

Joining the dots – understanding the complex interplay between the values we place on wildlife, biodiversity conservation, human and animal health: A review

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Abstract

The value of wildlife has long been ignored or under-rated. However, growing concerns about biodiversity loss and emerging diseases of wildlife origin have enhanced debates about the importance of wildlife. Wildlife-related diseases are viewed through these debates as a potential threat to wildlife conservation and domestic animal and human health. This article provides an overview of the values we place on wildlife (positive: socio-cultural, nutritional, economic, ecological; and negative: damages, health issues) and of the significance of diseases for biodiversity conservation. It shows that the values of wildlife, the emergence of wildlife diseases and biodiversity conservation are closely linked. The article also illustrates why investigations into wildlife diseases are now recognized as an integral part of global health issues. The modern One Health concept requires multidisciplinary research groups including veterinarians, human physicians, ecologists and other scientists collaborating towards a common goal: prevention of disease emergence and preservation of ecosystems, both of which are essential to protect human life and well-being.

Keywords: biodiversity, disease, interdisciplinarity, One Health, wildlife

Verbindungen schaffen – das komplexe Zusammenspiel verstehen zwischen den Werten, die wir Wildtieren zuteilen, der Erhaltung der Biodiversität und der Gesundheit von Mensch und Tier: Eine Übersicht

Der Wert der Wildtiere wurde lange Zeit ignoriert oder unterschätzt. Jedoch haben die wachsende Sorge über den Verlust der Artenvielfalt und neu auftretende Krankheiten die Debatten über die Bedeutung der Wildtiere intensiviert. Wildtierkrankheiten werden dabei sowohl als potentielle Gefahr für die Erhaltung von Wildtieren als auch für die Gesundheit von Haustier und Mensch angesehen. Dieser Artikel gibt eine Übersicht über die Werte, die wir Wildtieren zuteilen (positiv: soziokulturell, alimentär, ökonomisch, ökologisch; negativ: verursachte Schäden, gesundheitliche Aspekte) sowie über die Bedeutung von Wildtierkrankheiten für die Erhaltung der Biodiversität. Er zeigt auf, dass diese Werte mit dem Neuauftreten von Krankheiten und der Erhaltung der Artenvielfalt eng verwoben sind. Im Weiteren wird dargelegt, weshalb die Erforschung von Wildtierkrankheiten heute als integraler Bestandteil der globalen Gesundheitsüberwachung anerkannt ist. Das „One Health“ Konzept erfordert multidisziplinäre Forschungsgruppen, in denen sowohl Tierärzte, Humanmediziner, Ökologen wie auch andere Spezialisten gemeinsam ein Ziel verfolgen: Die Prävention von Krankheitsausbrüchen und die Erhaltung der Ökosysteme, die beide für das Wohlergehen und die Gesundheit der Menschen essentiell sind.

Schlüsselwörter: Biodiversität, Interdisziplinarität, Krankheit, One Health, Wildtiere

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Introduction

The value of wildlife has long been ignored or underrated by the international community and conceived of as an aesthetic object or a tourist attraction (Chardonnet et al., 2002). However, growing concerns about biodiversity loss, conflicts around conservation issues, increasing interactions between wild and domestic animals and emerging zoonoses of wildlife origin have enhanced debates about the importance of wildlife. They have also raised questions about the potential threat of wildlife-related diseases for wildlife conservation, domestic animal and human health and the role that wildlife plays in our environment per se. Thus, wildlife and interest in wildlife diseases have enjoyed an increasing popularity in recent years (Gortázar et al., 2007; Rhyan and Spraker, 2010). This has been well reflected in the exponential increase of scientific articles published in this field (Gortázar et al., 2007), a trend that continues to grow (Fig. 1).

The term “wildlife” can apply to all wild plants and animals; however, as far as animal health is concerned, it refers to wild animals. “Wild” animals are animals with phenotypes not selected by humans, in contrast to “domestic” animals. Qualifying words such as “free-ranging” and “feral” refer to animals which do not live under direct human supervision and control (although free-ranging wildlife populations are often managed). The term “feral” applies to domestic animals that have returned to an untamed state and live free in a wild environment. In contrast, “captive” wildlife includes zoo animals and game in fenced private or public parks

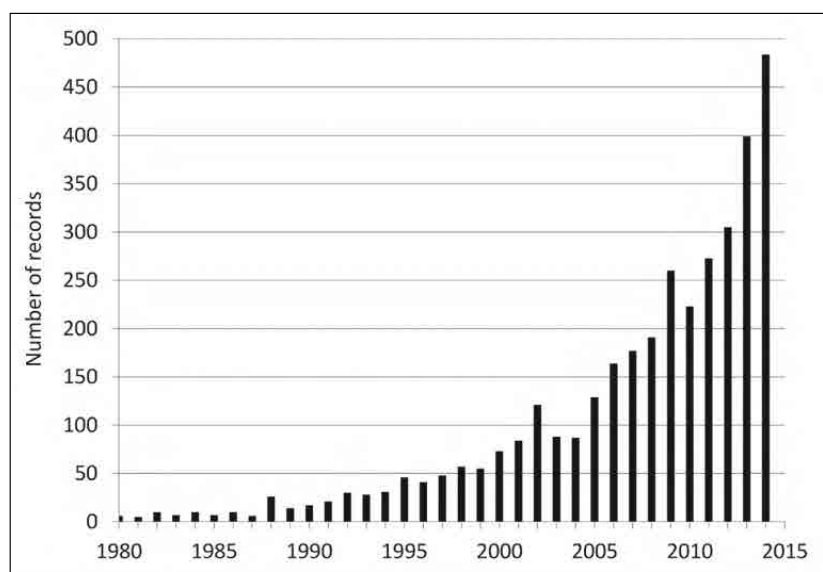


Figure 1: Number of scientific articles registered per year in PubMed when searching for “wildlife” and “disease” for the past 35 years (accessed January 2015: <http://www.ncbi.nlm.nih.gov/pubmed?term=wildlife%20disease>).

(OIE, 2010). Nevertheless, “wildlife” is often used to refer to free-ranging wild animals.

“Wildlife disease” is a broad notion which is not restricted to infectious and noninfectious diseases affecting wildlife. It also refers to all diseases related to wildlife, i.e. it includes pathogens which are carried by healthy wildlife and have the potential to cause disease in humans or domestic animals. Wildlife is increasingly regarded as a source of threatening pathogens worldwide. However, the importance of wildlife in ecosystems and the consumptive and non-consumptive values of wildlife for humans are manifold. The aim of this article is to provide an overview of the values we place on wildlife and of the significance of diseases for biodiversity conservation, and to explore the relationships between the values of wildlife, animal and human health, and biodiversity conservation.

The value of wildlife

Whether the role of wildlife is perceived of as positive or negative (Fig. 2) largely depends on personal opinions and interests, and the concept of what a resource is differs among cultures. However, some convergence does exist, particularly towards an anthropocentric perception of nature.

Socio-cultural value

In traditional societies, wild animals play a prominent role as guardian spirits, in the incarnation of gods, as symbols of power or ceremonial signs (Chardonnet et al., 2002). However, wildlife also has a clear cultural importance and symbolic value in industrialized countries including Switzerland, as illustrated by representations of wild animals on blazons and stamps (Fig. 3).

Divergences in perception often occur between rural and urban people. This was, for example, illustrated by reactions related to lynx (*Lynx lynx*) poaching in Switzerland: An inquiry revealed that lynx acceptance was high in the city of Zurich while rural populations supported lynx opponents, resulting in political motions aiming to repeal the legal protection of the lynx (Breitenmoser et al., 2010). Similarly, the so-called “Bambi syndrome” is a common attitude among urban populations, belying an inclination to anthropomorphize animals and avoid facing the facts and realities of nature (Chardonnet et al., 2002). Suffering of wild animals can raise even stronger emotions than human suffering, as illustrated by the reactions observed after the intrusion of a man in the Bernese bear pit: Following injuries to both man and brown bear (*Ursus arctos*), newspapers reported more often on the health status of the bear than of the man (Scholl, 2009).

Nutritional value

Wildlife has been a source of food for humans since the dawn of humankind. Today, meat production from wildlife ranges from traditional bush meat in Africa to modern deer farming schemes in New Zealand. Fletcher (1998) has proposed that human anatomy and physiology have been shaped by eating the lean meat of wild animals. Meat of wild ruminants is indeed known for its low intra-muscular fat content, and while cholesterol levels are quite similar or higher compared to domestic animals, fatty acid composition in wild ruminants seems to be better suited for human nutrition (Ramanzin et al., 2010). Furthermore, in an era of increasing preoccupation with animal welfare and interest in organic food production, hunted meat is now gaining importance as a product originating from animals that have lived in the most natural and animal-friendly environment (Volery, 2006).

In industrialized countries, meat of wildlife is often considered a festive dish, and Europe was reported to be the largest importer of game and venison in the world (Chardonnet et al., 2002). In 2011, venison constituted in average 3% of the meat consumed outside private households in Switzerland; in 2013, a total of 4,394 tons of wild meat was consumed (of which 1,406 tons originated from inland production), which represents nearly half of the consumed amount of sheep and lamb meat (Proviande, 2014). Currently, in Europe the availability of meat from local free-ranging wildlife overwhelms that of local farmed populations (Ramanzin et al., 2010). In Switzerland about 70,000 free-ranging ungulates are killed annually by hunters (Swiss Federal Hunting Statistics, 2014), while 11,351 farmed deer were registered in 2013.

Economic value

As a valuable food resource, wildlife also bears an economic value. Husbandry of wild animals and production in general is regaining importance in industrialized countries. It includes wildlife ranching (extensive husbandry of wild species in a semi-wild state) and wildlife farming (more intensive management). In Switzerland, farmed deer production was officially promoted by the Swiss Federal Office for Agriculture three decades ago. Since then the farmed deer population has steadily increased. Wild animal production also includes breeding indigenous wildlife species for hunting purposes, e.g. brown hare (*Lepus europaeus*) or grey partridge (*Perdix perdrix*), and farming exotic species for meat, fur, other products and tourist purposes, e.g. crocodiles, bison (*Bison bison*) or ostrich (*Struthio camelus*). In Switzerland, the bison population has doubled from 2006 (239 animals in 10 farms) to 2014 (517 animals in 20 farms; data source: Identitas AG).

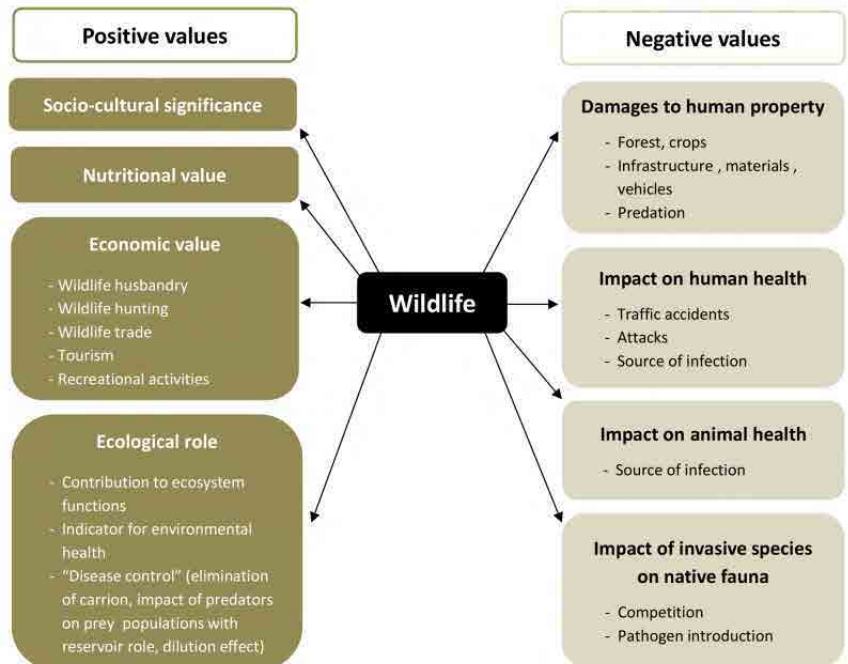


Figure 2: Overview of the values of wildlife, inspired by the review of Chardonnet et al. (2002).



Figure 3: A. Blazons of Swiss cantons with representations of indigenous wild animal species (left to right: brown bear *Ursus arctos*, Bern; Alpine ibex *Capra ibex ibex*, Grisons; golden eagle *Aquila chrysaetos*, Geneva). B. Collection of Swiss stamps illustrated with indigenous wild birds.

Hunting is practiced across the world with purposes varying from subsistence to commerce, management and leisure. Sustainable use of free-ranging wildlife is fully recognized as legitimate and where incomes of hunting safaris are a strong incentive for maintaining the natural habitat rather than transforming it for agriculture or husbandry, hunted game plays the role of an

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umbrella species for the entire biodiversity (Chardonnet et al., 2002). In Switzerland, the hunting bag reflects the population increase observed in wild ungulates and red fox (*Vulpes vulpes*) during the past decades (Fig. 4) but the number of active hunters has remained relatively stable with 29,585 active hunters (Swiss Federal Hunting Statistics, 2014) in a population of about 8 million people in 2013 (Swiss Federal Statistical Office, 2012). Incomes from hunting licenses and hunting ground rental currently amounts 25.7 million Swiss francs (Jagd-schweiz, 2015).

Wildlife products include not only meat but also live animals and various products harvested from either live or dead animals. Amphibians, reptiles, mammals, fish and birds are commonly exported to be sold as pets in industrialized countries. Velvet antlers, elephant tusks, rhinoceros horns, semen and musk are particularly valued in Asian markets. Commercial trapping for fur remains very important in some geographic regions (Chardonnet et al., 2002). Quantifying the global wildlife trade is almost impossible. The illegal wildlife trade is considered the second largest black market after narcotics and is estimated to be about 70-213 billion dollars annually (Nellemann et al., 2014). It was this strong interest in wildlife products that brought Eurasian beaver (*Castor fiber*) populations close to extinction already by the beginning of the 20th century as a consequence of overharvesting mainly for fur, but also for castoreum and meat (Angst, 2010). Other wildlife products believed to have medicinal properties have been popular in Switzerland in the past, such as fat from brown bear or red fox, which was supposed to prevent hair loss (Gonseth et al., 2011), and marmot ointment remains a widespread natural remedy for muscle and joint disor-

ders. Even most recently, a Swiss drugstore developed a mouth spray with aphrodisiac properties based on ibex horn extract, a product apparently much appreciated by male clients (Waldmeier, 2011).

Wildlife also has significant non-consumptive economic and recreational values, i.e. values related to aesthetic aspects. Nature-oriented tourism, including wildlife watching, is an increasing market on all continents (Chardonnet and Le Bel, 2012). Sport in natural environments is increasingly practiced in the Alps today but nature observation remains one of the most popular nature activities in Switzerland, with nearly 70% of the population engaging in them at least once a week (Klaus et al., 2011). Bird watching in particular is very popular in a number of European countries. The Swiss Ornithological Institute mentions over 1'200 volunteers contributing to its work (Schweizerische Vogelwarte, 2015).

Ecological value

It is now recognized that ecosystem functions decline as biodiversity is lost, and that this process has the potential to adversely affect human well-being by influencing the productivity and services provided by the ecosystems. Wild animals are an integral part of the environment and they contribute, for instance as grazers or predators, to the equilibrium of ecosystems. They also play an important role in seed dispersal and pollination of certain plants and thereby influence their spread and evolutionary adaptations. The removal of a key species can trigger a trophic cascade. For example, the return of the gray wolf (*Canis lupus*) in the Yellowstone National Park contributed to the regeneration of aspen by reducing the impact of elk (*Cervus elaphus canadensis*) on the vegetation (Ripple and Beschta, 2007). Another potential important role of wildlife species diversity is the reduction of disease risk through the “dilution effect” (Ostfeld, 2009): Species that are not hosts or only suboptimal hosts for given pathogens maintain encounter rates between pathogens and hosts at a low level, thus diluting the pathogen in the concerned region, and reducing the infection risk for susceptible hosts.

Scavengers play a beneficial role in the elimination of dead animals, which can be ecologically important by limiting the propagation of diseases and recycling nutrients which cannot be used by other species. Predators, in particular those giving priority to diseased and weak animals, may limit the development of potential epizootics and contribute to the improvement of genetic diversity among prey communities (Chardonnet et al., 2002). Through their limiting effect on prey populations that represent a reservoir for zoonotic pathogens, predators may also control the risk of human infections; Ostfeld and Holt (2004) proposed that the loss of me-

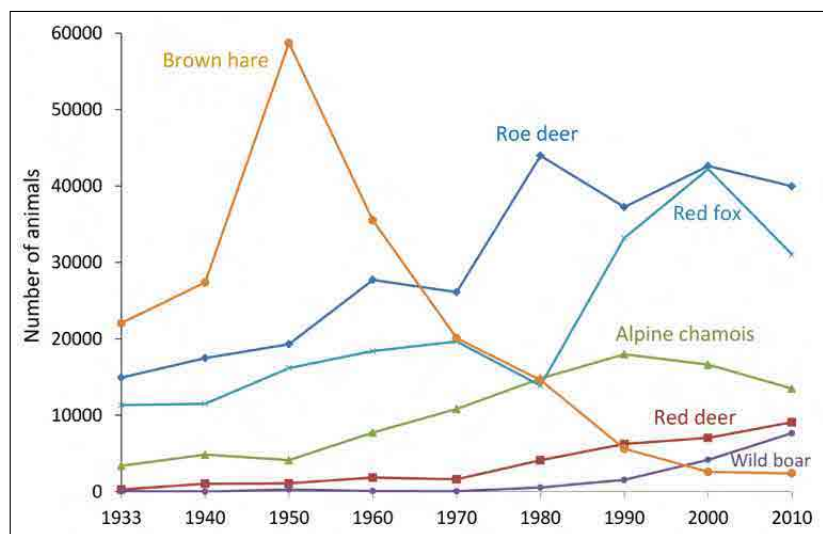


Figure 4: Hunting bag of selected free-ranging wild mammals hunted per year in Switzerland from 1933 to 2010. Information is given for every 10 years (Swiss Federal Hunting Statistics, 2014).

dium-sized rodent predators could lead to an increase of rodent-borne zoonotic disease cases.

The health status of wildlife may also be a barometer of the health of the environment. Wild animals act as sentinels for the early detection of emerging pathogens. All predators, including birds of prey, are indicator species: Their survival and health status at the top of the trophic chain highlights environmental problems on lower levels, such as poisoning, pollution and disease (Chardonnet et al., 2002). For example the Eurasian otter (*Lutra lutra*) vanished from Switzerland and the neighbouring regions of France and Italy during the second half of the 20th century. Besides human persecution and water streams' degradation, the contamination of fish with organo-chlorine substances, especially PCBs, is believed to have significantly contributed to their decline (Weber, 1990). Brown hare (*Lepus europeus*) populations have been declining throughout Europe since the 1960s, believed to be mainly due to loss of habitat as a result of agriculture intensification. In Switzerland, this decline has been dramatic, as shown by the rapidly decreasing hunting bag (Fig. 4) and parallel decrease of road kills (Roedenbeck and Voser, 2008). Another example of wildlife serving as an indicator for ecosystem health was demonstrated by a study revealing that PCBs in red foxes from the city of Zurich reflected toxic contaminants in humans (Dip et al., 2003).

Damage to human property

Negative perceptions of wildlife rise when wildlife is in competition with human interests. In Europe, several wildlife species (e.g. wild boar *Sus scrofa* and red deer *Cervus elaphus elaphus*) cause significant damage, both to crops and to regenerating forests. Large predators such as the bear, wolf or lynx are regularly responsible for attacks on livestock, and they additionally compete with hunters (Breitenmoser et al., 2010). Total costs paid for wildlife damage compensation (predation and damages to vehicles excluded) amounted to 3,785,000 Swiss francs per year in 2009-2011 in Switzerland (Jagdschweiz, 2015), with an additional average of 95,300 francs per year related to predation by large carnivores (Bundesrat, 2013). The growth of wild animal populations together with the increase in traffic has also led to an increase in vehicle collisions (Seiler and Helldin, 2006). In Switzerland, 16,000-18,000 roadkills are registered each year, with damages on vehicles of 25 Mio Swiss francs per year (Mosler, 2005).

Impact on human health

In addition to material damages, traffic collisions cause human injuries and deaths. From 1995 to 2005, almost 500 persons were injured in traffic accidents involving wildlife in Switzerland, many severely, and four people died as a consequence of such accidents (Mosler, 2005).

Large carnivore attacks on humans are another problem encountered in different parts of the world. For example, at least 870 humans were killed or injured by lions in Tanzania from 1990 to 2005. However, the main concern for human health is related to infectious diseases: Wildlife carries and spreads pathogens which can be transmitted to humans. The emergence of diseases such as acquired immunodeficiency syndrome (AIDS), severe acute respiratory syndrome (SARS), H5N1 avian influenza and most recently Ebola, have highlighted the importance of wildlife as reservoirs or vectors for human disease (Cunningham, 2005; Marí Saéz et al., 2014). It has been estimated that 60.3% of the infectious emerging diseases in humans are zoonoses, with 71.8% of them originating in wildlife (Jones et al., 2008). Depending on the pathogen, transmission from wildlife to humans may be either a rare event after which the infection cycle is maintained by human-to-human transmission (e.g., AIDS virus, SARS Coronavirus), or typically occurs by direct contact or via vectors, in which case animal populations are the principal reservoir of the pathogen and horizontal infection in humans is rare (e.g. *Borrelia burgdorferi*, *Francisella tularensis*, *Leptospira* spp.; Bengis et al., 2004). Furthermore, while some zoonotic pathogens cause disease in both animals and humans (e.g. rabies), others have wildlife reservoir hosts in which they rarely or never cause disease (e.g. Lyme disease). The vast majority of zoonotic reservoir species are mammals: Bats and rodents are recognized as particularly threatening taxa (Daszak et al., 2000; Ostfeld and Holt, 2004) but other species including lagomorphs, ungulates, birds and reptiles are regularly identified as sources of human infections (Kruse et al., 2004; Martin et al., 2011).

Impact on domestic animal health

Wildlife can serve as carriers for non-zoonotic diseases of livestock, potentially devastating to human populations not only economically (due to commercial bans, control and preventive measures) but, in many regions, in terms of the resulting loss of human dietary protein (Rhyhan and Spraker, 2010). Sympatric wildlife is often resistant to diseases threatening livestock and may be silent carriers of infection (Bengis et al., 2002). Thus, in Switzerland and other European countries, the wild boar is frequently infected with *Brucella suis* and sheds this bacteria, representing a risk to domestic pig health (Wu et al., 2011, 2012). Importantly, pathogens jumping from livestock to wildlife (spillover) may result in the emergence of a wild reservoir with subsequent spillback to livestock. For instance, bovine tuberculosis is believed to be originally spilled over from livestock to native wildlife species, with subsequent reservoir formation in wildlife. In Europe, the Eurasian badger (*Meles meles*), wild boar and red deer have become important reservoirs for this disease in regions where wildlife man-

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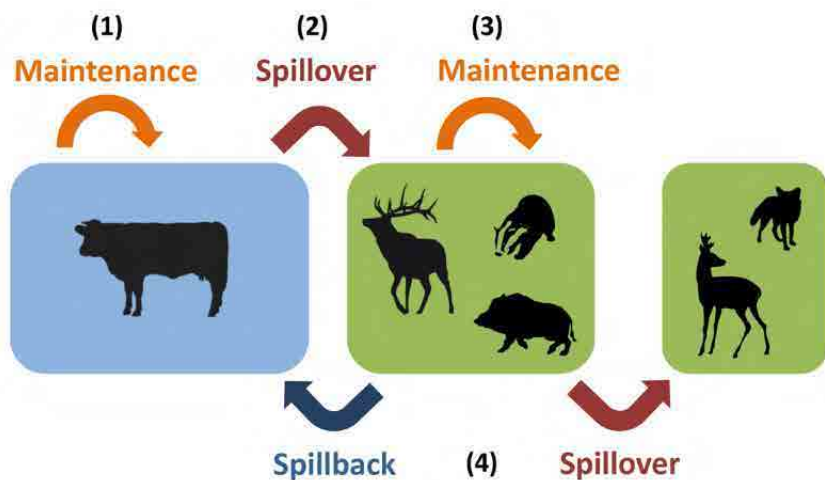


Figure 5: Spillover of livestock pathogens such as *Mycobacterium bovis* or *M. caprae* to wildlife can result in the establishment of reservoirs in wildlife populations, with subsequent further spillover events to other wildlife species as well as spillback to domestic animals. It is essential to prevent transmission to wildlife, as disease control in wild populations is extremely challenging and success often limited.

agement favors pathogen maintenance (Schöning et al., 2013; Fink et al., 2015; Fig. 5). Pathogens originating from wildlife also may represent a threat to pets, although not associated with consequences as dramatic as those for livestock. For example, the bobcat (*Lynx rufus*) has been recognized as a natural host and reservoir of the piroplasm *Cytauxzoon felis*, and while the bobcat is usually a healthy carrier, infected domestic cats typically develop fatal disease (Meinkoth and Kocan, 2005). Epidemics of sarcoptic mange in red fox populations lead to the emergence of cases in domestic dogs in affected areas (Soulsbury et al., 2007).

Impact on native fauna by alien wildlife species

Introduced alien species that become invasive are considered to be one of the principal threats to biodiversity. Invasive species can have a detrimental impact on autochthonous species through competition for natural resources, predation, loss of genetic identity as a consequence of hybridization, or transmission of pathogens (Baur and Nentwig, 2011). For example, the European crayfish (*Astacus astacus*) has disappeared from numerous water streams due to the introduction of the Signal crayfish (*Pacifastacus leniusculus*) which carries the crayfish pest, to which European crayfish is highly susceptible (Alderman, 1996).

Wildlife conservation and diseases

While wildlife is increasingly seen as a threat to humans and their goods, human activities represent a growing threat to wildlife conservation. Changes in human demography and behavior and increasing human en-

croachment into wildlife territory play a major role in the unprecedented rate of wildlife habitat loss, habitat fragmentation and loss of biodiversity that is faced worldwide (Ryser-Degiorgis, 2013a). In addition, the negative values we place on wildlife can have devastating direct effects. For example, large carnivores had vanished from Switzerland at the end of the 19th century not only as a result of habitat degradation and prey depletion but also of direct persecution because they were perceived as a threat to the life of domestic animals and humans (Breitenmoser and Breitenmoser-Würsten, 2008). Even positive values can have destructive effects on wild populations by resulting in illegal trade, overharvesting or disturbance. Finally, diseases pose an increasing threat to species conservation, which in turn can affect the productivity and density of wildlife populations with economic or recreational value. Recent dramatic examples of disease emergence in wildlife are the global decline of amphibian populations due to chytridiomycosis (Skerrat et al., 2007) and mass mortalities in bats in North America due to the white nose syndrome (Frick et al., 2010), two contagious diseases spread by human activities.

Humans may be a source of wildlife infection (so-called anthroponoses). Examples are the transmission of *Mycobacterium tuberculosis* from humans to mongooses (Alexander et al., 2002) and the infection of beavers with *Giardia* of human origin through accidental ingestion (Thompson et al., 2010). As the global human population continues to increase, anthroponoses are becoming an increasing problem in wildlife conservation (Taylor et al., 2001; Siembieda et al., 2011). They may also result in new reservoirs of human pathogens (Taylor et al., 2001; Chomel et al., 2007; Thompson et al., 2010). Similarly, domestic animals such as dogs and cats can contribute to the extinction risk of endangered wildlife populations by acting as a source of pathogens, as illustrated by an outbreak of feline leukemia from domestic cat origin in one of the two remnant populations of the highly endangered Iberian lynx (*Lynx pardinus*; Meli et al., 2010).

Pathogen pollution (i.e. the introduction of pathogens into previously unexposed wild populations) has been implicated in many wildlife emerging infectious diseases and represents a particularly serious challenge to conservation efforts (Daszak et al., 2000). Animals which have evolved in the absence of a particular infectious agent and have only recently been exposed to a parasite may be highly susceptible and develop fatal disease. This phenomenon can lead to population extinction of the host and additionally impact other sympatric species via knock on effects, e.g. by causing the extinction of uninfected species further up the food chain (Daszak et al., 2000, 2001). For example, rabbit hemorrhagic disease not only had a dramatic impact on

Iberian rabbits in Spain but has also indirectly affected predator populations (Moreno et al., 2006).

Further factors resulting from human activities may seriously impact wildlife health, such as genetic mixing due to cross-breeding of feral domestic animals with their wild counterpart. It has been suggested that cross-breeding between domestic cats and European wildcats (*Felis silvestris*) could, in the long term, reduce the fitness of wildcat populations by destroying their specific selective advantage in their primary habitat (Hertwig et al., 2009). The impact of predation by domestic cats on wild birds, reptiles and small mammals is also of increasing concern (Loss et al., 2013). Another example is the negative impact of veterinary drugs released into the environment such as diclofenac, a nonsteroidal anti-inflammatory drug administered to livestock, which has caused a rapid decline of vulture populations in Pakistan (Margalida et al., 2014). Finally, measures to control diseases relevant to human or domestic animal health can also affect conservation and animal welfare, for example culling wild animals to keep bovine tuberculosis, rabies or avian flu under control (Gortázar et al., 2007).

Overall, human encroachment, animal management issues and the aspects of wildlife that we value inevitably lead to interactions between wildlife, humans and domestic animals. These interactions enhance the risk of exposure to new pathogens, and the ensuing emergence of diseases in both humans and domestic animals can negatively impact the value that we place on wildlife. This, in turn, might decrease motivation for conservation efforts. In parallel, human and domestic animal diseases affecting wild populations and non-sustainable use of wildlife populations negatively impact biodiversity (Fig. 6).

Concluding remarks

We see wildlife through the lens of a number of values that can be classified as positive or negative depending on our attitude. Major wildlife-related conflicts arise all around the world due to such divergence of opinion, rendering management difficult and threatening conservation efforts (Chardonnet et al., 2002). However, by showing the benefit that can arise from wildlife, the incentive for conservation may become stronger (Fig. 6). The conservation of biodiversity aims at matching the needs of people for biological resources while securing the long-term survival of the biological richness of the Earth. It has even been proposed that because human needs and biodiversity are so interwoven, the conservation of wild fauna and flora should be considered as an element of national security (Chardonnet et al., 2002).

Anthropogenic environmental alterations and increasing human encroachment into wild habitats resulting from human population increase and behavioral changes represent the main cause of wildlife disease emergence (Ryser-Degiorgis, 2013a). In the past decade, human and veterinary health research has been confronted with a number of emerging diseases with dramatic consequences. It is also of increasing concern that disease could result in considerable additional costs of global biodiversity loss, with potential dramatic consequences on ecosystem services. Overall, investigations into wildlife-related diseases are now recognized as an integral part of global health issues, and the surveillance of infectious agents in wildlife worldwide has become part of the strategy to counter emerging disease threats to humans. The situation requires integrated approaches to human and animal health and their respective social and environmental contexts (Zinsstag et al., 2011). The concept of One Health (Fig. 7) has resulted from contemporary thinking on health and ecosystems and their relevance for global public and animal health development. Furthermore, a new approach to understanding disease agents in relation to the environment and human activities has developed, with a view to parasite-host interactions: disease ecology (Gortázar et al., 2007). Pathogenicity is indeed not just a property of the parasite *sensu lato* – it is a function of the host, the parasite and their interaction in a given environment.

In conclusion, we have shown that (1) the values we place on wildlife do influence and are influenced by the occurrence of wildlife-related diseases, and that (2) these

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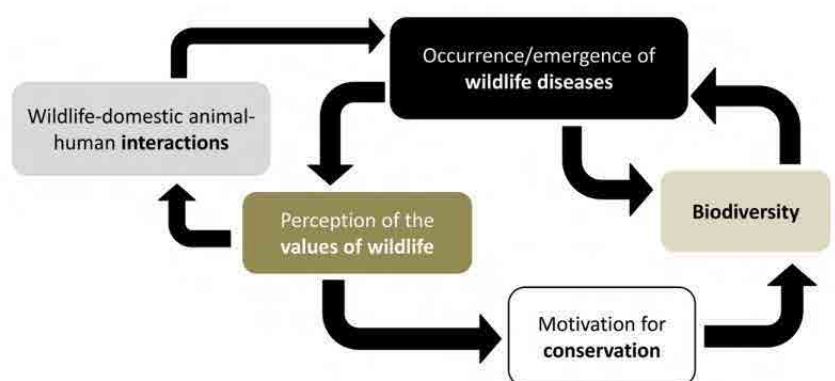


Figure 6: Relationships between the values of wildlife, wildlife diseases and biodiversity conservation. The value we place on wildlife directly influences the motivation for biodiversity conservation. When wildlife is seen as a valuable resource, its management often aims at increasing population densities (e.g. for the aim of hunting or wildlife viewing); together with changes in the management of domestic animals and behavior of humans, this increases the risk of interactions and of exposure to “new” pathogens with the resulting emergence of diseases. When disease emergence is attributed to wildlife, the value we place on wildlife decreases, diminishing the motivation for conservation. Furthermore, emergence of diseases in wild populations may represent a threat to biodiversity conservation. Conversely, increasing biodiversity, e.g. through species reintroduction, may be linked to the introduction of pathogens leading to disease emergence. At the same time, increasing biodiversity may reduce disease risk, e.g. through the dilution effect.

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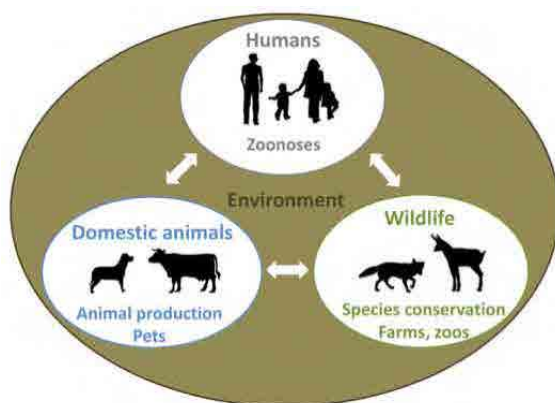


Figure 7: Novel health approaches include the One Health concept and disease ecology: When dealing with health issues, a “human-livestock-wildlife continuum” should be considered, rather than considering humans, domestic animals and wildlife as three independent entities. Furthermore, understanding disease requests investigations on interactions between pathogens, hosts and their environment.

values and disease occurrence are highly relevant in the context of biodiversity conservation. The One Health concept places as much importance on wildlife as on domestic animals and humans and requires that these three entities are not looked at separately but that health professionals with different backgrounds and interests collaborate. Investigations into wildlife diseases require the integration of veterinary skills with ecological considerations and a population-level perspective (Ryser-Degiorgis, 2013b). Therefore, multidisciplinary research groups need to include human physicians, veterinarians, ecologists and further experts working together towards a common goal: prevention of disease emergence and preservation of ecosystems, both of which are essential to protect human life and well-being.

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Etablir des liens – comprendre la complexité des interactions entre les valeurs que l’on donne à la faune sauvage, la conservation de la biodiversité, la santé de l’Homme et de l’Animal: Une synthèse bibliographique

La valeur de la faune sauvage a été longtemps sous-estimée voire ignorée. Cependant, les préoccupations croissantes à propos de la perte de la biodiversité et les maladies émergentes d’origine sylvestre ont étendu les débats sur l’importance de la faune. A travers ces débats, les maladies en relation avec la faune sauvage apparaissent comme une menace pour la conservation des espèces et pour la santé animale et humaine. Cet article fournit une vue d’ensemble des valeurs que l’on donne à la faune sauvage (positives: socio-culturelles, nutritionnelles, économiques, écologiques; et négatives: dégâts, problèmes liés à la santé) et de la signification des maladies pour la conservation de la biodiversité. Il montre que les valeurs de la faune, l’émergence de maladies liées à la faune et la conservation de la biodiversité sont étroitement imbriquées. L’article illustre également pourquoi l’investigation des maladies relatives à la faune est maintenant reconnue comme étant une partie intégrante des questions de santé mondiale. Le concept moderne «One Health» (une seule santé) nécessite des groupes de recherche multidisciplinaires comprenant des vétérinaires,

Unendo i punti – capire la complessa interazione esistente tra l’importanza che attribuiamo agli animali selvatici, la conservazione della biodiversità salute umana ed animale: Una review

L’importanza degli animali selvatici è stata ignorata o sottostimata per molto tempo. Tuttavia, le preoccupazioni crescenti legate alla riduzione della biodiversità e alle malattie emergenti di origine silvestre hanno contribuito a ravvivare il dibattito relativo all’importanza degli animali selvatici. Alle malattie di origine silvestre viene spesso attribuito il ruolo di minaccia potenziale per la conservazione stessa degli animali selvatici e per la salute umana ed animale. Questo articolo fornisce una panoramica dei valori che vengono attribuiti agli animali selvatici (positivi: socio-culturali, alimentari, economici, ecologici; e negativi: danni, problemi di carattere sanitario) e sul significato delle malattie relativamente alla conservazione della biodiversità. In questo articolo viene mostrato come il l’importanza attribuita agli animali selvatici, l’insorgenza delle malattie di origine silvestre e la conservazione della biodiversità sono intimamente collegati. Questo articolo spiega anche il perchè l’indagine delle malattie di origine silvestre è adesso pienamente riconosciuta come una parte integrante degli aspetti sanitari di interesse mondiale. Il concetto moderno di «One Health» richiede che sia

des médecins, des biologistes et d'autres scientifiques collaborant en vue d'un même but: la prévention de l'émergence de maladies et la préservation des écosystèmes, les deux étant essentielles pour protéger la vie et le bien-être de l'Homme.

svolto un lavoro interdisciplinare compiuto da gruppi di ricerca che comprendono veterinari, medici, ecologi e altri scienziati che collaborano al conseguimento di un obiettivo comune: La prevenzione dell'insorgenza delle malattie e la preservazione dell'ecosistema, due aspetti essenziali per la protezione della vita e del benessere umano.

Joining the dots – understanding the complex interplay between the values we place on wildlife, biodiversity conservation, human and animal health: A review

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