The implications of climate change for Veterinary Services

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Summary

Climate change affects the entire veterinary domain. Veterinary Services must, therefore, add climate change to their list of responsibilities. Although the goals of preventing disease, maintaining productivity, and sustaining healthy systems will remain, the form and scope of Veterinary Services will need to change. Climate change will have direct and indirect impacts on animal determinants of health in multiple, interacting ways, across a range of scales. Veterinary Services will need to work across the spectrum of health determinants if they intend to both address pre-existing problems expected to worsen with climate change and prepare for unanticipated threats. Animals will feel the impact of climate change through multiple, often interacting, means including changing patterns of infectious diseases, increased exposure to heat, contaminants and extreme weather, changes in access to the natural resources they need for daily living and shifts in animal ecology, sociobiology and population dynamics. To meet expectations for action across the veterinary domain, Veterinary Services need to: *a)* provide services to mitigate impacts; *b)* reduce population vulnerability to lessen those impacts; *c)* enhance population resilience to avoid impacts; and *d)* address climate change risks at their sources. Health intelligence that combines hazard surveillance with population reconnaissance (to determine vulnerability) will be needed to adaptively allocate resources. Rather than focus on risk management only, programmes will need to include capacity building for healthy, resilient

animal populations and animal health systems. Transformative changes are needed to allow Veterinary Services to address the inter-related challenges of sustainable development, climate change, and biodiversity loss. This will require partnerships and governance models that share and integrate knowledge and understanding of changes in global and local socioecological systems.

Keywords

Adaptation – Animal health – Climate change – Determinants – Resilience – Veterinary – Vulnerability.

Introduction

National Veterinary Services are expected to implement activities across the veterinary domain (1). The World Organisation for Animal Health (OIE) defines the veterinary domain as, 'all the activities that are directly or indirectly related to animals, their products and by-products, which help to protect, maintain and improve the health and welfare of humans, including by means of the protection of animal health and animal welfare, and food safety' (2). Climate change impacts all aspects of the veterinary domain. The World Health Organization declared climate change to be the world's biggest public health threat, and there is no reason to doubt that the same holds true for animal health.

The Director General of the OIE explained that, 'National Veterinary Services preserve and develop animal resources, reducing poverty and hunger worldwide through improving rural livelihoods and feeding the world. Their additional impact on global health security by addressing "risk at source" for emerging pandemic threats, antimicrobial resistance and food safety crises further safeguards the planet' (3). Veterinary Services must now add climate change to their remit due to its overwhelming impact on animal resources (through its effects on domestic animal and wildlife health, animal production and agricultural practices), poverty, hunger, emerging infectious diseases, and global health security. How we respond to climate change will have profound implications for people, biodiversity, economies, and ecosystems.

What is climate change?

Climate change is a long-term shift in global or regional climate patterns. Currently, the phrase 'climate change' is commonly used to refer specifically to the rise in global temperatures from the mid-20th century to the present. Recent changes in climate can be linked, for the most part, to the greenhouse effect, the process whereby radiant heat is absorbed and then re-emitted by gases in the atmosphere, trapping heat in the lower atmosphere. The heat-trapping capacity of the

atmosphere depends on its chemical composition and, more specifically, on the amount of atmospheric greenhouse gases (GHGs) it contains. The recent anthropogenically driven accumulation of GHGs has reduced the rate of heat loss to space, with a subsequent warming effect on the global climate system (4).

The evidence of anthropogenically driven warming of the global climate system is unequivocal, as is the evidence that recent changes in climate are resulting in widespread impacts on natural and social systems. The rate of climate change is not consistent across the globe. For instance, warming in Canada is, on average, about double the magnitude of global warming, and northern Canada has warmed and will continue to warm at more than double the global rate (4). The observed direct and indirect effects of climate change will be modified, amplified, or dampened by the nature, availability and sustainability of ecosystem services, which are supported by biodiversity, demographic change, and socio-economic development (5). The main impacts of climate change on natural systems are related to atmospheric and oceanic warming, the diminution of snow and ice, and the rising of sea levels. The Intergovernmental Panel on Climate Change (IPCC) noted that, 'all aspects of food security are potentially affected by climate change, including food production, access, use and price stability' (6). Climate change is projected to reduce global biodiversity and undermine food security, leading the IPCC to conclude that 'limiting the effects of climate change is necessary to achieve sustainable development and equity, including poverty eradication' (6).

Defining animal health in a climate-change context

The IPCC 5th Assessment Report concluded that health impacts from climate change are inevitable (6). As the anticipated consequences of climate change are occurring faster than expected (7), a growing number of countries and cities have declared climate emergencies. The impacts on animal health are increasing and transcending species and borders. Worldwide, people, animals and ecosystems are experiencing increased heat, extreme weather events, declining air quality, expanded ranges of parasites and pathogens, habitat loss, wildfires and diminished food and water safety and security. People and animals must now face and adapt to the inevitable changing patterns and rates of morbidity, mortality, and productivity.

Targets and priorities for Veterinary Services in anticipation of a changing climate will depend, in part, on how animal health is defined. Too often, animal health remains defined as the absence of specific infectious diseases. This definition is insufficient to encourage robust action on climate change mitigation or adaptation. The concept of health as the capacity provided to animals by interacting individual, environmental, ecological, and social attributes and circumstances, rather than a biological state of absence of disease, is better suited for climate

change planning. Moreover, this definition is consistent with prevailing definitions of human health and evolving definitions of wildlife health (8).

The underlying attributes and circumstances that ultimately shape the health of individuals and populations are called the determinants of health. Determinants of health influence the physiological and behavioural capacity essential for normal growth, development, survival and reproduction, all of which are need to allow animals to meet the requirements of daily living. Determinants also provide capacities to adapt to or recover from stressors or hazards operating at the individual and population level. Determinants of health, whether in domestic or wild animal populations, include individual-level factors (e.g. genotype, immune function, condition, behaviour, social status), population-level factors (e.g. density, social structure, husbandry, demographics), and environmental factors (e.g. climate, season, habitat quality, food and water security), as well as socio-economic and cultural factors (e.g. policies, cultural practices, values and beliefs) (8). Climate change will have direct and indirect impacts on animal determinants of health in multiple, interacting ways across a range of scales, from the sub-cellular to global levels (9). Vulnerability to the direct and indirect health impacts of climate change varies widely by species, location, and management system, but is ultimately determined by exposure to the effects of climate change and capacity to adapt to or cope with those effects (10). The determinants of health provide the raw material necessary for coping with, or adapting to, climate change. Thus, climate change strategies will need to work across the spectrum of determinants of health.

Healthy animals must be able to respond to, cope with, or adapt to multiple challenges, changes, or hazards (e.g. stressors) brought about by climate change in their dynamic social or physical environment, whether those challenges are predictable or not. Most attention in the animal health literature has focused on how climate change will impact infectious diseases, especially vector-borne disease (11). Maintaining a focus on infectious diseases at the exclusion of other determinants of health will severely limit the role of Veterinary Services in fulfilling their obligation to address global security needs, which they must do if they are to protect animal health and safeguard the planet in the face of a rapidly changing climate. Emerging evidence and experience in public health suggests that, to be fully effective, climate change and health management efforts must not only tend to the preventive and curative functions of the health sector, but also must protect and manage the determinants of health that fall outside the usual scope of practice of Veterinary Services (12).

Overview of climate change and animal health impacts

Veterinary Services are constrained by a lack of systematic study of the current and anticipated effects of climate change on animals. Fewer formal or comprehensive climate change studies have been done on animal health compared to human health (13). Little scholarly work has been dedicated to identifying evidence-based, sustainable adaptation actions for animal health (11). This section of the paper provides a high-level introduction to the main topics being discussed in the literature on animal health climate change adaptation, as reviewed in 2019 (11).

Infectious diseases

Climate has influenced, and will continue to influence, the occurrence and severity of infectious diseases in natural and agricultural systems. Studies on the role of climate impacts on host–pathogen relationships and the emergence and dynamics of infectious pathogens are accumulating (11). Changes in food webs, timing of lifecycles, and weather patterns will influence infectious and parasitic disease transmission pathways and frequency. While most attention has focused on vector-borne diseases, waterborne, windborne, and enteric infections can also be expected to increase (14).

The relationship between climate change and infectious diseases is not straightforward, as can be illustrated by the dynamics of avian influenza viruses (AIVs) in wild and domestic animal populations. Highly pathogenic or zoonotic AIVs continue to be a global concern, as they have the potential to threaten avian populations, human health, and food security. Wild migratory waterfowl are natural reservoirs for most subtypes of AIVs (15), can transport AIVs across and between continents along migratory pathways (16 and references therein), and drive seasonal dynamics of AIV via the influx of immunologically naïve juveniles each breeding season (17). Outbreaks in poultry have been associated with migrating waterfowl in Asia (18) and North America (19). Climate change has the potential to affect the dynamics and emergence of novel AIVs through multiple routes (20). Although increasing temperatures may reduce virus survivability in water (21), impacts on movement and behaviour of migratory birds may increase opportunities for transmission, viral reassortment, emergence of novel strains, and spread (22). Impacts on migratory behaviour could result in changes to timing of migration, northward expansion or shifts in distribution, an increase in the length of the breeding season, and altering population density and species compositions along flyways and stopover sites (20, 22, 23). Agricultural systems such as rice crops provide a major interface between domestic ducks and wild birds, and thus play a large role in the spread and evolution of AIVs (24). Lengthened growing seasons and northward expansion of paddy rice resulting from rising human populations as well as warming temperatures (25) may further increase opportunities for spread,

reassortment, and emergence of novel strains (20). Veterinary Service strategies to better anticipate and manage pathogens such as AIV will require multi-sector coordination and planning to identify modifiable factors within complex, dynamic socio-ecological systems that are changing with the climate.

Heat

Heat stress due to rising temperatures will not only cause suffering and premature death, but will also result in reduced productivity and fertility (14). Heat stress can negatively affect livestock health by causing metabolic alterations and oxidative stress (26), and by suppressing the immune and endocrine system, thereby enhancing disease susceptibility (27). Increased temperatures in marine and aquatic systems similarly threaten fisheries and aquaculture. As water temperatures increase, water quality declines, harmful algae blooms become more frequent, water oxygen levels decrease, and reduced feeding and growth occur, all of which can increase the incidence of diseases (28). The experience in the human health sector has clearly demonstrated the importance of heat-related problems (29) and highlighted the need to include strategies for adaptation to, and mitigation of, increasing temperatures as part of the Veterinary Services climate change agenda.

Contaminants

A literature review conducted by Noyes *et al.* (30) concluded that climate change will affect the environmental distribution and toxicity of chemical pollutants. Climate change alterations to food webs, lipid dynamics, ice and snow melt, and organic carbon cycling will affect pollutant levels in water, soil, air, plants, and animals. Flooding and melting events will remobilise contaminants and redistribute them onto grazing lands, thus contaminating animals and animal products (31). Changes in the distribution and abundance of insect pests are expected to change both *how much* pesticide enters the environment and *when* it enters the environment. (31). Increased production, frequency, and distribution of mycotoxins (32) and toxic algae (33) have implications for both animal health and food safety in terrestrial and aquatic systems. There is compelling evidence that increasing temperatures may alter the biotransformation of contaminants to more bioactive metabolites (30). Moreover, there is evidence of the synergistic effects of the combination of contaminants and parasitic or infectious diseases (34). Concomitant changes in patterns of contaminants and infectious diseases will undoubtedly result in syndemics of unexpected effect and severity and will have implications for animal health and food safety.

Extreme weather

The impacts of extreme weather events, such as typhoons, hurricanes, floods, wildfires and drought, have animal health and welfare implications that in turn will have public health, economic, and mental health implications. Despite this, many countries omit animals from their national and regional contingency planning (35). Efforts to incorporate One Health approaches into emergency preparedness for extreme weather disasters are, however, beginning to appear (36). The estimated losses of over a billion animals during the 2019 Australian wildfires, which led to reduced meat, wool, and honey production, along with untold social and ecological effects, exemplify the devastating impact that extreme weather (in this case, drought preceding the fires) can have on animal health.

Effects on other determinants of health

An animal's welfare is compromised when the circumstances in which it lives do not fit its evolved adaptations (37). The environments in which animals have evolved are changing with climate change. Oceans are acidifying. Desertification is occurring in some regions, while ice and snow loss are affecting others. Droughts are leading to crop failures and fires. There will be a reduction in water resources in most dry subtropical regions, and the frequency of droughts will likely increase, intensifying competition for water. The annual cycles of plants and animals are changing, affecting food webs, crop production, and disease cycles. All these changes will influence how wild and domestic animals access their needs for daily living and will impact how management decisions change to adapt to these changing determinants of animal health.

The role of Veterinary Services

Veterinary Services have four general climate change management options:

a) intervene before an adverse impact occurs by protecting determinants of health that affect population vulnerability or resilience

b) undertake warning surveillance and health intelligence to find adverse effects or high-risk situations quickly, and respond with early interventions to prevent significant impacts and reduce vulnerabilities

c) provide services to help populations recover from or cope with negative impacts that are occurring

d) collaborate in cross-sectoral policies and programmes that aim to eliminate or reduce climate change risks at the source, by targeting the causes of anthropogenic climate change.

Climate change impacts on animal health will be exacerbated by unanticipated threats created by climate change as well as by pre-existing problems that climate change will amplify (38). The priority for addressing amplified pre-existing problems is to ensure sufficient accessible and mobilisable animal health services that can be adaptively deployed and/or enhanced in response to locally changing situations. Veterinary Services will require timely situational awareness to deploy animal health services in advance of disaster or severe impacts. Key actions in this scenario include:

a) implementing adaptable surveillance and monitoring systems to ensure early detection and warning of expected health outcomes or hazards

b) implementing health intelligence activities to detect circumstances that are altering population exposure to, sensitivity to, and/or capacity to adapt to, known climate change hazards and risk (i.e. tracking population vulnerability)

c) strengthening core veterinary capacities, and building sustainable policies and infrastructures to manage increased effects and changing distributions of existing or reasonably expected threats

d) reducing socio-economic inequities that affect access to veterinary care.

A hazard-by-hazard approach to risk management is insufficient for climate change preparedness, because the interaction of climate change with other global and local forces is producing an increasing number of unanticipated and unimaginable hazards of increasing severity. Extreme or unanticipated events associated with climate change, such as hurricanes or pandemics, have so far caused more damage to human health than have amplified known problems (39). Thus, Veterinary Services must prepare for the unexpected. Better surprise anticipation comes with improved awareness of changes in the distribution of and exposure to emerging hazards, or changes in willingness to act on early signals of possible harms (40). Surveillance programmes need to be expanded to connect specialised pools of knowledge within and outside of the Veterinary Services. This will allow hazards to be detected and acted upon in advance of harms and make it possible to track changing exposures and vulnerabilities before a harm can occur. Surprise preparation also comes from tracking and bolstering the determinants of health that enhance the capacity of a farm, a population, or a community to cope with unexpected harms (40). Shifting from pathogen surveillance to health intelligence that combines hazard surveillance with population reconnaissance (to determine vulnerability) will help Veterinary Services better target scarce resources. It will also enable them to launch programmes

to improve the health of vulnerable populations before a climate impact occurs or becomes unacceptable or unmanageable.

A climate change strategy concerned with unanticipated health impacts requires investment in:

a) identifying and addressing pre-existing socio-economic, ecological, and health inequities that exacerbate climate change vulnerability

b) proactively building capacity for individuals and populations to cope with multiple interacting threats and stressors before an impact occurs

c) developing capacity in the Veterinary Services to enable them to adaptively respond to surges in unexpected disasters, emergencies, or disease outbreaks

d) integrating animal health climate change adaptation into agriculture planning and ecosystem management

e) incorporating climate change health literacy as a core component of Veterinary Services, to encourage and enable proactive adaptive and mitigative behaviours within and outside the Veterinary Services

f) investigating and communicating how the effects of climate change on animal health subsequently have an impact on conservation, sustainable food production systems, food security, public health, and community resilience, to encourage political and multi-sectoral collaboration

g) fostering innovative leadership, partnerships, and governance that support cross-sectoral, collaborative actions.

Because of compelling evidence that animal health harms are now or are soon to be realised, this paper has largely focused on climate change adaptation, which involves adjustments in responses to the current and expected effects of climatic change. It is also critical that efforts be made to reduce or prevent emission of greenhouse gases at their source to slow or halt the acceleration and duration of climate change. Animal health climate change mitigation actions generally focus on reducing the carbon footprint of Veterinary Services and limiting the greenhouse gas emissions caused by feeding, housing, and caring for livestock, fish, and companion animals. Innovations in animal husbandry and feeding predominate the literature on these subjects.

Discussion

Veterinary Services face the challenge of preventing adverse health consequences and finding health benefits likely to result from climate change. The components of effective adaptation to

the future impact of climate change will be unpredictable and emergent rather than predictable and planned (41). This is due to the unprecedent rate of social and environmental change and the complexity of interactions between co-occurring global threats and anthropogenic climate change. Climate change is part of a larger syndrome of systemic environmental and social changes. It must be put into the broader context of other largescale changes, such as land-use changes, habitat loss, and loss of biodiversity. Although the ultimate goals of Veterinary Services – preventing disease, maintaining productivity, and sustaining systems that promote health – will remain unchanged, the form and scope of Veterinary Services will need to evolve.

Veterinary Services cannot isolate their climate change response from their responses to other threats. Our world is experiencing multiple anthropogenically driven global crises simultaneously. Many of the concurrent global threats are intrinsically linked, not only in their ultimate causes, but also in their solutions. There is increasing global awareness of the need to take action on the 'causes of the causes' that are shared between climate change, food insecurity, biodiversity loss and other mega-threats. A joint statement of the Global Health Security Agenda Steering group (42) stressed that, in a time of multiple concurrent global threats, humanity will only be able to deal with the risk of climate change through global solidarity, international partnerships, and cooperation across multiple sectors. It emphasised the importance of cooperating on issues of shared concern and taking a whole-of-government and whole-of-society approach. Veterinary Services will need to shift from a veterinary focus to an animal health services focus if it is to mitigate, as well as adapt to, climate change across the veterinary domain. This will require strategic partnerships with a breadth of disciplines that can influence animal determinants of health as well as the social systems that influence them. Veterinary Services can fill a leadership gap by promoting animal health, linked with ecological and human health, as part of society-wide climate change plans and actions (38).

If Veterinary Services are to meet their obligations as set out by the OIE to 'protect, maintain and improve the health and welfare of humans, including by means of the protection of animal health and animal welfare, and food safety' (2), they are obliged to provide a continuum of climate change actions. This continuum includes:

a) providing services to mitigate climate change impacts

b) reducing population vulnerability to lessen those impacts

c) enhancing population resilience to avoid or cope with the impacts

d) attacking climate change risks at their sources.

Veterinary Services will not be able to provide this continuum of care without strengthening links between animal health practice, policy, and research, cooperating with the social, ecological, economic, and human health sectors, and working in concert with communities to build locally relevant actions. It will require Veterinary Services to expand their thinking on animal health and climate change to include not only risk management but also capacity building for healthy, resilient animal populations and animal health systems.

Climate change, biodiversity loss, and emergence of novel pathogens are occurring at unprecedented rates, with increasingly devastating consequences. These mega-threats are intrinsically linked, with each resulting from the massive and widespread destruction, exploitation, and pollution of our environment (43). The other major problem they share is that the poorest communities and most vulnerable populations (including women, children, and indigenous peoples) tend to be, and will continue to be, disproportionately affected by their consequences. Business-as-usual will exacerbate these global threats, while also exacerbating pre-existing global inequalities. Transformative solutions are needed for 'society to come to grasp with confronting the inter-related challenges of sustainable development, climate change, and biodiversity' (44).

Climate change action falls within the remit of Veterinary Services and they are well placed to provide leadership to build resilience to climate change. By taking action across every area of the veterinary domain, from disease prevention to sustainable food systems and ecosystem health, Veterinary Services can promote reciprocal maintenance; in other words, humans care for animals and ecosystems, and, in turn, healthy animals and a healthy environment help maintain human health.

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Resumen español: título

Resumen

Palabras clave

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