

Ecosystem health: an essential field for veterinary medicine

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Society has the immediate and daunting tasks of reducing human illness and poverty, achieving food security, staunching the loss of biodiversity, and arresting environmental degradation. Veterinary medicine deals with the health and disease of vertebrates.¹ This broad mandate can be addressed most effectively through an approach that combines concepts of health with an understanding of ecosystems, often referred to as ecosystem health.²⁻⁶ If veterinary medicine is to remain a strong profession, it must make itself more relevant to these problems. Ecosystem health management is perhaps one of the most effective vehicles for guiding veterinary medicine to address these societal imperatives.

More veterinarians than ever before are directly involved in caring for ecosystems or their constituent biotic and abiotic communities. The understanding that veterinarians have of comparative medicine and their experience in managing environmental requirements of many different species allows them to assist in such a role. The field of ecosystem health is a logical context for veterinarians whose primary interests are in wildlife diseases, epidemiology, and environmental toxicology (ecotoxicology).⁷⁻⁹

What is an Ecosystem?

An ecosystem is composed of air, water, soil, and organisms (including human beings), all of which interact within a geographic area. Ecosystems may change over time, but they remain self-organizing and maintain their structure and function. They can be thought of as being arranged within a nested spatial hierarchy.¹⁰ An example of such an ecologic hierarchy based in agriculture includes the following: a field, farm, land use district, watershed, ecologic region (ecoregion), ecologic zone (ecozone), ending ultimately with a biosphere (Fig 1).¹¹ A farm is a piece of landscape that has been restructured to have socio-economic and ecologic features and is a key unit of management within a given agricultural ecosystem (agroecosystem). One may also describe agriculture in terms of a sociopolitical hierarchy, such as farmer, family, community, region (eg, county), state, and country.¹²

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Presented in part in July 1996 at the AVMA annual convention, Louisville, Ky.

What is Ecosystem Health?

Health is a term that dates back to Greek antiquity and its definition has varied.^a Recently, literature on the promotion of human health has conceptualized health not as an end point but, rather, as a capacity for daily life to meet human needs and goals.^{13,14} Although health and medicine are sometimes used interchangeably, it is important to make a distinction between the 2 terms. Health is incorporable within human desires and is consistent with well-being or desired productivity. Health is the business of everyone, and many different professions and occupations contribute to its definition and attainment. In contrast, medicine is conventionally known as the practice of avoiding, preventing, or treating disease through the use of biomedical knowledge and is typically more restrictive and carefully legislated.

Health is applied to individuals and populations of the same species, namely public, population, community, and herd health. Applying health to populations of different species in biotic communities is the next step toward ecosystem health, a substantially more interdependent and complex extension.^b

When applied to ecosystems, health refers to the following: the capacity of an ecosystem to maintain or renew its organization or structure, to be productive (possess vigor), and to be resilient in the face of natural and anthropogenic stress.¹⁵ In addition, health refers to the effectiveness of an ecosystem in achieving reasonable human goals, including land stewardship and preservation of the biosphere,¹⁶ factors into what we collectively describe as integrity. Because application of these ideas is just beginning, circumstances of impaired health or even the risk of collapse (eg, desertification) of ecosystems are only beginning to be understood.

In the final analysis, whether it is applied to individuals, populations, or ecosystems, health is a social construct and not a science. Nevertheless, application of the concepts of health to the ecosystem at each level requires study of appropriate areas (eg, clinical medicine for patient health, epidemiology for population health, and complex systems analysis for ecosystem health).¹⁷

A three-dimensional framework can be helpful for assessing and managing ecosystem health (Fig 1).^{11,18} Categories in each axis can be subdivided into more definitive categories to suit individual problems or analyses. This matrix can serve as a means of positioning and rationalizing activities, such as assessment of resources, selection of operational objectives, and

development of indicators for ecosystem health in the complex reality in which managers, professionals, and scientists function.

Contamination of water supplies in an ecosystem, for example, can be analyzed at a number of spatial scales. From any of the levels in the spatial hierarchy, integrity of each of the 3 dimensions can be assessed along with how effectively the reasonable biophysical and socioeconomic goals are being met with respect to the water supply. In this way, ecosystem tradeoff decisions can be made more openly, carefully, and judiciously.

Ecosystem Health Management

Because of similarities between certain aspects of veterinary medicine and ecosystem health, veterinarians who possess advanced training in comparative medicine and health management can play a leading role in the development and implementation of ecosystem health management. General practitioners can also play a strong role in some aspects of implementation, as well as participate in the improvement of the environment in which they, their clients, and their clients' animals live.

Identifying community leadership—Initially, it is essential to identify the appropriate decision and policy-making body that can effectively represent stakeholders and interested parties within an ecosystem, to begin formulating general goals, and, eventually, to develop precise objectives that take into account ecosystem analyses. In terms of spatial and social scales, the community is the key level at which leadership should be identified.^{19,20} It is likely there are sufficient common interests at this level of the hierarchies to achieve consensus, or at least accommodation, while tempering individual goals that might be harmful to the community and ecosystem. Some social organizational structure or decision-making body that can speak for the community or set up appropriate means to do so is desirable.

In managing ecosystem health, ecosystem decision making would be facilitated if the goals of the social hierarchy (eg, political jurisdictions) were congruent with those of the ecologic hierarchy (eg, land use districts). Unfortunately, this is often not the case, and responsibilities for ecosystems are often fragmented and not effectively linked. Compared with other steps required to implement ecosystem health management, identification of community leadership is less directly related to the skills of veterinarians but is crucial to the effective completion of the ecosystem health management process.

Ecosystem health assessment and analyses—Objective data describing biophysical, economic, human, and social resources (and their histories) of the ecosystem in question need to be assembled and kept current for decision makers as a base of information for study.^{6,c} Information describing circumstances in contiguous communities and ecosystems will also need to be monitored, because a standard professional educational program has not yet been developed for the study of ecosystems. Assessment of ecosystem health usually involves several disciplines and methods of analyses.

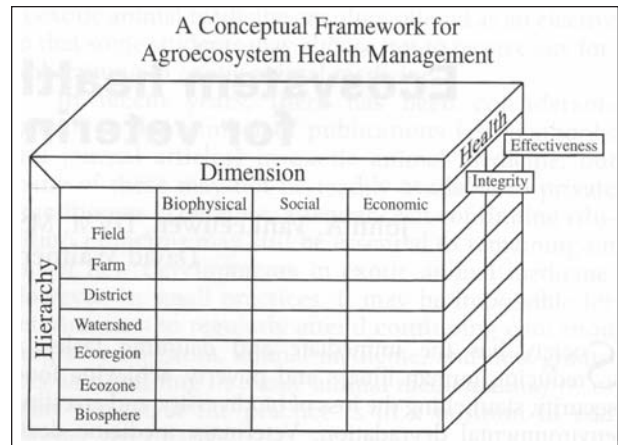


Figure 1—Model depicting relationships between hierarchy, dimensions, and components of health in the management of an agroecosystem. The Y and X axes represent hierarchy and dimensions, respectively. Because ecosystems include human beings, they not only have a biophysical (ecologic) dimension but also social and economic dimensions for each spatial scale in a given hierarchy. The Z axis represents essential components of health (ie, integrity and effectiveness). If replicated in time, the model also accommodates the temporal scale.

Skills required to gather and interpret complex histories, necessary for the practice of herd and public health, are essential for ecosystem health assessment and for setting realistic goals. Recently, ecosystem history has been combined with complex systems theories to provide new insights into the relationships between cultural and natural change.²¹ Participatory action research,²² soft-systems methods,²³ and interactive science²⁴ are all particularly useful methods for gathering and interpreting historic information, as well as for determining and implementing management goals and objectives. These methods depend on involvement by stakeholders in a manner similar to the farmer's involvement in designing herd health programs.

A variety of epidemiologic tools are available to make comparisons between units of interest and to study relationships within ecosystems over time (survival analysis and proportional hazard analysis).²⁵ Similarly, geographic information systems have proven useful in spatially related ecosystem and epidemiologic studies.²⁶ Multilevel statistical techniques have been developed to study relationships between individual and spatial determinants of health.^{27,28}

Various dynamic system-modeling techniques have become an essential part of identifying feedback loops and interactions and suggesting probable outcomes under conditions of uncertainty. Software packages^{d,e} are being used to study ecosystem dynamics, livestock-environment interactions, and the unfolding epidemics of emerging diseases. These approaches can be combined to produce a holistic, multiscalar, multitemporal, multidimensional assessment of ecosystem health.²⁹

Determination of objectives—Once the decision-making body for the community of stakeholders has appropriate information, it can begin formulating more specific objectives for the ecosystem under consideration. These objectives must account for the goals of individuals who are part of the ecosystem as well as

those determined by other contiguous ecosystems and, in particular, policies initiated from the upper end of the social hierarchy, such as a national government.

When there are conflicting goals and objectives in an ecosystem, whether across the scales of the ecosystem hierarchy or within one scale, there should be some negotiation or some other means of arriving at a decision to resolve the conflict. In those instances in which individuals bear the burden of larger social goals, one should consider whether, or how, those individuals will receive compensation.

Ecosystem health management must recognize the interconnectedness of the many elements in the ecosystem hierarchy, something that is often forgotten or ignored in conventional planning and decision making.³⁰ In order to avoid being paralyzed by this realization of interconnectedness, it is essential to identify which decisions are most appropriately made at each level of the hierarchy and to focus on particular units of concern (eg, farms, communities, or watersheds).

Indicators to measure, monitor, and reevaluate progress—Once more specific objectives are established for an ecosystem, indicators need to be selected that allow stakeholders and managers to measure or monitor progress toward biophysical, social, or economic goals. Identification and validation of useful indicators through research is an immediate imperative that is needed to lay a more solid foundation for ecosystem health management. Indicators appropriate to management objectives at each level of the ecosystem hierarchy need to be determined. Application of “fuzzy logic” to handle and integrate indicator data appears to be a promising method in assisting managers of ecosystem health.^{31,32} Finally, as in any health management program, there should be a sustainable process to periodically reevaluate methods and progress in the attainment of objectives.

Applying Veterinary Medicine to Ecosystem Health

Veterinarians are attuned to the notion that factors in the environment are among the determinants of health. It would seem logical, then, to extend the scope of their thinking from individuals and populations of a single species to multiple populations of species (biotic communities) and their physical environments in a given ecosystem.

Veterinarians, in the course of dealing with animal and human health problems, develop many of the scientific and professional skills necessary to deal with complex environmental and socioeconomic problems. Veterinarians consider such things as housing, nutrition, air quality, and biosecurity when assessing health and disease in a variety of species, including exotic species. They are already conditioned to think in terms of multiple spatial scales because they look at individuals and populations and the relationships between them. Recently, several veterinarians have explored links between health and disease problems as viewed in conventional epidemiologic terms in the context of farming systems and in broader, multilevel ecoregional contexts.³³

Furthermore, in veterinary medicine, herd health

programs already accommodate different management perspectives that incorporate appropriate medical, economic, or ethical objectives. The idea of tradeoffs existing in any decision involving various management options is already well ingrained in veterinary practice. With this experience, veterinarians possess a strong base of valuable expertise from which to tackle managing ecosystem health.

Several specialty veterinary organizations with ecosystem health related goals, such as the American Association of Zoo Veterinarians, American Association of Wildlife Veterinarians, and the Alliance of Veterinarians for the Environment, are flourishing. In particular, veterinarians with specialities in epidemiology, wildlife disease, toxicology, and public health are well suited to practice in the wider context of ecosystem health.³⁴ For example, epidemiologists have experience using various methods to identify determinants of health, productivity, and disease that can be applied to the wider scale of ecosystems. Knowledge of wildlife populations and their diseases can be useful indicators of the health of the ecosystem in which they reside. Toxicologists clearly are involved in protecting all forms of life from the current technical use of chemicals. Public health is the ultimate indicator of ecosystem health.

Conventional veterinary practitioners also make valuable contributions to ecosystem health, despite having little background or training in ecology. The health of their patients can reflect the health of an ecosystem, and they are in a strategic position to encourage their clients to help protect the health of the ecosystem when making their management decisions. For example, large animal practitioners can promote more efficient manure management that can not only improve animal health and reduce the cost of synthetic fertilizers but also prevent contaminating ecosystem water supplies. Many management decisions can have economic and environmental benefits and not just costs to veterinary clients. It is noteworthy that in France, veterinarians are developing more holistic approaches to animal disease at the level of the farm, under the rubric of ecopathology.³⁵

Although the practice of ecosystem health is generally more akin to health management of populations, sudden emergency situations occur, such as the Exxon Valdez oil spill, in which serious threats to the biota of an ecosystem create a need for veterinary involvement. Veterinarians need to be prepared to deal with such circumstances and to have a solid grasp of short- and long-term consequences of such accidents. The American Academy on Veterinary Disaster Medicine is providing leadership in this domain.

At 4 Canadian schools of veterinary medicine, a joint effort is underway to test application of training in veterinary medicine to management of ecosystem health by offering a 2-week elective rotation to senior veterinary students. This rotation has been offered annually to 16 senior students at one of the schools during the past 4 years and involves working through case studies and emerging theories in ecosystem health.^{36,37} In one case study, students met with a large animal practitioner retained by an oil industry firm to

monitor the health of an ecosystem, using herds of beef cattle as a sentinel species. In another rotation, students participated with veterinarians in studies of health and disease in Beluga whales, which are used as sentinel species for the health of the St Lawrence River basin. In 1996, they studied a situation in which veterinarians faced the dilemma that their farming clients were using land practices that degraded an estuary to the point that it put them in conflict with other veterinary clients who were engaged in intensive shellfish aquaculture. Interaction with these veterinarians, specialists, and community groups in real-life situations made it possible to demonstrate to students how useful our general veterinary training is in a wider context and that veterinarians possess the scientific, problem solving, and management skills necessary to deal with problems involving multiple species and complex environmental, socioeconomic, and ethical dimensions.

Conclusions

Historically, application of health sciences in problem solving and decision making has required integration of biophysical and socioeconomic circumstances with ethical and aesthetic considerations. This is precisely the nature of the task facing those who decide the fate or goals for ecosystems. There is every reason to believe that approaches used to promote, measure, and monitor the health of human beings, animals, and plants can be applied collectively in ecosystems. Ideally, we must integrate multiscale social, economic, and ecologic analyses with human values and goals.

In terms of the broad education obtained in veterinary colleges, the subject of ecosystem health deserves to be at least on a par with public health because of its overall importance in professional careers. It is a logical avenue through which to make veterinary medicine more relevant to key societal issues, such as loss of biodiversity, sustainable agriculture, and threats to human health from environmental degradation or change within a context of economic well-being.

Concepts in ecosystem health are being used by veterinarians involved in major projects to help solve complex practical problems of health, agriculture, and the environment in Canada, Peru, Honduras, Kenya, and Nepal.³³ Many veterinarians are already being called on to consider the social and economic context of their disease control efforts and the interactions between ecologic changes and public health hazards with regard to emerging diseases, such as Lyme disease and cryptosporidiosis. It would only seem prudent for the veterinary profession to help develop and provide the conceptual and practical tools to help facilitate this process. Therefore, if veterinarians are to live up to their potential in contributions to this field, veterinary curricula will have to be flexible and programs in ecosystem health will have to be brought into being for new graduates.

Veterinarians in conventional practice can be educated and encouraged to discuss broader client goals and ensure that consultation with clients guides not only production goals but also societal and stewardship goals. Small animal practitioners are increasingly faced with ecologic issues related to urban wildlife,

and public health. The role of cats in contaminating a major urban water supply³⁸ and in decimating populations of certain songbirds or the problem of the rabies epidemic in raccoons in the eastern United States are examples of grist for the veterinary ecosystem health mill. From these examples, it should seem apparent that there are many opportunities for veterinarians to act not only for the benefit of animals and their owners but also for society and the environment. Ecosystems need help now in dealing with escalating human population pressures.

^aIn Greek mythology, Hygeia was the goddess of health and emphasized wellness and its promotion. Aesculapius was the god of healing (medicine) and focused on illness.

^bCommunity health could, in fact, be used instead of ecosystem health, but its long use and meaning in human medicine precludes this option.

^cA biological inventory in this context may not be species based but, rather, may emphasize an evaluation of habitat availability, compared with what is expected for that type of ecosystem.

^dHigh Performance Systems Inc, Hanover, NH.

^eVENSIM Product Center, Ventana Systems Inc, Belmont, Mass.

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