophylactic measures were not very sensible ways of attacking such problems in the first place.

Some ecologists must have had doubts about these practices from analogy with the many broad-spectrum chemical defenses in nature that fail to defend. Toads will gorge on such poisonous insects as blister beetles, while snakes and crows eat the toads (poisonous skin glands and all) and so do skunks, which also eat the snakes, and which, in turn, are eaten by owls. And someone surely must have paused to wonder why, to obtain nicotine as an insecticide, it was necessary to treat the tobacco plants with lead arsenate to protect them from insects.

This is simply a manifestation of one of the most familiar of ecological generalizations. All ecological niches, or roles in the economy of nature, tend to be filled, and, if there is a way for another species to make a living in a community, we expect some species to evolve the mechanisms for doing so even if it requires drastic morphological and physiological modifications. Thus, all ecologists are aware of marsupials and placentals occupying comparable niches, even specialized ones such as the mole and anteater niches, in different regions. We teach about the finch that has learned to exploit the woodpecker niche, of lizards that substitute for grazing mammals, and of euphorbias that look like and live like cacti.

The general principle should be deducible *a priori* from the observation that, once a certain threshold is reached, organic matter is used up as rapidly as it is produced. It is true that organic matter accumulates continuously in peat bogs and that special conditions permit coal and petroleum to form, but these cases are clearly exceptional. The caloric value of the soil in a tropical rain forest or temperate deciduous forest or of arctic tundra is remarkably stable from year to year, and the same is probably true of most marine sediments. How very different things would be if even a few species had evolved chemical defenses that prevented digestion by any other species!

When once we accept the proposition that natural selection will operate in the direction of filling vacant ecological niches, we must logically begin to wonder whether total eradication of destructive forms is desirable. I have been fascinated to note that some leaders in medical research have recently arrived independently at the sound ecological conclusion that it might be more desirable to replace harmful viruses and bacteria with innocuous types than to leave niches open by trying to keep our bodies free of these forms.

By the same principle, the broad-spectrum antibiotic or pesticide is likely to empty not just one niche but several. Ever since antibiotics came into use, physicians have been plagued by secondary infections resulting from the destruction of an innocuous intestinal flora thus leaving ecological niches available for drug-resistant and pathogenic staphylococci. The same applies to biotic communities, and we have a wealth of examples of such secondary infections in which, for example, orchard mites replace the codling moth as the pest of apples and spider mites replace the spruce budworm as the defoliator of fir trees following the application of insecticides.

Another generalization of ecology, which has actually been noted for centuries by amateur naturalists, is that an environment with an ample food supply but special characteristics that make most organisms unable to adapt to it typically harbors enormous populations of a few species. Witness what Mark Twain said of a California lake containing "venomous water that would eat a man's eyes out like fire":

> "There are no fish in Mono Lake—no frogs, no snakes, no polliwogs—nothing, in fact, that goes to make life desirable . . . no living thing exists *under* the surface, except a white feathery sort of worm, one-half an inch long, which looks like a bit of thread frayed out at the sides. If you dip up a gallon of water, you will get about fifteen thousand of these. They give to the water a sort of grayish-white appearance. Then there is a fly . . . these settle on the beach to eat the worms that wash ashore—and any time, you can see there a belt of flies an inch deep and six feet wide, and this belt extends clear around the lake—a belt of flies one hundred miles long . . ."

The principle illustrated is of wide generality. Arctic waters contain fewer species than tropical waters, but far more individuals of each. The same applies to the tundra as contrasted with the tropical rain forest. This trend can be traced from cold springs to thermal springs and from low-altitude to high-altitude situations. And genuinely difficult environments, not only saline lakes but also sewage beds, sulfur waters, and the like, produce almost incredible concentrations of one or very few species. This would have to be so in view of our conclusion that organic matter tends to be used up. In an easy environment, many species participate in the task but, as the environment becomes more rigorous, fewer species occur and each is able to build up larger populations.

Now, as a general rule, about the last thing an agriculturist wants on his land is a tremendous concentration of individuals of one species of animal. Yet this is what he is asking for, under the laws of nature, when he makes the plants or the environment toxic and difficult to adapt to. Only a few kinds of animals can inhabit saline lakes, or eat blister beetles or hairy caterpillars, or attack skunks with impunity, but the specialists that can do these things find little competition and can build up populations commensurate with the food supply. So the animals that succeed in adapting to DDT or other toxins reach population levels far beyond what they could achieve without the toxin. I suspect that this would have become obvious and this general approach to pest control abandoned if it were not for the time factor. So many commercial crops are annuals, subject to damage only over a brief growing season, that the farmer who succeeds in avoiding pest damage for this critical period fails to recognize that his protective measures may be producing the counterpart of a saline lake. The problems are more difficult and the difficulties more apparent for perennial crops. Objective entomologists are aware (1) that chemical treatment has greatly reduced the number of pest species in orchards without necessarily reducing the amount of pest damage to the crop and (2) that the problems of dealing with, for example, the pests of apples are continuously increasing in complexity as chemical treatment increases. Most of my apple-growing neighbors now spray their orchards twelve times per year with mixtures of some five chemicals, and they worry incessantly about outbreaks of pests. They must worry because they are producing environments comparable in inhospitality to the tundra, where populations of voles and lemmings and foxes erupt and migrate and crash to an extent that has inspired legends.

Population eruptions do not occur in the tropical rain forest where there are a great many ecological niches, and all of these are filled. Every species there is beset by an assortment of predators and parasites which can turn on any adjacent species that begins to increase in numbers. Without alternative foods to maintain their numbers, predators are likely to be ineffectual in holding down prey populations. Consequently, as we move from the rain forest to simpler biotic communities with fewer alternative foods, we note instability of the predator-prey systems growing and reaching an extreme in the arctic.

All this suggests to an ecologist that clean cultivation, routine pesticide application, and other agricultural practices that reduce the diversity of species in the community may be working in exactly the wrong direction. A healthy, diverse biotic community is not easily invaded by exotic forms and has considerable ability to adjust to invaders. Thus we have seen the Japanese beetle invade new areas, become a major pest, and then decline to a minor status without human intervention. Similarly, our pondweed *Elodea* invaded England and choked major rivers, then declined and ceased to be a pest. Nonselective toxins must inevitably reduce the possibility of such mutual adjustment.

Turning again to the clinical analogy, we find that physicians have now largely discarded the old man's hypothesis of chemical defense except as a temporary emergency measure, as in cases of exposure to plague. They now treat the patient only when needed and, by preference, will use the most highly specific drug available for the particular infectious organism. This is ecologically sound and is the very way nature has designed our own bodies to function. Our bodies do subsidize predators, maintaining large populations of phagocytes which are quite non-selective of the invaders they attack. But when the body brings out its chemical pesticides, in the form of antibodies, these are exceedingly specific, as they should be. Too broad a spectrum of chemical defense results in allergic reactions in the human body and, I suggest, in the biotic community also.

Epilogue

For two years, the Ecological Society of America has had a Committee on Public Affairs, so now there is a place that our administrators and the public can turn to for competent advice on ecological problems. Another committee of the Society has in the planning stage an Information Center on Environmental Pollution. These, and other signs, indicate that ecologists are at last going to lend their specialized fund of knowledge to the attack on important public problems. My little discourse here has been intended to suggest that some of these problems will change in appearance when seen from the viewpoint of an ecologist. It is safe to predict that such viewpoints are about to emerge in increasing numbers from their sheltered retreats.