Vertebrate Ecology in Public Health

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MY OBJECTIVE IS to indicate the scope and place of vertebrate ecology in modern public health. Ecology is a term which has recently gained vogue; today an ecologist is almost never called upon to explain its meaning. Yet, because of the broad scope of the term—encompassing all interrelationships between an organism and its environment—he usually finds it necessary to specify the branch of ecology in which he has specialized.

If one accepts the literal definition of ecology, nearly every worker in the biological or medical field can be considered an ecologist, for each is concerned with the relationships of organisms to their environment in one sense or another. A viral geneticist, for example, studies the effects of naturally occurring or purposeful changes in the environment upon the genetic characteristics of viruses. Similar examples can be drawn from practically any biological field, yet the workers in these fields rarely identify themselves as ecologists. The term can be applied far from its original intent, such as the "ecology of thymus cells," and still be well understood. Actually, most people today think of ecology as the study of an integrated system, the study of living organisms in situ.

Traditional ecology evolved from the study of natural history. The application of scientific methods to the already broad field of natural history brought about an inevitable fractionation. No single man can now hope to identify himself as simply an ecologist; he is either a plant ecologist or an animal ecologist. He also has major fields of interest, such as the effects of stress on the population dynamics of vertebrates or the effects of ionizing radiation on the phytoecosystem. In addition, ecological techniques have become sophisticated. For example, lightweight, relatively powerful radio transmitters have been developed for the telemetry of physiological information from free-living wild animals, and the application of radiological techniques has created the whole new field of radiation ecology.

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Methods of Investigation

Several approaches may be used in ecological investigations. One is autecology, the study of the relationship of single organisms to their total environment. Another is synecology, the investigation of groups of animals or plants living together, an approach somewhat more attractive than autecology to the majority of contemporary investigators. In turn, varied approaches to the investigation of interacting groups of organisms are possible. The population approach is usually applied on a species basis, in which the numbers of animals and their responses as a population to environmental change is of primary interest. This approach is probably the one most directly applicable to public health; I discuss it later in greater detail. Another is the community approach, which is requisite to a clear appreciation of the results of population studies.

Studies of the community. The earth's vegetation is essential to all higher life. Animals are parasitic upon the plant world since only plants have the ability to convert solar energy into usable food for animals. Vegetation is affected by climate and is, therefore, classified into easily recognized major "formations," or "biomes," such as desert, tropical rain forest, and tundra. Before reaching their basic unit—the "community"—the biomes, in turn, are usually further subdivided by the specialists. The community is a complex integrated system of plants and animals living together. A complete understanding of the interactions of the community, or "ecosystem" (a term which includes both animate and inanimate portions of the environment), is the ultimate goal of community ecologists, but its achievement is a tremendous task that has not yet been completely accomplished for any community.

Communities appear to grow irresistibly toward stable "climax" situations. The climax community has reached a final position in successional change; its composition may fluctuate, but its changes are reversible, as opposed to the unidirectional growth of the subclimax successional stages. Subclimax successional stages are characterized by simpler communities; that is, the community consists of fewer interacting species, but the total numbers of individuals of each species are compensatingly greater. One example is an agricultural community in which man purposely tries to limit the species to those producing desired products.

Most communities around us are disturbed by man's activities to a greater or lesser degree. Man may bring about, unintentionally, concentrations of species (other than those desired) in both his agricultural acreages and the marginal lands, thus creating a potentially dangerous condition which occasionally is manifested in the form of epizootics. Dense populations are usually far more sensitive to environmental change than sparse ones. Small changes in climate may bring about drastic fluctuations in plant or animal populations, and overpopulation greatly facilitates the spread of disease. The present growth of suburbia is fraught with such possibilities, for as man moves from the city into new housing developments, picturesquely interrupted by idle fields, woodlands, and swamps, he places himself in intimate contact with populations of wild rodents and birds which may be hosts to various diseases.

Studies of populations. Because of the great difficulty in making indepth studies of communities, some ecologists have limited their investigation of populations to single species, studying the internal responses and interactions of this species with the rest of the ecosystem. Populations, like communities, have a tendency to approach stability or, lacking the ability to stabilize because of factors such as drastic seasonal changes, they tend to become stationary. Stationary populations are those in which births balance deaths for any single annual cycle, so that population densities are approximately similar from year to year. How populations achieve this stability is the subject of many current investigations.

A free-living population appears to be characterized by a negative feedback reaction so that when a population becomes too dense for the carrying capacity of its environment, both an increase in mortality and a decrease in reproduction occur. Characteristically, this reaction occurs well before some limiting factor of the environment, such as shortage of food, begins to exert its influence. We know, however, that some organisms, such as bacteria and certain insects, are more likely to be limited by environmental conditions than vertebrates, which are more likely to be self-limiting. A dense vertebrate population thus subsides, and as it falls below the capacity of the environment, the reverse procedure occurs—reproduction increases and mortality decreases. The factors which bring about this compensation for overabundance or underabundance of populations are called density dependent and are classified separately from the factors which are independent of density, such as weather. Both predation and disease are density-dependent factors in mortality which tend to stabilize a population at the carrying capacity of the environment.

Population compensation that is effected by an altered reproductive rate occurs through changes in (*a*) the proportion of females that become pregnant, (*b*) the age of sexual maturity, (*c*) the sex ratio, (*d*) the average size of litters, and (*e*) the length of the breeding season. That these changes occur in response to changes in population density is a matter of record for many species, but the mechanisms which bring the changes about are only now coming to light. Social structure and its stress on the individual seem to play an important part.

Almost all of these negative feedback factors have a time lag, and therein lies the potential hazard to man. Overpopulations of reservoir hosts of the zoonoses may result in an epizootic of such magnitude as to spill over and affect man before the host population is reduced.

Natural History of Diseases

In the past, the natural history of diseases, including the interrelationships of etiological agents and various hosts, has been studied mainly by virologists, bacteriologists, and parasitologists. More recently, however, the need has become evident for a team approach in which several investigators of varied disciplines work on the complexities of diseases, particularly of the zoonoses. Here the ecologist, by applying his knowledge of the interactions between the animals of an ecosystem, can best contribute to the field of public health.

Wild animals have been increasingly implicated as reservoirs of the zoonoses, and the need for ecological studies has correspondingly increased. For example, rabies, long known to occur in wild animals, was considered a paradox among diseases since it was believed to kill all the hosts that it infected and within a relatively short period. In fact, the period of infectivity in foxes appears inadequate to maintain the disease in an enzootic state in view of their relative sparseness. Recently, however, many bat species have been found to carry rabies and to maintain infectivity for many months. Ecological investigations are required to determine whether a significant relationship exists between bat rabies and the sylvatic rabies of other wildlife.

Leptospiral organisms have been isolated from many species of wild mammals in all parts of the world. The list of the species of mammals that harbor these organisms is growing so rapidly that some specialists now believe that all species of mammals (except possibly marine forms) harbor some leptospiral strain. The peculiar attraction of urine to most species of mammals has long been known and applied by trappers. And as anyone who has used urine scent on his trap sets can attest, the attraction is not limited to furbearers, although these animals seem to be more highly motivated to respond than the prey species. Actually, a wide variety of animals, including squirrels, rabbits, porcupines, rats, and deer, are attracted by urine baits of almost any source. Perhaps they associate the smell of urine with a concentration of salt. Whatever the reason for the attraction, this phenomenon is an effective means of transmission of leptospires, for animals will frequently lick the freshly voided urine of others. Use of an ecological approach in studying this transmission would probably be profitable.

Patagonia is an important sheep-raising region in Argentina, where hydatid disease is a public health problem. The wild foxes of Patagonia have been found to serve as definitive hosts for *Echinococcus granulosus*, the causative agent of hydatidosis (*1*). In this region, an eradication program based upon the treatment of dogs alone would ignore the reservoir in foxes. Foxes are not large enough to kill adult sheep, the only animals containing viable, infective cysts. Also, the rate of infection in the foxes appears too high for the animals to have been infected by eating adult sheep which have died of disease or accidents. Therefore, the intermediate host of the parasite may be a wild animal. An ecologist might (*a*) determine the existence of the intermediate wild host, (*b*) devise methods for control of the wild intermediate host population and the foxes, and (*c*) devise methods for treating the fox population as a corollary to an eradication campaign.

The arbovirus encephalitides have reservoirs in wild birds and other vertebrates. Studies of recent urban epidemics of St. Louis encephalitis in Texas have indicated that the most abundant resident bird species, the house sparrow and feral pigeon, were the principal reservoir hosts. Control of these pest species by limitation of their food supply—application of the knowledge of population compensation—should greatly reduce the likelihood of epidemics.

Many other diseases, such as plague, tularemia, spotted fever, yellow fever, and Bolivian and Argentine hemorrhagic fevers, have reservoir hosts in wild animals. Their investigation also demands some measure of ecological science.

The basic principles of epidemiology and population ecology are similar. Attack rates, morbidity rates, and survival rates are all part of the working data of the population ecologist, who adds such items as prevalence of pregnancy, average litter size, age-specific reproduction, and population density. The quantitative approach to the study of ecological interactions of disease organisms and hosts finds its application in public health.

Disease and Population Density

The likelihood of man's contracting a zoonosis may be affected as much by the prevalence of the disease within the animal population as by the mode of contact between the animal species and man. The prevalence of a communicable disease within an animal population depends to a considerable degree upon the density of the population. Measurements of the density of wild animal populations usually fall into two categories, absolute and relative censuses.

Absolute censuses are estimates of the total number of animals on some given unit of area and may be difficult to make. Relative censuses, on the other hand, are measurements of the number of animals in relation to some feature of the environment and are more quickly performed. For example, in a roadside census in a city, a population figure might be expressed as the number of house sparrows seen per mile of census route. Another frequently used relative census is the track count, in which random sampling results are expressed as the percent of stations with animal tracks and, where traps are used, the percent of animals per trap-night.

The choice of an absolute census or a relative census depends upon the requirements of the research. If a project does not require an absolute census, considerable time and effort can be spared by using the simpler relative census. Relative censuses, however, although generally better for detecting differences between populations, may have limited application. Frequently they cannot be used to show population changes throughout a year because of seasonal changes in the behavior of the animals. They are best applied to comparisons of populations at the same time of year, either on different areas or on the same area from year to year.

Absolute censuses fall into one of four categories:

1. The total count, in which some technique or characteristic of the species permits counting all the animals on a unit area. Examples are aerial counts of elk in winter and aerial photographs of ducks resting on water.

2. The recapture method, which is analogous to the dilution method of estimating the volume or the erythrocyte population of a person's blood. It requires taking and marking a sample and then returning the sample to the population. Later another sample is taken, and the ratio of marked to unmarked individuals in the population is determined; this determination permits calculation of the size of the entire population.

3. The removal method, in which the rate of removal of animals from an area (by trapping, for instance) is calculated or plotted. Projection of this rate permits an estimation of the size of the whole population.

4. The change-in-ratio method, in which a known effect produces an observable change in the age or sex ratio of a population, permitting us to calculate the amount of effort that would be required to bring about a complete change in the ratio and to arrive at an estimate of one of the age or sex classes. To determine the size of the entire population, the appropriate proportion of the other sex or age class may then be added. This method has been applied successfully to populations of game in which males only are harvested and the number killed is known, as with pheasants and deer.

Mathematically, all of these techniques are sound. The pitfalls lie in the reactions of the animals being censused to the techniques being applied. For example, a rabbit that has been trapped may become trap prone when it learns that the trap is a good source of food and shelter. If this factor is not considered, the recapture technique will result in underestimation of the size of rabbit populations. Other animals may become trap shy, and their populations may, consequently, be overestimated. Therefore, to obtain dependable results and avoid false interpretation, it is desirable to perform several counter-checking censuses.

The spread of a disease within a vertebrate population depends upon the density of that population. It is axiomatic that reduction of the population below a certain threshold of density will retard the spread of the disease and may result in its eventual disappearance from the population. The range of factors affecting the position of this threshold is great. Included are not only the behavior of the disease organism within the host, its mode of transmission, and its resistance to environmental stresses, but also the behavior of the host species, seasonal changes in the circadian rhythm of the host species, the characteristics of its reproductive cycle, and fluctuations in its population. A knowledge of the natural history and ecology of the host may be more important in controlling a zoonosis than detailed knowledge of the disease organism itself.

Control of Disease by Oral Antidotes

The ultimate goal of disease control is eradication of the disease in all its hosts, in other words, extinction of the disease agent. Although such a goal is difficult to reach, it is not impossible. Its attainment, however, should not include extermination of the wild reservoir host, but rather, treatment of the disease in this host at some crucial point in its life cycle. Such treatment may be within the realm of practicability, depending upon the availability of effective, inexpensive oral antidotes and sound ecological knowledge. By applying treated baits that are attractive to the reservoir host over large areas at the proper time by airplane or helicopter, disease control might be achieved. Oral immunization is another approach with even more potential, since the density of those members of the species susceptible to the disease, rather than the density of the total host species, determines the spread of disease organisms. Introducing the vaccine into members of the population would be less difficult than to procure economically an effective vaccine in the quantities which would be required.

Control by Lowering Animal Density

Until the necessary drugs and vaccines are available and in quantitites great enough for mass distribution to wild hosts in enzootic regions, we must rely on lowering the density of the wild reservoir host. Basically, the many known methods for decreasing wild animal populations entail increasing their mortality, decreasing their reproduction, or both methods. Control of rats in a city is achieved by manipulating the environment to the detriment of the rat population, thus increasing mortality and decreasing reproduction. Essentially, permanent rat control is achieved by removing food and available shelter. Removing food will not force adult rats to desert an area in which they have established a home, but it will increase their susceptibility to such factors in mortality as predation by cats, dogs, and man, as hunger drives them to a boldness which they would not ordinarily exhibit. Also, scarcity of food may reduce reproduction and increase the rats' susceptibility to diseases. Food scarcity, together with the restriction of breeding sites by removal of shelter, spells a sure end to the rat population.

Traps, guns, and poisons. Many methods have been devised for killing wild animals—traps, guns, and poisons—and properly applied, these methods can be very effective. By taking advantage of some crucial factor in the life history or ecology of a species, the ecologist can apply a poison and eradicate a species from an area or exterminate it completely. Indiscriminate use of poisons without sound planning, however, will not have permanent effects and may result in the death of many adventitious species besides the ones at which control is aimed.

Proper application of any of these methods of killing requires a sound knowledge of the life cycle of the species and of any limiting ecological factors. Most wild species have a regular annual cycle in respect to their abundance, with the peak near the close of the breeding season and the low point generally just before the first births of the year. The species is most vulnerable at the low point because it is then that the death of an individual has the greatest impact in depressing the population. In temperate zones, control at this point is particularly effective because it coincides with a time when food is scarce, and this scarcity makes poison baits more attractive. Furthermore, because the sex drive is at its peak, many of the animals are more mobile, a factor increasing the likelihood of their finding baits or traps.

Oddly, many control programs are so poorly timed that they miss this favorable season. In one State, for example, trappers mistakenly carry out a program for control of fox rabies in the late summer and early fall because they can catch more foxes at that time. A basic knowledge of ecology would make it clear that effectiveness is not measured by how many foxes are caught, but by decreases in the total fox population. In this State, they are not only trapping at the high point of the population curve, but also, they are wasting efforts on many animals that would die of natural causes anyway. The annual turnover in a fox population is approximately 65 percent; the average total lifespan of a fox which survives to 7 months of age is only 17 months. The same trapping effort applied in late winter and early spring, when the population is at its lowest, would far more effectively lower the fox population of the region. The success of a program of control of a wild species should be measured by censuses of animals after it is completed rather than by a mere count of the animals killed.

Dissemination of disease agents. Diseases are probably at least as important as predation in the death of wild animals. Their importance is particularly apparent in the case of wild predator species. Foxes, for example, have surprisingly high mortality rates (*2*), yet few animals include foxes in their diet. The mortality of prey species is even higher. The average lifespan of a cottontail rabbit is about 6½ months; the annual turnover of the population is about 92 percent. Yet only a portion of the deaths can be attributed to predation. The mortality rates of many rodents are even higher than those of rabbits.

Many of the diseases which affect wild animals are more or less specific for particular species. Biological control of particular species through planned dissemination of a specific disease agent can therefore be highly effective. This method, however, can be dangerous if its application is not limited. The disease may affect domesticated relatives of the species or may spread beyond the areas where control is desired. Myxomatosis is a good example. This disease was highly effective in controlling rabbits in Australia, but its unwise introduction into rabbits on an estate in France led to its spread to the rest of the continent and even across the English Channel (*3*). The results were both beneficial and detrimental. The dying off of wild rabbits resulted in more available pasture forage for domestic stock, but occurrence of the disease in domestic rabbits severely damaged an important food industry. The spectacular effects of myxomatosis prove the practicability of biological control but emphasize the need for research and forethought before using it.

Birth control. Although increasing the mortality of a species is an effective method of control, it is probably less efficient than control through a decrease in reproduction. The whole process of life is a struggle against death. Protozoans fight decimation through spore formation; fish compensate for decimation of their numbers by producing large numbers of offspring, as do mice and primitive men. Reproduction assures immortality, and successful species use it to full advantage. In fact, most populations will compensate for increased mortality by increased reproduction. And when reproduction has been curtailed, these same populations compensate by increasing the survival time per individual. The effectiveness of reduced fertility is well illustrated in the Department of Agriculture's successful campaign against the screwworm fly in the southeastern part of the United States (*4*). Large numbers of these flies were sterilized by gamma irradiation and released. Since the females mate but once, eradication was accomplished over wide areas.

"Gametocide" is a term which includes control of animal populations by use of chemical substances to reduce fertility. Such control is still so new that spectacular results in vertebrates have yet to be demonstrated. The potential of this method is based, however, on established ecological principles (*5*). Gametocidal control, besides being more effective than shooting, trapping, or poisoning, has the advantage of not killing adventitious species which might eat the baits. Even accidental sterilization of innocent species is usually unlikely since few species occupying the same area have identical reproductive patterns or eat the same kinds of food. Furthermore, most known gametocidal compounds do not cause permanent sterilization. In fact, it is difficult to find oral gametocides with a sufficiently long period of effectiveness.

Some presently available gametocides kill a proportion of the target animals. This limited mortality, however, is not a factor if most of the survivors are sterile and cannot compensate with increased reproduction. On the contrary, a highly effective combination is application of a poison to a population just before the breeding season, followed by use of a gametocide on the survivors.

Until effective treatment or immunization of wild vertebrate reservoirs of the zoonoses is achieved, gametocidal reduction of populations appears to offer the most effective and flexible system of managing the zoonoses. The effects of gametocides can be controlled by varying the density and temporal distribution of baits, just as is done with poisons. Complete eradication of a species can be prevented by applying the gametocidal baits during only a part of the breeding season. A measurable and predictable degree of reproduction may thus be permitted that will maintain the population at a desired low level.

Conclusion

The field of ecology, a scientific outgrowth of natural history studies is coming more to the fore in attempts to solve many important public health problems. As members of multidisciplinary teams, ecologists are investigating zoonotic diseases all over the globe. Today it is possible to foresee the eradication of some diseases in the wild hosts. Ideally, this end would be achieved by mass immunization or treatment of the wild hosts. If these methods cannot be used, however, another possibility is to lower the density of the hosts below the level necessary to maintain the diseases in nature.

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Tearsheet Requests

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Dr. Steinfeld Assumes Duties as Surgeon General

Dr. Jesse L. Steinfeld has assumed the responsibilities of Surgeon General of the Public Health Service. He succeeds Dr. William H. Stewart, who retired in the summer of 1969.

Dr. Steinfeld continues to serve as Deputy Assistant Secretary for Health and Scientific Affairs, Department of Health, Education, and Welfare.

Dr. Steinfeld came to the National Institutes of Health in 1952 to conduct research in the National Cancer Institute's Laboratory of Experimental Oncology. From 1954 to 1958 he was a senior staff physician of the institute's General Medicine Branch in the Clinical Center. In this period he also became head of the Radioisotope Unit and associate editor of the *Journal of the National Cancer Institute.*

After leaving the National Institutes of Health, Dr. Steinfeld spent a year on the staff of the City of Hope, Duarte, Calif. Then for 9 years he was professor of medicine and head of the Cancer Chemotherapy Program at the University of Southern California School of Medicine.

Dr. Steinfeld returned to the National Cancer Institute in 1967, serving first as associate director for program and then for a few months as deputy director. He left the newly created post of deputy director to become Deputy Assistant Secretary for Health and Scientific Affairs.

Community Mental Health Centers Now Number 376

More than 25 percent of the U.S. population will be served by 376 community mental health centers now funded under a Federal program, according to the National Institute of Mental Health, Health Services and Mental Health Administration, Public Health Service. Since 1965, centers have received $292.2 million in Federal funds and some $595 million from State and local tax funds and private sources.

Kentucky, with 82.5 percent coverage, has the largest proportion of its population served by centers. North Dakota, South Carolina, Washington, D.C., Colorado, and Maine follow Kentucky in statewide coverage. Each center serves an area with a population of from 75,000 to 200,000 persons. Presently, more than 170 centers have opened and are accepting patients. Others are under construction, are being remodeled, or are recruiting personnel or preparing to open.

All 50 States, Puerto Rico, and Washington, D.C., have received funds to build new centers or expand existing facilities and to help staff centers in their initial years. States and localities share costs. Some centers are located in general hospitals. Many centers were formed by affiliations of several local agencies.

Community-based psychiatric services provided by the centers include inpatient and outpatient treatment, partial hospitalization, and emergency services. Their consultation and education function is the key to preventive service.

The Community Mental Health Centers Act of 1963 and subsequent amendments provide for financial grants to public and nonprofit facilities for the construction and staffing of mental health centers. The aid program is administered by the National Institute of Mental Health.

Community mental health centers funded as of July 1, 1969

State	Number of centers			Total number of centers	Percent of State population covered
	Construction and staffing	Construction only	Staffing only		
Alabama	0	6	0	6	25.0
Alaska	0	0	1	1	6.7
Arizona	2	1	1	4	35.9
Arkansas	2	1	3	6	37.0
California	14	10	10	34	25.4
Colorado	4	1	4	9	52.5
Connecticut	0	2	1	3	17.2
Delaware	1	0	0	1	27.4
District of Columbia	1	0	2	3	77.3
Florida	8	5	0	13	30.0
Georgia	0	9	0	9	27.9
Hawaii	1	1	0	2	30.9
Idaho	2	0	1	3	41.1
Illinois	1	6	3	10	11.1
Indiana	1	6	0	7	24.4
Iowa	1	3	0	4	13.5
Kansas	2	3	1	6	35.5
Kentucky	9	0	12	21	82.4
Louisiana	2	9	1	12	35.9
Maine	2	1	1	4	70.3
Maryland	2	3	0	5	15.9
Massachusetts	3	2	5	10	24.8
Michigan	3	4	4	11	17.1
Minnesota	4	1	1	6	21.8
Mississippi	0	2	2	4	27.1
Missouri	3	4	1	8	24.6
Montana	0	1	1	2	36.7
Nebraska	1	2	0	3	25.1
Nevada	0	1	0	1	28.9
New Hampshire	0	1	0	1	15.5
New Jersey	2	9	0	11	20.7
New Mexico	1	0	1	2	26.1
New York	9	8	2	19	19.0
North Carolina	1	9	3	13	32.4
North Dakota	2	0	3	5	76.0
Ohio	3	9	1	13	19.1
Oklahoma	1	1	1	3	24.3
Oregon	1	1	0	2	12.7
Pennsylvania	9	13	7	29	38.8
Rhode Island	0	1	0	1	9.2
South Carolina	5	1	0	6	43.5
South Dakota	0	1	0	1	27.3
Tennessee	2	5	0	7	25.2
Texas	3	4	10	17	21.8
Utah	1	0	1	2	28.5
Vermont	2	0	0	2	28.5
Virginia	1	3	0	4	15.9
Washington	1	3	3	7	25.4
West Virginia	1	2	1	4	33.3
Wisconsin	1	8	1	10	33.9
Wyoming	0	0	1	1	13.8
Puerto Rico	3	0	5	8	38.6
Total for United States	118	163	95	376	26.1