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PERSPECTIVE

WILDLIFE HEALTH AND THE NORTH AMERICAN MODEL OF WILDLIFE CONSERVATION

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Abstract: The management of wildlife in the United States and Canada, including the monitoring and maintenance of the health of wildlife populations and the ecosystems on which they depend, are conducted under a set of principles that aim for sustainable use. This set of principles is known as the North American Model of Wildlife Conservation (the Model), and it guides wildlife management and conservation decisions in both countries. The purpose of this perspective is to highlight how wildlife health is an important part of the Model and is vital to its future. It is proposed that wildlife health and the Model support one another. First, the history and fundamental ideas of a *public trust* that shaped the Model are reviewed. Next, wildlife health is defined and examples are offered that highlight how the Model supports wildlife health and how health affects the Model, as well as the limitations or threats if one moves away from the Model's defining principles. Finally, controversies surrounding the Model are reviewed and a perspective on the future is offered, based in large part on the work of Aldo Leopold. Leopold's thinking about health of the land and its organisms was well ahead of its time, and the scientific underpinnings of his writings in making the case for wildlife health and the Model are recounted. As a simple addendum to Leopold's *land ethic*, a plea for a *health ethic* is called for, whereby healthy wildlife and healthy landscapes are an obligation of the Model and modern society because health "tends to preserve the integrity, stability and beauty of the biotic community."[41]

INTRODUCTION

Beginning around the turn of the 20th century, the management of wildlife in the United States and Canada, including the monitoring and maintenance of the health of wildlife populations and the ecosystems on which they depend, has been conducted under a set of principles that aim for sustainable use.[35,47,67] This set of principles is known as the North American Model of Wildlife Conservation (the Model), and although the name was not formally articulated until 2001,[29] the concepts have been in place for over a century.[28,52] The Model has its origins in 19th-century conservation movements, the near extinction (American bison, *Bison bison*, bald eagle, *Haliaeetus leucocephalus*, and peregrine falcon, *Falco peregrinus*) and extinction (passenger pigeon, *Ectopistes migratorius* and Carolina parakeet, *Conuropsis carolinensis*) of several species of wildlife and the rise of sportsmen in the middle class.[46,67]

In 1887, Theodore Roosevelt and George Grinnell founded the Boone and Crocket Club. Grinnell was a prominent anthropologist, author, and naturalist who became an outspoken proponent for preserving the American Great Plains. His advocacy led to the first protections for endangered bison and helped establish Yellowstone as the first national park. The club and its members went on to fund early conservation efforts, led the campaign to eliminate commercial market hunting, and helped create the National Park Service, US Forest Service, and National Wildlife Refuge System, all under the umbrella of what is known today as the North American Model of Wildlife Conservation. Two of the nation's enduring conservation legacies were authored by club members, The Lacey Act (1900)[38] by Congressman John Lacey of Iowa, and the Migratory Bird Treaty Act (MBTA; 1918)[50] by Canadian Charles Gordon Hewitt.[52] The Lacey Act provided the first federal protection for wildlife by making it a crime to illegally take, possess, transport, or sell wild animals, fish, and plants. Through signature to treaties with Canada, Mexico, Japan, and Russia, the MBTA extended these protections for migratory species across international boundaries.

Today, the Model continues to guide wildlife management and conservation decisions made by regulatory agencies in the United States and Canada, and it applies to species that are not harvested, as well as those that are. The Model rests on two basic principles—first, fish and wildlife are for the noncommercial use of citizens

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Table 1. The Seven Tenets of the North American Model of Wildlife Conservation.

The tenet	The principle defined	The origin or legal precedent
I. Wildlife as a Public Trust Resource	Wildlife is held in the public trust; individuals may own the land, but not wildlife; fish and wildlife are managed by state and federal governments for the benefit of the public	Public trust doctrine origins began in Roman times and English common law; In United States, 1842 Supreme Court ruling *Martin v Waddell*[52]
II. Elimination of Markets for Game	Wildlife is allocated to the public by law, as opposed to market principles or land ownership; commercial hunting and the sale of wildlife is prohibited to ensure the sustainability of wildlife populations	The Lacey Act of 1900[38] effectively made market hunting illegal in the United States; Migratory Bird Treaty Act of 1918[50] provided international protections[52]
III. Allocation of Wildlife by Law	Laws regulate game species through established seasons and licensure; nongame species are protected by legislation: Bald and Golden Eagle Protection Act (1940),[1] Marine Mammal Protection Act (1972),[48] and Endangered Species Act (1973)[22]	US Constitution (Section 8; Article 1)[71] gives states primary legal responsibility for wildlife protection (*Geer v. Connecticut*, 161 US 519 (1896); federal government retains authority over migratory, marine mammal, and endangered species
IV. Wildlife Should Only be Killed for a Legitimate Purpose	Under the North American Model, the killing of game is to be done only for food, fur, self-defense, and the protection of property, including livestock[46]	Aldo Leopold defined hunter ethics as a responsibility to practice sportsmanship, advance ecologic thinking, confront moral dilemmas, enhance ecologic education, and experience cultural heritage[62]
V. Wildlife is Considered an International Resource	Wildlife do not exist within fixed political boundaries; effective management of international wildlife resources must be done through treaties[47] (e.g., Migratory Bird Treaty Act[50] and Convention on International Trade in Endangered Species[15])	US Constitution (Section 10; Article 1)[71] gives the Federal government primary role in treaty making with sovereign nations and regulation of trade
VI. Science is the Proper Tool for Discharge of Wildlife Policy	North American Model recognizes science as the basis for informed management decision making; science directs wildlife policy in species conservation, adaptive management, and national surveys of hunting and fishing[52]	Aldo Leopold led a wildlife conservation movement of trained wildlife biologists to support decisions and policy based on professional principles and academic research[40]
VII. Democracy of Hunting	Access to firearms is universal and hunting industry provides funding for conservation[29]; Pittman-Robertson Federal Aid in Wildlife Restoration Act (1937)[53] created 11% excise tax on sporting arms and ammunition allocated to states for wildlife management	Theodore Roosevelt believed open access to hunting would benefit society; this principle became the founding doctrine of the Boone and Crocket Club (1887)[52]

and second, they should be managed such that they are available at optimal levels indefinitely.[46,52] The core principles of the Model are elaborated upon in seven major tenets (Table 1).

Wildlife as a public trust

The public trust doctrine is a foundation for the Model. It is a concept that has evolved into common law from older Roman and English laws.[59,67] In English law, property was distinguished into two categories: 1) property the Crown could grant to private citizens and 2) property that the Crown held in trust for the general public. The latter properties were primarily coastal waters, navigable with the tides and offering access to important fisheries. American underpinnings of the public trust doctrine arose at the time of statehood from similar disputes around private and public rights over waterways and access to fisheries, which 19th-century American courts recognized were uniquely important to the public for navigation, commerce, and food.[7] More than 100 yr later, the public trust doctrine

provides the legal basis for private citizens who demand accountability of local, state, and federal government actions in disputes over land use that range from clean air and water to offshore oil drilling and climate change.[59]

Reference to health in the public trust doctrine is primarily to public health, though paradigms that link animal, human, and ecosystem health (One Health) increasingly fall within public trust thinking.[35] For most wildlife populations, health is required for sustainability, so it follows that maintaining healthy wildlife falls under the public trust doctrine and is the responsibility of government wildlife management agencies (US state and federal; Canadian provincial) and the Crown (Canada).[52] Fundamental to the doctrine is the concept that natural resources are universally valued by people and a public asset to be used and enjoyed by current and future generations. Under the public trust doctrine, natural resources (including but not limited to fish and wildlife) belong in common to all the people of the nation, and government agencies have legal responsibility for their care, including maintaining health.[59,64] At its core, the public trust doctrine is a democratic process, whereby the people elect representatives in government (the trustee) who enact, enforce and adapt wildlife management laws (e.g., protection laws, hunting and fishing laws and regulations, licenses, stamps) and wildlife or conservation policy (e.g., Endangered Species Act [ESA] of 1973,[22] Migratory Bird Treaty Act of 1918,[50] Clean Air Act [CCA] of 1963[13] and Clean Water Act [CWA] of 1977[14]) on behalf of the people (the beneficiaries of the trust).[67] Thus, under the public trust doctrine, maintaining the health of wildlife populations is a social and legal obligation of the trustee.

What is wildlife health?

Defining *health* has been difficult and controversial in both human and veterinary medicine.[33] Historically, health has been defined as the absence of disease. However, this idea is antiquated and has been criticized on several levels: It fails to recognize that pathogens and parasites are ubiquitous in nature; that some level of disease may be normal and may serve a larger ecologic purpose; it does not address thresholds of disease that lead to illness or recovery; it overlooks the epidemiologic view that a population of animals can be healthy even while having diseased members; it is a reactive approach to disease that misses the opportunity to promote preventative health; and it is inconsistent with holistic thinking that sees health as a *coping ability* in the face of socioecologic interactions that are increasingly responsible for modern health threats (land use, global trade, introduced diseases, climate change, and invasive species).[66]

The ambiguity of what wildlife health means and its historic focus on disease and pathogens has impeded the development of a shared concept of health across wildlife, domestic animals, and people. A modern definition for health should include resilience and sustainability of individuals and populations and a reorientation of management goals away from preservation of individual animals (except for critically endangered species) and toward sustaining populations, the complex ecosystems that support them, and their capacity to adapt.[2,34,73] Therefore, the concept of health is not purely a biologic or epidemiologic construct but is the output of a desired condition, namely, the ability of animals and populations to cope with change, particularly anthropogenic change. Core to this concept is that modern drivers of disease are more than pathogens and parasites themselves but include human-induced stressors, such as climate change, land use, pollution, invasive species, and wildlife trade.[18] More than half a century before the present-day attempts to define wildlife health, Aldo Leopold (1944) wrote about health of the land as analogous to the functioning of an organism, with health being a condition of stability and self-renewal: "The land consists of soil, water, plants, and animals, but health is more than a sufficiency of these components. It is a state of vigorous self-renewal in each of them, and in all collectively."[42]

To understand how health supports, and is supported by, the Model, a definition of wildlife health that recognizes both the societal forces increasingly responsible for a departure from the desired condition one calls health and the ecologic resilience that helps protect wildlife from such deviations is required.[5,9,39] For these purposes a new definition of wildlife health is offered following Stephen[66] within the context of Leopold's three principles of health (stability, self-renewal, and ethos; 1944[42]): Wildlife health is the interaction of biologic, social and environmental determinants that affect a wild animal population's ability to cope with change (stability), recover in the face of change (self-renewal), and meet societal goals (ethic). Stability and self-renewal are separate but complementary goals. Leopold (1944) equated stability with health of a diverse community.[42] Health was associated with, and perhaps caused by, this diversity and complexity.

More and more, species richness meant more and more complex relations between them, and this increase in species diversity correlates positively with increasing health. Leopold's self-renewal is analogous to resilience, defined by Walker et al. (2004) as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks."[73] Resilience in an ecosystem requires redundancy of both function and response, whereby species fulfill more than one role in the ecosystem and individuals vary in their ability to deal with a threat, enabling some members of the population to survive change and the system to continue operating.[3] Therefore, health is more than mere survival (not an end goal or target state), but rather a dynamic process. At the population health level, species build resilience and overcome vulnerabilities through high genetic diversity, and at the individual animal level, by changing behaviors in response to their environment throughout life.[20,60,75] Finally, healthy wildlife must be healthy in the eyes of the public and meet the goals and ethos (the guiding beliefs and ideals that characterize a group) society holds for their wildlife resources.[5] This final part of the definition is especially critical when considering health in the context of the public trust doctrine that forms the heart of the Model. It is the healthy population, more than just the individual, which must meet societal goals. A definition of health that incorporates these three key elements will help realize the greatest impact on wildlife health and sustainability and stand the best chance of advancing policy.

Wildlife health and the Model

Even though the Model faces significant future challenges, it has endured as one example for sustainable natural resource stewardship. A main reason for the Model's enduring legacy is that it grants *value* to the public by clarifying ownership in, and management of, the nation's wildlife resource (a living asset) and, in so doing, empowers the public to help secure the resource for future generations.[35] Few attributes of a living asset could be considered more valuable than its health, both in terms of public perceptions and sustainability. Indeed, wildlife health, or the capacity of animal populations and ecosystems to exhibit stability and self-renewal, is dependent upon a public ethos for their management and preservation.[5]

The health of wildlife and the Model are uniquely integrated (Fig. 1), and the Model supports the health of wildlife (and, as a consequence, people) in diverse ways that extend well beyond the traditional values of disease surveillance and disease management. Likewise, the concept of health supports the Model. A modern definition of wildlife health can be used to show a wide application of the Model to protecting the health of both game and nongame species, as well as humans. Stability, self-renewal, and ethics all contribute to the unique interrelationships of wildlife health and the Model.

How the Model protects wildlife health

One of the most important contributions of the Model to the protection of wildlife health is stewardship of (e.g., surveillance of and informed actions that sustain) healthy animal populations (Fig. 1). Wildlife health research (science as a tool for wildlife policy) is essential for sound wildlife management, and it includes work in the fields of epidemiology, toxicology, parasitology, pathology, ecology, and climate sciences to name a few disciplines, all of which inform ecosystem-level processes. Although research can provide practical solutions, it is incumbent upon policy makers to enact these solutions; therefore, setting priorities for wildlife health research is critical to the future of the Model.[54,58] Although facts alone are not enough to guide important wildlife decisions and drive policy,[51] science is a critical tool that provides much of the information that managers, administrators, and lawmakers need to debate policy. Given that there exist conflicting uses of wildlife (e.g., utilization vs preservation), it is essential that the best knowledge is used to develop strategies that satisfy the broadest public interest.[69] Financial support for trust management has historically come from consumptive interests (sales of hunting and fishing licenses, wildlife stamps, and taxes on ammunition and fishing tackle). Although the Model does not in itself provide funding and infrastructure for research, it does provide an underlying philosophy that government agencies use to allocate funding and guide how it is applied; see Model tenets such as "science is the proper tool for discharge of wildlife policy" (Table 1).[52]

For endangered species, small populations are inordinately susceptible to health threats and management interventions can often mean the difference between survival and extinction.[18,49,44] A good example is the decline of the peregrine falcon (*Falco peregrinus*) as a result of organochlo-

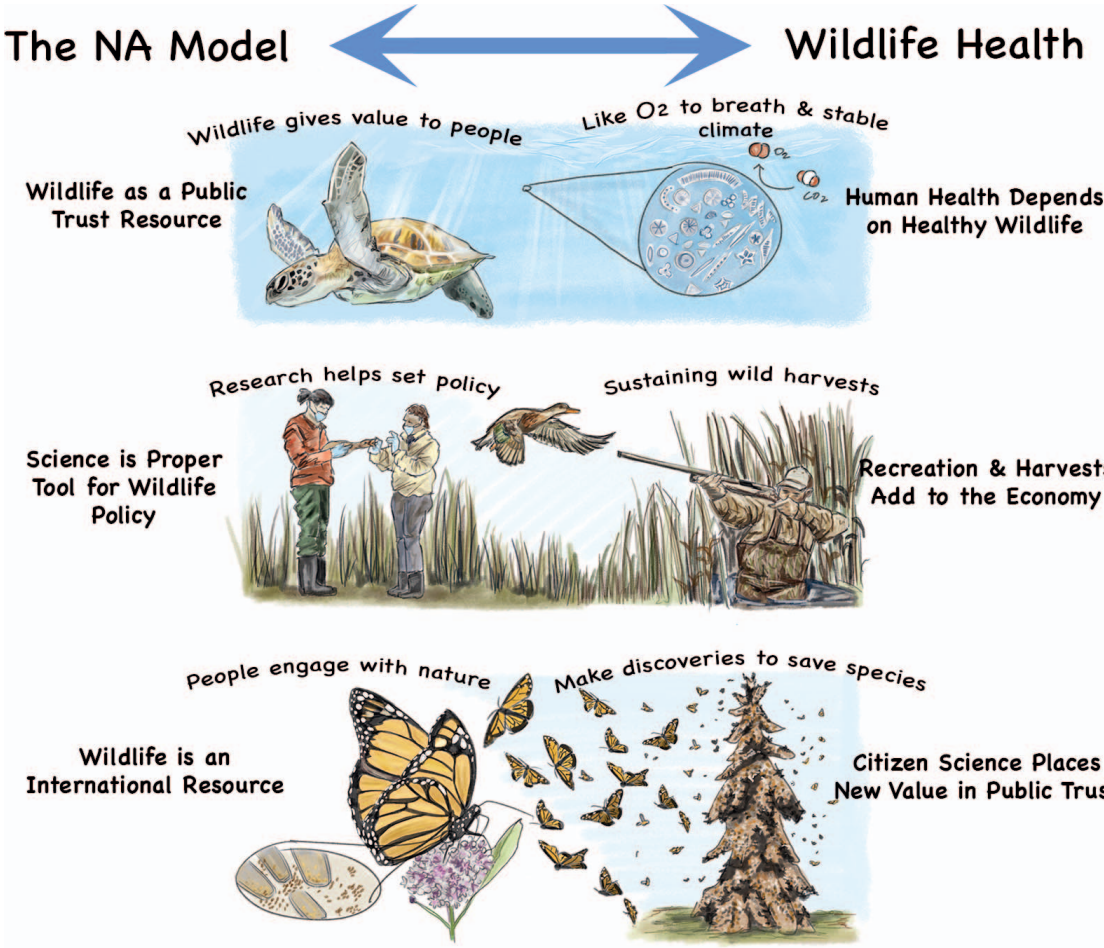

Figure 1. The North American Model of Wildlife Conservation, a set of beliefs for the care of wildlife and wild places, is founded on the public trust doctrine. The Model's seven tenets protect wildlife health, and, in return, healthy wildlife give value back to the people as beneficiaries of the trust. The authors submit that the intergenerational model gives in perpetuity: *when we take care of nature, nature takes care of us.* Illustration credit to Laura Donohue

rine pesticide–induced eggshell thinning.[23] Although not endangered, the peregrine falcon had a limited number of breeding pairs prior to widespread use of dichlorodiphenyltrichloroethane (DDT), thus leaving them more susceptible to its effects.[72] Research revealed a link between reproductive failure in the form of thin and weak eggshells and DDT contamination through bioaccumulation in the food chain in peregrine falcons, as well as many other fish-eating raptors, brown pelicans (*Pelecanus occidentalis*), and other species.[23,65] Science and policy decisions resulted in bans on the production and use of DDT and eventual recovery of the peregrine.[8] In this case and others like it, the science-based approach of the Model facilitated health and management interventions that proved essential to preserve the wildlife resource and secure the public's investment in the future (wildlife resource of the public trust doctrine). Under the public trust doctrine, government agency intervention to save endangered species is mandated under the Endangered Species Act (ESA 1973),[22] a landmark legislation made possible by the structure of the Model.[2]

Wildlife health monitoring, disease interventions, and health-related policy decisions are facilitated under the Model, but health threats to wildlife populations can also increase if one moves away from the Model. A good example is chronic wasting disease (CWD) and the effects of commercialization of wildlife. Efforts to deal with

CWD as an emerging health threat to North American cervid populations has both benefited from tenets of the Model (science as a tool for wildlife policy: Table 1) and suffered from exceptions to the Model's application (failing to eliminate markets for game, and allocation of wildlife by law, by defining wildlife as agricultural animals and ignoring wildlife as an international resource, respectively). Knowledge about cervid health has benefited from intensive hunter harvest surveillance and culling, as have related monitoring and research efforts.[37] But the raising of captive cervids has exacerbated the emergence of CWD and represents a clear departure from the Model and public trust doctrine—while land can be privately owned, the wildlife living on the land must not be.[52] With the raising of wild cervids in captive environments (game ranching) in North America, came a shift from public trust to private ownership, and management of captive wildlife by landowners complicates the control of a wildlife disease. A glaring weakness of the Model is that it is a set of principles rather than established law, so agencies of the government may at times ignore it, political and financial forces may compromise it, but sufficient social pressure can work through political and legal channels to reverse these exceptions.

How healthy wildlife gives value to the Model

There is perhaps no greater value of wildlife than the support of Earth's life systems (clean air, clean water, photosynthesis, carbon sequestration, and nutrient cycling), which healthy wild animals, plants, and intact ecosystems provide at minimal cost to people (Fig. 1).[39] If one agrees that the driving goal of the Model is to ensure that wildlife populations and the ecosystems they are a part of, are maintained for future generations (intergenerational equity), then humans will need to protect the processes that support wildlife (and human) health, even if one does not understand them fully.[35] To move science, to policy, to action, there is often a need for legislation to evolve (e.g., the Endangered Species Act) away from only saving individuals of a species and toward saving complex systems on which the populations depend.[2]

An overlooked aspect of wildlife is the nutrition and food security that *healthy* wild animals provide to people. Although the monetary value of wild harvests in North America are poorly understood, if humans were to lose the billions of pounds of wild animal protein from hunting and fishing, the replacement costs associated with domestic livestock production and modern agriculture would add considerable burdens to both the environment and the economy (Wild Harvest Initiative).[45] Indeed, in parts of the world where unsustainable practices have decimated wildlife populations, the loss of essential protein in the diet of the rural poor has significant health implications, including childhood anemia and cognitive deficits.[30] Indigenous peoples rely heavily on wild harvests of game, and an estimated 45 million Americans and Canadians annually engage in hunting and fishing for food.[68,74] When one considers that the amount of money recreational hunting and fishing pump into regional, local, and national economies exceeds the actual market value of the wild food, the larger economic value of harvesting wildlife becomes apparent.

People are connecting with nature in new ways that represent an evolution of the Model. One change is citizen science, and it has contributed significant new understanding of the natural world.[19,70,77] Given that the Model requires public approval and engagement, its value may be weakened by changing public perceptions of wildlife as a result of increased separation from nature, a lack of understanding of where food comes from, changing philosophies on animal rights, and a decline of hunting and fishing traditions. In this landscape, citizen science offers a unique opportunity for people to realize new value in wildlife and how natural systems are connected to their health.[4,19] Given the growing consensus that a broad alliance of people is necessary for resource conservation, one intimately connected with the health of a living asset, let us now explore controversies surrounding the Model and examine its relevance moving into the 21st century.

Controversy and the Model

Following the first written articulation of the Model by Geist in 1995, there has been mounting debate about its shortcomings.[12,61] Critiques of the Model focus on a handful of major challenges that can be viewed from two perspectives: 1) application of the Model to the wildlife resource (threats to wildlife stability and self-renewal) and 2) human perceptions of wildlife (threats to a public ethos for wildlife). In the first viewpoint, the application of the Model has suffered from confusion about public trust responsibilities resulting in a mosaic of state laws and policies, inadequate regulation of invasive species, the need for sustainable funding beyond a single user pay system, and a failure to incorporate indige-

nous peoples' knowledge and rights.[36] In the second viewpoint, the fitness of the Model is increasingly questioned as wildlife abundance brings conflict, private ownership competes with public ownership of wildlife, and a nonhunting public doubts the relevancy of the Model.[76] The latter is a consequence of the Model's historical focus on game animals at the expense of nongame wildlife that has favored hunters and anglers over other trust beneficiaries. Thorough reviews of these challenges can be found elsewhere.[12,51,61,69] Therefore, examining the shortcomings that most directly impact the connection between wildlife health and the Model is necessary: a focus on game animals, wildlife overabundance, and invasive species.

Focus on game animals at the expense of nongame animals: The Model's overt focus on hunting and fishing gives the perception that it lacks inclusion of other wildlife conservation interests.[6,29] A philosophy based predominately on harvest as a management tool does not adapt itself readily to more holistic ecosystem health approaches, and it is not very useful for the vast number of species (many of them threatened or endangered) that are not harvested. Although often used for sampling, hunting and fishing are not precise tools by themselves and are too often circumvented to make them a primary means of controlling most diseases and parasites. They are somewhat more useful for reducing health problems that are population associated, nutritional, and/or density dependent. Health threats have also arisen directly from hunting and angling, notably lead toxicity resulting from environmental contamination by lead-based ammunition and ingestion of lead fishing weights. This has hampered endangered species conservation programs, including the recovery of the common loon (*Gavia immer*) and bald eagle in the northeastern United States and the California condor (*Gymnogyps californianus*) in the West.[25,32,63] Concern regarding continued health risks to wildlife from lead has given rise to negative perceptions of hunters and anglers, in general, despite the many responsible individuals who are using and promoting nontoxic materials and the fact that many are simply unaware of the risks.

Wildlife overabundance: a new dilemma: Overwhelming land-use changes and decimation of predators (in part, an outcome of the Model) have created a new problem: wildlife overabundance. Many of the game animals prioritized under the Model have made remarkable recoveries. Today 30 million white-tailed deer (*Odocoileus virginianus*), 10 million beaver (*Castor canadensis*), 7 million wild turkey (*Meleagris gallopavo*), and 5 million Canada geese (*Branta canadensis*) are at levels wildlife managers consider overabundant or reaching densities that adversely affect other native species, ecosystems, or humans.[27] Most of these species are generalists or opportunists, primarily herbivores, but include carnivores and omnivores like the coyote (*Canis latrans*) and raccoon (*Procyon lotor*), which have benefited from large predator elimination, taken advantage of anthropogenic agricultural activities, or have adapted to urban landscapes. When wildlife grow so plentiful that conflict ensues, wild animals may be seen as a liability rather than a benefit, and some people increasingly see them as pests, vermin, or nuisances.[21,76]

Leopold warned of the impending threats of too many deer on the landscape, and the ecologic toll can be significant with deer wreaking havoc on the forest understory, leading to widespread decline of migratory songbirds as a contemporary example.[10,16,40] However, the health implications to the deer, and to a variety of cohabitating wildlife species, are just as severe.[31] Leopold recognized that the loss of top predators had an adverse effect on the health of the food web, affecting not only prey, but parasites and pathogens as well. The trophic cascade following the loss of top predators can lead to a disproportionate survival of unhealthy animals and a higher burden of disease in the system.[5] Anthropogenic changes impacting the diversity of wildlife species and the structure of ecologic guilds may also affect public health—the overpopulation of deer and white-footed mice (*Permomyscus leucopus*) are largely responsible for the emergence of Lyme disease, the most common vectorborne epidemic in the United States.[55]

Invasive species: Invasive alien species (IAS) are animals, plants, fungi, or microorganisms moved by humans to environments outside their original range, and being highly adaptable, often outcompete native animals and bring harm to ecosystems.[11] In the United States, invasive species are the second leading cause of floral and faunal extinctions, costing an estimated US$120 billion each year.[16] Alarmingly, of the "100 World's Worst IAS" outlined in the Convention on Biological Diversity, one quarter of those listed are linked to diseases of wildlife.[57]

The first federal court case affirming the public trust doctrine in the United States occurred in 1842. Leopold noted that by 1840, the beginnings of a decline in native plant and animal communi-

ties were evident, with the loss of iconic species such as the bison and passenger pigeon and the import of invasive sparrows, starlings, rodents, and pheasants.[42] The Model arose at a time before significant global spread of species and, therefore, lacks any specific protections for native animal populations against harmful invasives. Furthermore, the Model's support for game animals for the purpose of harvesting has damaged the health of some native communities, including the movement of non-native game animals and fish that have degraded both landscapes and fisheries. Similarly, the movement of species from one area to another, whether for hunting, purposeful translocation, or biologic control, is not addressed in the Model, and this has occasionally harmed both wildlife and human health.[11]

Health and the future of the Model

A revival of the public trust doctrine has been attributed to the case law writings of Judge Joseph Sax and includes language that goes beyond consumptive uses of wildlife (primarily in the form of hunting and angling) to include individual rights to a healthy, diverse, and productive natural environment where clean air, clean water, and other natural resource entitlements, including the right to healthy wildlife, are defensible against a noncompliant government.[24,56,59] Thus, maintaining healthy wildlife has a legal as well as biologic, social, and moral basis.

Increasingly, one must recognize that the health of animals is intimately connected to one's own health (both physical and mental) and that of the environment.[39] The global pandemics arising from Ebola, human immunodeficiency virus, severe acute respiratory syndrome, and related coronaviruses threaten the foundation of species management, conservation, and health and challenge one to embrace a new understanding of the world.[18,26] The concept that health is shared among all living things has led to new viewpoints of health that reach across disciplines (e.g., One Health, conservation medicine, and Planetary Health), varying primarily in perspective and degree of anthropocentric thinking.[43]

The authors agree with Nelson et al. (2011) in their critique of the Model when they argue that "the greatest value of the Model is that it highlights the need to confront a more basic question: What is conservation?"[51] This perspective may help answer an equally urgent question facing society: Can humans appreciate how health (both one's own and that of cohabiting species) is central to a public trust, thereby bestowing upon us a responsibility for care of the earth? The Model has taken us a long way toward achieving healthy wildlife populations through a variety of means, including hunting and fishing. Notably, the public trust doctrine has garnered essential public interest that bestows value on natural resources, while giving citizens enforceable rights.[59,62] To keep the Model relevant, however, one should be open to new ideas of health that encompass far more than abundance of consumable fish and wildlife. *Health* must extend beyond a biologic state of individuals to include the ecosystems in which animals live, the processes that connect and sustain them, and, importantly, unite squarely behind a renewed societal contract, where human actions as a cohabiting species are held accountable.

Healthy wildlife as an ethic of modern society

In this perspective, it is reasoned that wildlife health supports the North American Model of Wildlife Conservation and, in turn, the Model protects the health of wild animals. Toward that end, wildlife health is defined as the interaction of biologic, social, and environmental determinants that affect a wild animal population's ability to cope with change (stability), recover in the face of change (self-renewal), and meet societal goals (ethic). The final tenet of the triad, meeting societal goals**,** is perhaps the most vital of the three because it serves to protect the first two. If one is to see the Model change to keep up with changing public attitudes and trends in natural resource use, the public must find real value in its wildlife resource. Health is perhaps one of the most easily understood values of a living system and serves to connect the realities of modern threats to wildlife with the need to protect its resilience through public education and deliberate guardianship.[5,21,34]

In his land ethic, Leopold conveys the idea that individual respect for, and responsibility of, a community is part of an ethical sequence.[41] The first part of this sequence is respect for the individual (the golden rule), the second is respect for society (democracy), and the final part is respect for the land organism, which he widened to encompass the soils, waters, plants, and animals. Leopold equated ethics with cooperation in a community and understood that "we can be ethical only in relation to something we can see, feel, understand, love, or otherwise have faith in."[41] Aldo Leopold never put down on paper a set of principles to define his land ethic. Rather, he

believed that "nothing so important as an ethic is ever 'written'" and can only evolve "in the minds of a thinking community."[41] The thinking community, Leopold knew, would act with an ethical conscience if they believed "a thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise."[41] An ethic is a moral principle that affirms a form of conduct—in essence, it is the "trust" in the public trust that upholds the Model. Consequently, the Model provides the framework for a health ethic. Health brings integrity and stability and leads to the faith that Leopold hoped for; and so, the authors offer a simple addendum to Leopold's land ethic: *when we take care of nature, nature takes care of us.*

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LITERATURE CITED

1. Bald and Golden Eagle Protection Act of 1940. Title 16 of the United States Code; Chapter 5A: Protection and Conservation of Wildlife; Subchapter II: Protection of Bald and Golden Eagles: https://www.govinfo.gov/content/pkg/USCODE-2010-title16/pdf/USCODE-2010-title16-chap5A-subchapII.pdf

2. Benson MH. Intelligent tinkering: the Endangered Species Act and resilience. Ecol Soc. 2012; 17(4):28.

3. Benson MH, Hopton ME. Bringing resilience to wildlife management and biodiversity protection. In: Garmestani AS, Allen CR (eds.). Social-ecological resilience and law. New York (NY): Columbia Univ. Press; 2014. p. 37–62.

4. Benoiston AS, Ibarbalz FM, Bittner L, Guidi L, Jahn O, Dutkiewicz S, Bowler C. The evolution of diatoms and their biogeochemical functions. Philos Trans R Soc Lond B Biol Sci. 2017;372(1728): 20160397.

5. Berkes F, Doubleday NC, Cumming GS. Aldo Leopold's land health from a resilience point of view: self-renewal capacity of social-ecological systems. Ecohealth. 2012;9(3):278–287.

6. Beuchler M, Servheen G. Mirror, mirror, on the wall: reflections from a nonhunter. In: Trans N Am Wildl Nat Res. 2008;73:163–179.

7. Blumm MC, Wood MC. The Public Trust Doctrine in environmental and natural resources law. Durham (NC): Carolina Academic Press; 2013.

8. Cade TJ, Enderson JH, Thelander CG, White CM (eds.). Peregrine falcon populations: their management and recovery. Boise (ID): The Peregrine Fund; 1988.

9. Callicott JB, Crowder LB, and K Mumford. Current normative concepts in conservation. Conserv Biol. 1999;13(1):22–35.

10. Challot S, Martin JL. Declining woodland birds in North America: should we blame Bambi? Divers Distrib. 2013;19(4):481–483.

11. Chinchio E, Crotta M, Romeo C, Drewe JA, Guitian J, Ferari N. Invasive alien species and disease risk: An open challenge in public and animal health. PLoS Pathog. 2020;16(10):e1008922.

12. Clark SG, Milloy C. The North American Model of Wildlife Conservation: an analysis of challenges and adaptive options. In: Clark SG, Rutherford MB (eds.). Large carnivore conservation: integrating science and policy in the North American West. Oxford (United Kingdom): Oxford Univ. Press; 2014; p. 289–324.

13. Clean Air Act of 1963. Title 42 of the United States Code; Chapter 85: Air Pollution Prevention and Control: https://uscode.house.gov/browse/prelim@title42/chapter85&edition=prelim

14. Clean Water Act of 1977. Title 33 of the United States Code; Chapter 26: Water Pollution Prevention and Control: https://www.govinfo.gov/content/pkg/USCODE-2018-title33/pdf/USCODE-2018-title33-chap26.pdf

15. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Title 50 of the United States Code; Chapter I; Subchapter B; Part 23: CITES: https://www.ecfr.gov/current/title-50/chapter-I/subchapter-B/part-23

16. Côté SD, Rooney TP, Tremblay JP, Dussault C, Waller DM. Ecological impacts of deer overabundance. Annu Rev Ecol Evol Syst. 2004;35:113–147.

17. Crowl TA, Crist TO, Parmenter RR, Belovsky G, Lugo AE. The spread of invasive species and infectious disease as drivers of ecosystem change. Front Ecol Environ. 2008;6(5):238–246.

18. Deem SL, Karesh WB, Weisman W. Putting theory into practice: wildlife health in conservation. Conserv Biol. 2001;15(5):1224–1233.

19. Dickinson JL, Shirk J, Bonter D, Bonney R, Rhiannon CL, Martin J, Phillips T, Purcell K. The current state of citizen science as a tool for ecological research and public engagement. Front Ecol Environ. 2012;10(6):291–297.

20. Döring TF, Vieweger A, Pautasso M, Vaarst M, Finckh MR, Wolfe MS. Resilience as a universal criterion of health. J Sci Food Agric. 2015;95(3):455–465.

21. Dratch P, Kahn R. Moving beyond the model: our ethical responsibility as the top trophic predators. Wildl Prof. 2011;5(2):61–63.

22. Endangered Species Act of 1973. Title 16 of the United States Code as amended through the 108th Congress: https://media.fisheries.noaa.gov/dam-migration/esa-accessible.pdf

23. Enderson JH, Craig GR, Burnham WA, Berger DD. Eggshell thinning and organochlorine residues in rocky mountain peregrines, *Falco peregrinus*, and their prey. Can Field Nat. 1982;96(3):255–264.

24. Feldpausch-Parker A, Parker ID, Vidon ES. Privileging consumptive use: a critique of ideology, power, and discourse in the North American Model of Wildlife Conservation. Conserv Soc. 2017;15(1):33–40.

25. Finkelstein ME, Doak DF, George D, Burnett J, Brandt J, Church M, Grantham J, Smith DR. Lead poisoning and the deceptive recovery of the critically endangered California condor. Proc Natl Acad Sci U S A. 2012;109(28):11449–11454.

26. Friend M. Disease emergence and resurgence: the wildlife human connection. Circular 1285. Reston (VA): US Geological Survey; 2006.

27. Garrott RA, White PJ, White CAV. Overabundance: an issue for conservation biologists? Conserv Biol. 1993;7(4):946–949.

28. Geist V. North American policies of wildlife conservation. In: Geist V, McTaggert-Cowan I (eds). Wildlife conservation policy. Calgary (Canada): Detselig Enterprises, Ltd.;1995.

29. Geist V, Mahoney SP, Organ JF. Why hunting has defined the North American model of wildlife conservation. In: Trans N Am Wildl Nat Res. 2001;66: 175–185.

30. Golden CD, Fernald LCH, Brashares JS, Rasolofoniaina BJR, Kremen C. Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. Proc Natl Acad Sci U S A. 2011;108(49):19653–19656.

31. Gortázar C, Ferroglio E, Lutton CE, Acevedo P. Disease-related conflicts in mammal conservation. Wildl Res. 2010;37(8):668–675.

32. Grade TJ, Pokras MA, Laflamme EM, Vogel HS. Population-level effects of lead fishing tackle on common loons. J Wildl Manag. 2018;82(1):155–164.

33. Gunnarsson S. The conceptualization of health and disease in veterinary medicine. Acta Vet Scand. 2006;48(1):20.

34. Hanisch SL, Riley SJ, Nelson MP. Promoting wildlife health or fighting wildlife disease: insights from history, philosophy, and science. Wildl Soc Bull. 2012;36(3):477–482.

35. Hare D, Blossey B. Principles of public trust thinking. Hum Dimens Wildl. 2014;19(5):397–406.

36. Hoagland SJ. A tribal model of wildlife stewardship. Wildl Prof. 2016;10(6):28–30.

37. Hopkins MC, Carlson CM, Cross PC, Johnson CJ, Richards BJ, Russell RE, Samuel MD, Sargeant GA, Walsh DP, Walter WD. Chronic wasting disease—research by the US Geological Survey and partners (ver. 2.0). Reston (VA): US Geological Survey; 2019.

38. Lacey Act of 1900. Title 16 of the United States Code; Chapter 53: Control of Illegally Taken Fish and Wildlife: https://uscode.house.gov/view.xhtml?path=/prelim@title16/chapter53&edition=prelim

39. Lackey RT. Values, policy and ecosystem health. Bioscience. 2001;51(6):437–443.

40. Leopold A. Game management. New York (NY): C. Scribner's Sons; 1933.

41. Leopold A. A Sand County Almanac: and sketches here and there. Oxford (United Kingdom): Oxford Univ. Press; 1949.

42. Leopold A. Conservation: in whole or in part? Report to University of Wisconsin Committee on post-war agricultural policies (1944). In: Flader SL, Callicott JB (eds). The river of the mother of God and other essays. Madison (WI): Univ. of Wisconsin Press; 1991. p. 310–319.

43. Lerner H, Berg C. A comparison of three holistic approaches to health: One Health, EcoHealth, and Planetary Health. Front Vet Sci. 2017;4:163.

44. MacPhee RDE, Greenwood AD. Infectious disease, endangerment, and extinction. Int J Evol Biol. 2013(20);1–9. doi.org/10.1155/2013/571939

45. Mahoney S. Consumption patterns of wild protein in North America: a literature review in support of the wild harvest initiative. St. John's (Canada): Conservation Visions; 2016.

46. Mahoney SP, Geist V. The North American Model of Wildlife Conservation. Baltimore (MD): John Hopkins Univ. Press. 2019.

47. Mahoney SP, Geist V, Krausman PR. The North American Model of Wildlife Conservation: setting the stage for evaluation. In: Mahoney SP, Geist V (eds.). The North American Model of Wildlife Conservation. Baltimore (MD): John Hopkins Univ. Press. 2019.

48. Marine Mammal Protection Act of 1972. Title 16 of the United States Code; Chapter 31: Marine Mammal Protection: https://media.fisheries.noaa.gov/2021-04/mmpa_2018_revised_march_2019-508_%282%29.pdf?null

49. McCallum H. Disease and the dynamics of extinction. Philos Trans R Soc Lond B Biol Sci. 2012; 367(1604):2828–2839. doi:10.1098/rstb.2012.0224

50. Migratory Bird Treaty Act of 1918. Title 16 of the United States Code; Chapter 7: Protection of Migratory Game and Insectivorous Birds; Subchapter II: Migratory Bird Treaty: https://www.govinfo.gov/content/pkg/USCODE-2018-title16/html/USCODE-2018-title16-chap7-subchapII-sec703.htm

51. Nelson MP, Vucetich JA, Paquet PC, Bump JK. An inadequate construct? North American Model: What's flawed, what's missing, what's needed. Wildl Prof. 2011;5(2):58–60.

52. Organ JF, Geist V, Mahoney SP, Williams S, Krausman PR, Batcheller GR, Decker TA, Carmichael R, Nanjappa P, Regan R, Medellin RA, Cantu R, McCabe RE, Craven S, Vecellio GM, Decker DJ. The

North American Model of Wildlife Conservation. The Wildlife Society Bethesda (MD): The Wildlife Society; 2012.

53. Pittman-Robertson Federal Aid in Wildlife Restoration Act of 1937. Title 16 of the United States Code; Chapter 5B: Wildlife Restoration: https://www.govinfo.gov/content/pkg/COMPS-3013/pdf/COMPS-3013.pdf

54. Peters A, Carver S, Skerratt LF, Meredith A, Woods R. A solutions-focused translational research framework for wildlife health. Bioscience. 2019;69(12):1019–1027.

55. Rochlin I, Ninivaggi DV, Benach JL. Malaria and Lyme disease—the largest vector-borne US epidemics in the last 100 years: success and failure of public health. BMC Pub Health. 2019;19(1):804.

56. Rockel ML, Kealy MJ. The value of nonconsumptive wildlife recreation in the United States. Land Econ. 1991;67(4):422.

57. Roy HE, Hesketh H, Purse BV, Eilenberg J, Santini A, Scalera R, Stentford GD, Adriaens T, Bacela-Spychalska K, Bass D, Beckmann KM, Bessell P, Bojko J, Booy O, Cardoso AC, Essl F, Groom Q, Harrower C, Kleespies R, Martinou AF, van Oers MM, Peeler EJ, Pergl J, Rabitsch W, Roques A, Schaffner F, Schindler S, Schmidt BR, Schönrogge K, Smith J, Solarz W, Stewart A, Stroo A, Tricarico E, Turvey KMA, Vannini A, Vila M, Woodward S, Wynns AA, Dunn AM. Alien pathogens on the horizon: opportunities for predicting their threat to wildlife. Conserv Lett. 2017;10(4):477–484.

58. Ryser-Degiorgis. Wildlife health investigations: needs, challenges and recommendations. BMC Vet Res. 2013;9(1):223.

59. Sax JL. The public trust doctrine in natural resource law: effective judicial Intervention. Mich Law Rev. 1970;68(3):471–566.

60. Scheffer M, Bolhuis JE, Borsboom D, Buchman TG, Gijzel SMW, Goulson D, Kammenga JE, Kemp B, van de Leemput IA, Levin S, Martin CM, Melis RJF, van Nes EH, Romero LM, Rikkert MGMO. Quantifying resilience of humans and other animals. Proc Natl Acad Sci U S A. 2018;115(47):11883–11890.

61. Serfass TL, Brooks RP, Bruskotter JT. North American Model of Wildlife Conservation: empowerment and exclusivity hinder advances in wildlife conservation. Can Wildl Biol Manag. 2018;7(2):101–118.

62. Simpson SV, Cain KD. Recreation's role in the environmental ethics dialogue: the case of Aldo Leopold and the morality of hunting. J Appl Rec Res. 1995;20(3):185–201.

63. Slabe VA, Anderson JT, Millsap BA, Cooper JL, Harmata AR, Restani M, Crandall RH, Bodenstein B, Bloom PH, Booms T, Buchweitz J, Culver R, Dickerson K, Domenech R, Dominguez-Villegas E, Driscoll E, Smith BW, Lockhart MJ, McRuer D, Miller TA, Ortiz PA, Rogers K, Schwarz M, Turley N, Woodbridge B, Finkelstein ME, Triana CA, DeSorbo CR, and TE Katzner. Demographic implications of lead poisoning for eagles across North America. Science, 2022;375(6582):779.

64. Smith CA. The role of state wildlife professionals under the public trust doctrine. J Wildl Manag. 2011;75(7):1539–1543.

65. Steidl RJ, Griffin CR, Niles LJ, Clark KE. Reproductive success and eggshell thinning of a reestablished peregrine falcon population. J Wildl Manag. 1991;55(2):294–299.

66. Stephen C. Toward a modernized definition of wildlife health. J Wildl Dis. 2014;50(3):427–430.

67. The Wildlife Society. The Public Trust Doctrine: implications for wildlife management and conservation in the United States and Canada. Bethesda (MD): The Wildlife Society; 2010.

68. Tidball KG, Tidball MM, Curtis P. Extending the locavore movement to wild fish and game: questions and implications. Nat Sci Educ. 2013;42(1):185–189.

69. Treves A, Chapron G, Lopez-Bao JV, Shoemaker C, Goeckner AR, Bruskotter JT. Predators and the public trust. Biol Rev. 2017;92(1):248–270.

70. Urquhart FA, Urquhart NR. Aberrant autumnal migration of the eastern population of the monarch butterfly, *Danaus p. plexippus* (Lepidoptera: Danaidae) as it relates to the occurrence of strong westerly winds. Can Entomol. 1979;111(11):1281–1286.

71. US Constitution. America's Founding Documents. National Archives: https://www.archives.gov/founding-docs/constitution-transcript

72. US Fish and Wildlife Service. Peregrine falcon factsheet. Washington (DC): US Fish and Wildlife Service; 2006.

73. Walker B, Holling CS, Carpenter SR, Kinzig A. Resilience, adaptability and transformability in social-ecological systems. Ecol Soc. 2004;9(2):5.

74. Watkins T. How we pay to play: funding outdoor recreation on public lands in the 21st century. Bozeman (MT): PERC Public Lands Report; 2019.

75. Wittrock J, Duncan C, Stephen C. A determinants of health conceptual model for fish and wildlife health. J Wildl Dis. 2019;55(2):285–297.

76. Yablonski B. Rethinking the North American wildlife model: new challenges require new solutions for wildlife management. Bozeman (MT): PERC Public Lands Report; 2019.

77. Yang D, Wan HY, Huang TK, Liu J. The role of citizen science in conservation under the telecoupling network. Sustainability. 2019;11(4):1108.

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