

## **ECOSYSTEM HEALTH CONCEPTS AND PRACTICE FROM THE VETERINARY HYGIENE POINT OF VIEW**

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### **Pristine Ecosystems, Ecological Services, Ecological Resilience—and Public Health**

Worldwide, largely pristine ecosystems support robust communities of healthy plants and animals. In such ecosystems, there is incessant competition among innumerable genetically-diverse microbial and macroscopic organisms to utilize and recycle water, nutrients, and energy. Ecological services generated through this competition include: i) regulating atmospheric oxygen, carbon dioxide, nitrogen, and the climate, ii) detoxifying the environment; iii) sequestering nutrients as vital biomolecules, thereby limiting growth of pathogens, toxigenic phytoplankton, and poisonous higher plants; iv) engulfing, ingesting, and digesting pathogens and their vectors; and v) preying on organisms as well as avoiding predation, so that strains or species that are unfit, including those that tend to be genetically predisposed to disease, are removed from the system. From a human perspective, ecological services include provision of: breathable air, drinkable water, fertile soil, wholesome food, abundant fiber, plentiful lumber, useful biomolecules, and reduced exposure to infectious and toxic stressors. Another ecosystem service—the reliable generation of the vast beauty and rhythmic dramas of nature—gives rise to a great human sense of security and serenity. Of note, due to high organismal and genetic diversity that confer functional redundancy, ecosystem services in largely natural locales are resilient, and thus they typically “bounce back” after climatic extremes or other forms of stress, including that related to small-scale changes from human activity.

### **Definitions of Ecosystem Health**

Ecosystem health is the discipline that focuses on sustaining the structural and functional integrity—and the related services—of ecosystems. Ecosystem health is also a desirable condition of ecosystems—with ample diversity and density of organisms to provide services despite environmental stress and without expensive human intervention. These definitions are applicable to Earth’s natural lands and water bodies, as well as its purposefully-altered regions and interface zones. In the author’s opinion, the health of most ecosystems that are largely dedicated to human goals will be recognized as reliant upon wild segments that are sufficiently large and interconnected to enable metapopulation dynamics among native

species with considerable gene flow, ample natural selection, and effective predator/prey relationships.

### **Human-induced Degradation of Ecosystem Health/Public Health**

The book “Guns, Germs, and Steel” asserted that prehistoric regional distributions of plants and animals suited to domestication set the stage for human population growth, with specialization into worker, technological, warrior, and ruling classes.<sup>1</sup> It maintained that sustained close contact between livestock and poultry also facilitated zoonotic diseases with eventual development of population-level resistance. Finally, it proposed that the infected and technologically armed human populations gained geopolitical dominance over immunologically naïve and technologically disadvantaged groups. The book “Collapse” proposed that anthropogenic degradation of environments have repeatedly catalyzed societal disintegrations.<sup>2</sup> Today, anthropogenic degradation of environments is unparalleled—and among the accompanying threats to global society are lethal, pandemic zoonotic diseases. Environmental mis-management has facilitated the jump of many disease agents/diseases such as influenza, HIV-AIDs, SARS, ebola, plague, rabies, lyssa virus, toxoplasmosis, trichinellosis, and methyl mercury from wildlife reservoirs to human beings. As discussed below, the opportunities to intervene through more astute management are many.

Global and local climate change are recognized stressors on ecosystems that aggravate disease risks. Carbon dioxide from burning forests to open land for (often unsustainable) agriculture, burning fuels for electricity and transportation, and methane from decaying organic matter and digestive tracts of herbivores are causing persistent global warming. This stresses heat-intolerant species (including humans) and it enables hosts, vectors, microbes, and parasites to track farther from the equator. In most of the world, agriculture effectively supports the food needs of human beings, despite burgeoning populations. However, conversion of natural ecosystems to agricultural landscapes is causing local stress from heat, desiccation, and altered disease ecology. In addition, large-scale planting of row crops; grazing systems that allow loafing livestock to trample plant communities and erode soils; and widespread overgrazing that prevents forage plants from completing sexual reproduction are undermining sustainability. As practiced, agriculture reduces water quality; decreases the depth, nutrient balance, microbial complexity, and water-holding capacity of soils; decreases regional plant and animal biodiversity; increases numbers of poisonous plants; pollutes soils and water bodies with nutrients, pesticides, drugs, metals, salts, and pathogens; and impairs ecological mechanisms of disease control. Despite its many benefits, the methods used and

its occupation of more land than any other component of human development result in agriculture playing an immense role in ecological dysfunction.

Agriculture and other businesses cause large-scale fragmentation and degradation of habitat. But after local insults, ecosystem services are restorable only when native organisms are available at the periphery to move in. In degraded, isolated habitat fragments, native species experience crowding, inbreeding, predator prey imbalances, and high-level exposures to pathogens. Because of degradation of terrestrial and aquatic habitats, species declines and extinctions are becoming exceedingly common. When keystone species (which by definition are critically important in ecosystem structure and function) become involved, the impacts ripple throughout the system. For example, when larger predators are depleted, herbivores, omnivores, and small carnivores become overpopulated and deplete their food supplies, creating area-wide stress. The crowded under-nourished species may also disseminate disease organisms. Zoonotic diseases such as Lyme disease, plague, and rabies may be influenced by such predator prey imbalances.

In some regions, confinement-based game ranching and net-pen aquaculture are rapidly expanding. Even with informed producers and professional veterinary care, knowledge of the basic biology and pathogen burdens of the animals being produced is often insufficient to prevent major disease losses and the resort to widespread drug use. Appreciation of economically-devastating infectious disease problems, including zoonoses, in long-domesticated species should prompt great restraint in initiating wildlife confinement systems, especially where the animals or the effluents from production units come in contact with free-ranging animals.

Wildlife, whether confined or free-ranging can also be harmed by infectious agents, including zoonotic agents, that originate in domestic animals. Examples include brucellosis from European cattle in wapiti, bison and other wild ungulates of North America, bovine tuberculosis from cattle in multiple species of wildlife in South Africa and Michigan (USA), and toxoplasmosis in endangered southern sea otters off the coast of California.

Hunting, the pet trade, and ecotourism pose additional risks to ecosystem, animal, and human health. Hunting and the pet trade can deplete animals in the wild by over-harvest; and hunters are at risk from diseases of their prey. In addition, animals in the pet trade and ecotourists can readily become vectors of disease. The recent remarks of Professor Corrie Brown of the University of Georgia are pertinent to risks posed to livestock production and human health. "Hunting adds [billions of] dollars to the US economy; and eco-tourism is a

sector of growing importance.” “In the US alone, wildlife trade accounts for 101 billion dollars a year. Twenty million exotic animals are imported into the country every year, and this is only what happens legally. Illegal trade is even more lucrative.” “I went to the Masai Mara, which is the most frequented game park in all of Africa, and I saw an African green monkey urinate into the bowl of pineapple on the breakfast buffet—tremendous possibility for disease transmission.”

Clearly, veterinary and human medical professionals have not succeeded in limiting wildlife exposure to chemical and microbial contaminants derived from human activities, or in maintaining barriers that are adequately protective of humans from pathogens of the wild.

Wildlife depletion and emerging human diseases will surely increase as humans pursue poorly conceived forms of ecotourism, and as they convert natural habitat to human-managed regions, crowding, stressing, and interacting with wildlife—to harvest products such as ivory, furs, and hides; to put more bushmeat from more species into human food; to put more reptiles, birds, and mammals into the pet trade, and to put more wildlife products (such as lizard parts, carnivore parts, and rhinoceros horn) into “herbal remedies.”

Acting together, habitat loss and fragmentation, over-harvest, predator prey imbalances, exotic species, chemical and pathogen pollution, and climate change are believed to be responsible for current extinction rates that are 100 to 1000 times faster than that which was present prior to the appearance of modern man. Risks of zoonotic diseases in humans capture great public attention, but the risks of emerging infectious diseases to survival of *Homo sapiens* seem minuscule relative to risks posed to endangered species. Again quoting Dr. Corrie Brown, “How long will it be before we [eco-tourists] give a devastating disease such as measles to the gorillas?”

Despite the successes of international bodies such as UNEP, WHO, and OIE, investment in international public health seems grossly inadequate considering the risks of the globalizing world. Consider the emerging risk of another immunodeficiency virus in Africa as people build roads to extract lumber, thereby facilitating primate-based bush meat traffic. Consider also the recently recognized avian influenza virus strain (H5N1) in south Asia. Because of contact between human beings, poultry, swine, and wild birds, a human pandemic seems a looming probability. In view of all the pathogens in the world, their fast evolutionary rates, and the reduced barriers between them and human hosts, risks of further pandemics seem likely to grow.

Addressing local zoonotic risks in profitable farms, abattoirs, retail stores, restaurants, and homes of developed countries has been proven to be a wise investment. But, application of most public health resources on such proximate risks—with inadequate attention to more distant but far greater risks—may soon be recognized as short-sighted, illogical, inhumane, uneconomical, and thus indefensible. Are the public and their decision makers aware of the character and magnitude of disease risks associated with ecological degradation? Should animal hygiene professionals, wildlife health professionals, and others work in transdisciplinary teams to summarize, interpret, and disseminate information—while offering better options for the future?

### **Who Makes the Decisions?**

Producers of food animals must weigh risks and benefits, with an eye toward profit margins. To ensure return on investment, they choose simplified animal containment structures (buildings, feedlots, pastures) with controlled inputs of animals, water, food, and animal stewards. As competition spreads—locally, nationally, regionally, and globally—many producers invest in animal health care to protect their assets and access to markets. Others, responding to market pressures or simply maximizing short-term profits, unwisely limit disease control efforts. Crop and food animal production are moving to developing countries to capitalize on limited animal welfare and environmental stewardship, as well as low wages. When local commodity prices fall due to the globalizing agricultural economy, subsistence farmers are economically overwhelmed; they abandon farms; migrate to cities; and crowd into settlements with inadequate or non-existent systems for hygienic drinking water and waste disposal. Some of these individuals take food animals (e.g. chickens, ducks) with them. The myriad increases in disease risks remain to be addressed. Clearly, it is dangerous for public health professionals to quietly acquiesce to a system in which the ecologically rational and ethically necessary—for public health and animal stewardship—are falsely classified as economically or sociologically impossible.

We live in an era of insufficient education of society by public health specialists about extreme risks from avoidable wildlife, domestic animal, and human diseases. In the past, health officials could plead ignorance for failing to inform the public and decision makers regarding how human endeavors were setting the stage for disease emergence. Now, ignorance is not a viable excuse. Despite available ecologically benign or beneficial methods for agriculture, forestry, mining, manufacturing, transportation, power generation, residential development, and commerce, citizens and their governments tolerate economic

gain and corruption through business and governmental practices that degrade ecological services and increase zoonotic disease risks.

Do animal hygiene specialists—first and foremost—serve human and animal health, or rather an illogically conceived system of economic and political rewards? Should health specialists communicate more often and more clearly to the public and their decision makers until regulations, incentives and disincentives ensure that rational ecological and health management costs are internalized into the market economy? To provide economic security to the populations of central and west Africa, would it be wiser to maintain tree-harvest and bushmeat traffic or to invest in the educational systems, agricultural production, and industrial output of the countries involved? In south Asia, should the animal hygiene community address critical control points of ecological/animal management related to preventing the emergence of new influenza strains?

Specialists in veterinary medicine and animal hygiene have the opportunity and the obligation to step forward and assume major responsibility to counteract avoidable downward trends in public health. Societies have invested i) funds in their educations, ii) trust in their knowledge and dedication, and iii) authority in their positions of employment. Societies are therefore entitled to expect these professionals to be: i) well-informed as to current conditions and threats, ii) insightful and candid as to underlying societal causes, and iii) visionary and purposeful in bringing about solutions.

### **An Achievable Vision of Future Environmental and Animal Health Management Systems**

To be achievable, any rational approach to management must thoroughly accommodate human nature: benefits must therefore include food security, food hygiene, and economic wellbeing. All of these can be sustained through a combination of tightly controlled human housing/ business/industry systems, tightly controlled animal production systems, effective buffers in interface zones, and truly wild places with enhanced biological diversity brought about through ecological rehabilitation. Strong public education from pre-school through old age using conventional and unconventional means will be essential to secure necessary political pluralities.

The simplest way to counteract the exotic pet trade is to implement harmonized enforceable international laws banning it, interdict the trade and return healthy individuals to their place of origin if known or to confinement for life in sanctuaries. If a ban is deemed unworkable, then all animals in that trade should be captive bred in ways that conserve genetic diversity,

certified as to health, permanently and uniquely identified, and isolated from creatures of the wild through effective indoor confinement that prevents any direct contact with wild species. Ecotourism and hunting should be regulated to ensure benefits to the regional ecosystem and wildlife populations, as well as benefits including improved economic gain, health care, and education to local human stewards. Some such systems exist and should become the norm. Agricultural impacts on the natural environment and reductions in zoonotic health risks can be achieved most readily through vegetarian diets with plant-based agriculture that uses integrated pest management or is organic. If fishes, meats, dairy products, and eggs are to provide for a major part of human diets, they should be acquired from one of three general types of systems. All three types of systems can readily be phased in over the next 10 to 30 years.

The first system consists of strict confinement in indoor production systems in which the animals are provided with proper nutrition, clean air, comfortable temperatures, desirable humidity levels, effective waste control and sanitation, mental/emotional enrichment, plus complete isolation from insects, rodents, birds, and other free-ranging species. Such animal production systems should be permitted only where waste management will eliminate pathogens, conserve the full complement of nutrients and water, and ensure their use to enrich agricultural productivity or to meet other societal needs. Often, production units should be centered within large crop fields that receive most of the waste-derived nutrients and that limit exposures to wild animals. Feeding programs should limit metal and phosphorus pollution. Between crop fields and natural areas (such as stream-side corridors), hay fields or other buffers should take up nutrients and pesticides, plus form an additional barrier to limit exposure to pathogens of the wild. Governments should provide needed incentive/disincentive systems. Duties or bans on imports should be levied to prevent competition from places that tolerate substandard disease control, poor environmental stewardship, unfair wages and benefits to workers, and long-range transport that consumes non-renewable fossil fuels and contributes excessive carbon dioxide.

In the second type of system, wildlife should be managed extensively—at low densities consistent with historic numbers so that soil, water, and other biota are enriched rather than degraded by their presence. Limited numbers of native predators should be allowed to contribute to disease control as they remove the weak and sick. This approach is consistent with wildlife management for hunting, and is being done now for multipurpose harvesting (meat, hides, support of native subsistence cultures, and/or generation of hunting revenues) in

parts of North and South America and Africa. Some such areas might include carefully conceived pastoralism with selected strains of livestock and astute vaccination and parasite-control. Appropriate herd sizes and migratory patterns should be used to prevent over-grazing. Marketing products from such animals as “free-range” meat would likely attract consumers interested in animal welfare.

The third type of system should consist of wild places. Ecological rehabilitation might initially need to be intensive. Overtime, however, as ecosystem services rebound, management should become less valuable and necessary. The numbers of animals harvested should never interfere with consistent long-term trends toward healthy self-sustaining populations and strong ecosystem services. In some cases, where animal numbers have been reduced so that genetic diversity cannot be maintained by natural breeding, populations may initially need to be supplemented by healthy, genetically-characterized individuals through corridors established from other nearby locales or from captive breeding facilities. Expert public health and veterinary health care should be provided to limit disease transmission to, from, or between the natural areas.

Ultimately, the extensively managed places and wild places should enclose buffers; and the buffers should enclose intensive agricultural, urban, and industrial zones. Thus, areas of human endeavor would need to be linked by transportation systems that traverse corridors using bridges, fences, and other means that prevent wildlife injury yet allow them to migrate and interbreed.

Within the next six months, transdisciplinary teams with animal and human health as well as agricultural, business, and political expertise should be deployed to the locales that pose the greatest risks for emergence of important zoonotic diseases. In developing and developed countries, transdisciplinary teams should acquire mandates to work at the most poorly managed farms, and especially the places with the most intimate contact among poultry, swine, cows, sheep, goats, other domestic species and wildlife. They should work in regions of Africa where bushmeat trade (especially that involving primates) proceeds unchecked, in the animal markets of south Asia, and in other places where zoonotic disease emergence looms.

Transdisciplinary preventive medicine teams should infuse insight, expertise, modest capital, public education, media attention, and political pressure. Veterinary hygiene specialists are well-suited to this task, provided they can literally “think outside the box” of their traditional work assignments and the borders of their home countries. Veterinary hygiene specialists are critically important to planning, implementation, study, and refinement of ecosystems of the future.

## References

1. *Diamond, J. Guns, Germs and Steel: The Fates of Human Societies. W. W. Norton, New York. (1996).*
2. *Diamond, J. Collapse. How Societies Choose to Fail or Succeed. Viking Penguin, New York. (2005).*