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Planetary boundaries and Veterinary Services

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Summary

National Veterinary Services (NVS) play a crucial role in animal health, production and welfare. They are also intimately involved with safeguarding global health security and the health of the planet. Climate change is just one of the nine planetary boundaries (PBs), i.e. Earth system processes, that can be used to monitor the vital signs of our living planet.

In this paper, the authors identify the positive and negative impacts of human-induced management of aquatic and terrestrial animals in relation to these PBs. In the context of NVS, the authors provide an overview of the real and potential impacts of NVS policies on Earth systems and offer suggestions as to how new sustainability paradigms may assist with reviewing and revising NVS mandates and facilitating stakeholder engagement. Opportunities are proposed for the World Organisation for Animal Health to contribute to the global debate on the role of aquatic and terrestrial animal agriculture and wildlife in sustainable development. In addition, the paper suggests that a wider debate is required in relation to recent significant increases in domestic animal populations and PBs.

Intersectoral and interdisciplinary collaboration are required to achieve the transformation of the framework in which NVS operate. While such transformations cannot be driven by the veterinary profession alone, veterinarians have proven very effective operators in the One Health arena. By building on these intersectoral linkages, it will be possible for our profession and NVS to actively contribute to the crucial discussions and transformations required to pull Earth system metrics back within safe boundaries.

Keywords

Agro-ecology – Animal-source food – Circular food systems – Climate change – Earth system processes – National Veterinary Services – One Health – Planetary boundaries – Sustainable diets – Sustainable production.

Introduction

National Veterinary Services (NVS) play a crucial role in animal health, production and welfare; they are also intimately involved with safeguarding global health security and the health of the planet (1). For example, delivering sensitive and responsive animal disease surveillance systems and addressing the impact of climate change on aquatic and terrestrial animals, both domestic and non-domestic, are receiving increasing attention (1, 2, 3). However, disease and climate change are linked to only two of the nine

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planetary boundaries (PBs), i.e. Earth system processes, that can be used to monitor the vital signs of our living planet.

Veterinarians deal with boundaries routinely. In clinical practice, boundaries or limits of what constitute normal ranges of various physiological functions are used to determine the health or otherwise of animals. In terms of environmental health, the PBs concept provides a mechanism for review and discussion of the nine broad metrics that reflect the stability, status and trajectory of the Earth system (Table I) (4, 5, 6). The PBs concept is a communication device for conceptualising a specific set of limits and can help to focus attention and define overarching goals for the veterinary profession. The nine Earth system metrics are:

- biosphere integrity
- biogeochemical flows
- ocean acidification
- land-use change
- global freshwater use
- stratospheric ozone depletion
- atmospheric aerosol loading
- chemical pollution
- climate change.

Table I
An overview of the nine processes known as 'planetary boundaries' and the indicators used to monitor their status (5, 6)

Boundary (i.e. Earth system metrics)	**Indicators**
Biosphere integrity	Extinctions per million species-years Biodiversity Intactness Index
Biogeochemical flows	Amount of nitrogen removed from the atmosphere for human use Quantity of phosphorus flowing into the oceans
Ocean acidification	Global mean saturation state of aragonite in surface sea water
Land-use change	Area of forested land as percentage of original forest cover
Global freshwater use	Maximum amount of consumptive blue water use (km^3 per year)
Stratospheric ozone depletion	Concentration of ozone
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis
Chemical pollution	Amount emitted, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in the global environment
Climate change	Atmospheric carbon dioxide and methane concentrations Change in radiative forcing

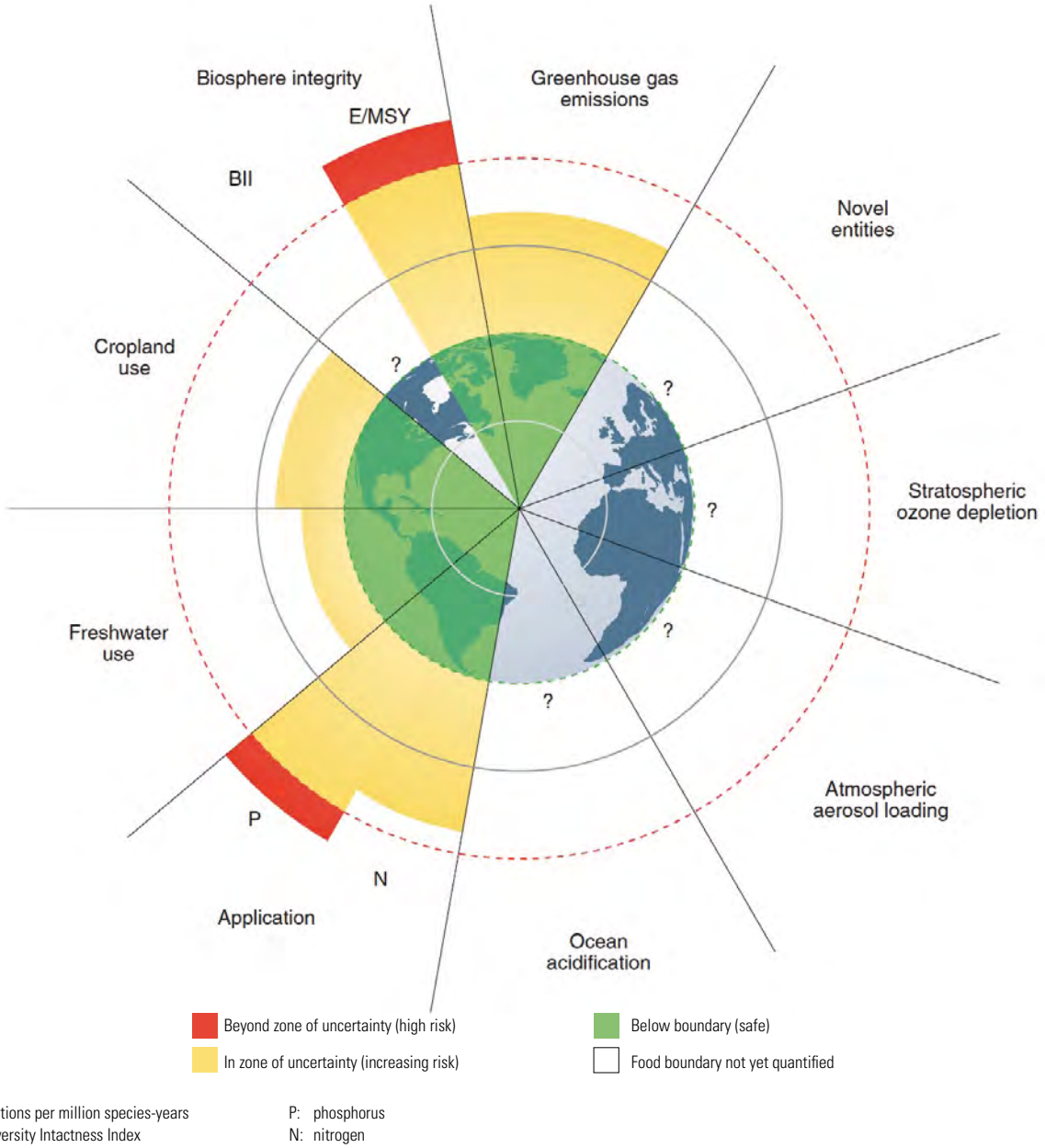
The framework defines a 'safe operating space' for humanity and animals based on the intrinsic biophysical processes that regulate the stability of the Earth system (6). Crossing these boundaries increases the risk of generating large-scale, unwanted, abrupt or irreversible environmental changes.

In 2020, Rockström *et al*. (5) illustrated how the PBs concept could be employed to communicate options for 'planet-proofing' the global food system, which was reported to transgress five of the nine PBs (Fig. 1). The article first defined the PBs for food system thresholds to identify the critical overuse of global commons. Second, it stressed the need to look beyond carbon and climate. The authors argued that 'building resilient food systems requires a systems-approach integrating carbon, nitrogen, phosphorus, water, soils, biodiversity and biome stability; and taking a truly inter-disciplinary planetary health approach by addressing food cultures, nutritional security and geopolitical stability, as well as the role of governance, trade and equity' (5).

This paper identifies the positive and negative impacts of human-induced management of aquatic and terrestrial animals in relation to the PBs. In the context of NVS, the paper provides an overview of the real and potential impacts of NVS policies on the Earth system and highlights how new sustainability paradigms (including circular economics [7] and the 'doughnut' model of social and planetary boundaries [8]) may assist with reviewing and revising NVS mandates and facilitating stakeholder engagement. The authors indicate opportunities for the World Organisation for Animal Health (OIE) to contribute to the global debate on the role of animal agriculture in sustainable development. In addition, the paper suggests that a wider debate is required within the profession concerning the impact on PBs of the huge growth in numbers and biomass of domestic aquatic and terrestrial animals. To facilitate this discussion, domestic animals have been divided into four categories: animals that directly contribute to human health, food security, nutrition and livelihoods (e.g. aquatic and terrestrial food animals, traction animals, bees, etc.) via (a) extensive, (b) semi-intensive, or (c) intensive production systems, and (d) animals that rely on humans for their food security and other needs and do not directly contribute to human physical health, food security and/or nutrition (e.g. most companion animals) (Table II).

How national Veterinary Services policies relate to planetary boundaries

Veterinarians and NVS are uniquely placed to contribute to considerations of both the impact that animals have on



E/MSY: extinctions per million species-years
BII: Biodiversity Intactness Index
P: phosphorus
N: nitrogen

Fig. 1

An estimate of the global food system's transgression of planetary boundaries

Here, the safe operating space (green) provides an estimate of the food-related share of the planetary boundaries. The zone of uncertainty (yellow) defines dangerous risk, whereas the high-risk zone (red) indicates where production has exceeded the assessed uncertainty range in science. The range of uncertainty originates both from quantitative assessments and expert judgement. Control variables have been normalised for the zone of uncertainty; the centre of the figure therefore does not represent zero values for control variables. Processes for which the food system contribution or the planetary boundary itself have not yet been quantified are highlighted with a question mark (5). Values are based on Fig. 6 from Jurgilevich *et al.* (7); image credit: PIK, 2019; taken from Rockström *et al.* (5)

landscapes and also that the environment has upon animal health and production. Aquatic and terrestrial animals have a range of positive and negative effects on processes that can result in either exceeding PBs or staying within them. These effects are moderated by the actions taken by veterinarians and NVS. The animals are in turn affected by changes to these Earth system processes (Table III), requiring action by veterinarians and NVS. There are notable examples where NVS policies contribute to improving these Earth processes via animal health legislation on infectious disease prevention and control, responsible antimicrobial stewardship and animal welfare. A positive example of this

Table II
Classification of aquatic and terrestrial domestic animals compiled to facilitate discussions concerning contributions to sustaining the Earth system

Category	Description	Legal status
Extensive production	Directly contributing to human food security, nutrition, socio-cultural obligations and livelihoods – raised under extensive conditions involving browsing, filtering, foraging, grazing and scavenging for feed (that is usually not suitable for human consumption) in low-density units. Animals able to exhibit most natural behaviours. Usually high diversity of species, breeds and age groups which buffers against various disruptions. May displace indigenous peoples	Property, protected by animal welfare and disease control legislation (9)
Semi-intensive production	Directly contributing to human food security, nutrition and livelihoods – raised under semi-intensive conditions involving the provision of supplementary feed in addition to browsing, filtering, foraging, grazing and scavenging for feed in medium-density units. Animals able to exhibit most natural behaviours. Some degree of diversity of species, breeds and age groups	Property, protected by animal welfare and disease control legislation (9)
Intensive production	Directly contributing to human food security, nutrition and livelihoods – raised under intensive conditions with all feed (frequently including food suitable for human consumption) requirements transported from off-site locations and provided directly to animals in high-density units. Temperature may be artificially controlled. Natural behaviours frequently constrained. Usually limited diversity of aquatic and terrestrial species and breeds with animals kept in same-age groups	Property, protected by animal welfare legislation when enacted (9)
Companion animals	Raised and cared for by people to meet a range of human requirements not including food, where feed and other requirements of the companion animals are provided. Natural behaviours frequently constrained. Some diversity of species, breeds and ages at community level with ongoing breeding of animals with reduced welfare (e.g. brachycephalic dog breeds)	Family members requiring evacuation during emergencies in some countries, protected by animal welfare legislation (10, 11)

is the way in which governments of many shrimp-farming countries have banned the sourcing of shrimp broodstock and/or seed from the wild. This has led to innovations in shrimp domestication and specific-pathogen-free breeding programmes. The global shrimp industry is now less reliant on harvesting wild resources and better able to manage infectious diseases (49). However, there are also examples where NVS or overarching government policies, or their absence, increase the pressure on PBs. National development strategies that focus on increased animal-source food production for both domestic and international markets, without taking environmental impacts into account, can have a negative impact on PBs, including biosphere integrity, land-system change, freshwater use, chemical pollution and climate change (48). Examples include:

– inappropriate disposal of waste that introduces disease (e.g. the spread of African swine fever via the feeding of contaminated swill) (50), allows access by feral animals, and contaminates environments (sea aquaculture, manure spreading)

– the use of broad-spectrum parasiticides that remove non-target species (e.g. ivermectin and dung beetles) (51, 52, 53)

– veterinary clinical practice use of disposable plastics and expectations of same-day delivery with robust lightweight packaging – all fossil-fuel dependent (54).

Ignoring PBs has long-term consequences with losses in sustainability, viability and profit.

The rapid growth in intensive animal production systems since the 1950s has increased risks to human and environmental health (25, 55), yet animal health regulation and enforcement remain patchy in relation to managing these risks (56). The massive increase in intensive livestock production is reported to be the most significant cause of biodiversity loss in recent decades, with the extinction rate estimated to be 100 to 1,000 times that of pre-industrial levels (18, 57, 58, 59). In addition to contributing to biodiversity loss, the expansion of livestock production, and intensive livestock production systems in particular, has been associated with increased risks of emerging infectious disease, antimicrobial resistance and air pollution due to fine dust and ammonia (25).

How can new sustainability paradigms assist with reviewing and revising national Veterinary Services mandates?

The United Nations (UN) is calling on countries to 'build back better' after the COVID-19 pandemic (60), and the Food and Agriculture Organization of the UN (FAO) (61) promotes 'build forward better' by revitalising agriculture through strengthening natural resource management. This is an opportunity to usher in new national and global frameworks that focus specifically on, and align with, the Sustainable Development Goals (SDGs).

Table III

Examples of the range of positive and negative effects of aquatic and terrestrial animals on Earth processes that could feasibly be influenced by veterinarians and NVS, and can result in either exceeding or staying within planetary boundaries

Includes the effects of changing boundaries on animals

Boundary (i.e. Earth system process) *(Possible actions by individual veterinarians)*	**Positive examples** (i.e. relieving strain on planetary boundaries)	**Negative examples** (i.e. placing strain on planetary boundaries)
1. Biosphere integrity *(Action: be an advocate for productive agriculture within sustainable and diverse ecosystems)*	Sustainable, safe harvesting of animal species well adapted to local environments (I) (12) Adaptation of welfare-friendly livestock production practices that enhance plant and animal biodiversity and ecosystem function (I) (12) Nutrition-sensitive aquatic food production systems (I) (13, 14, 15) Sustainable aquaculture and fisheries management; poly-culture systems farming multiple compatible species adding to diversity and reducing inputs (I) (16) Companion animals that do not kill or otherwise displace indigenous animals and plants (I) (17)	Animal-source food produced by a limited number of species and breeds at the global level (I) (12) Feed demands for intensively raised animals requiring the expansion of livestock and crop production into new landscapes, including forests and wetlands (e.g. for soy and other feed), has frequently led to loss of biodiversity (18) and increased risk of pathogen spillover events from wild animal and bird reservoirs to domestic animals and humans (e.g. avian and swine influenzas and severe acute respiratory syndrome coronavirus 2 or SARS-COV-2) (I) (19) Living conditions of local people are deteriorating as livelihoods, socio-economic institutions and cultural values are affected (I) (18) Environmental and genetic hazards associated with escape of aquatic species into the wild (I) (20) Impact of domestic cats (and feral animals) on indigenous animal and plant species (I) (12, 17) Transboundary movement of aquatic and terrestrial animal diseases with live animal trade and their products (I) (21) Over-harvesting including dynamite or poison harvest techniques for coral fish (I) (22) Disruption of food chain by selective harvesting of predator species (I) (23)
2. Biogeochemical *(Action: consider animal waste and its means of disposal for environmental impact)*	Integrated aquaculture–agriculture closed circular systems (I) (12) Appropriate use of manure for organic fertiliser (I) (12) Maintaining wetlands as part of an integrated aquaculture–agriculture closed circular system and ecological balance of ecosystems (I) (16) Farming seaweeds and filter-feeding marine bivalves (extractive species) benefits the environment by removing waste materials including waste from fed species, thus lowering the nutrient load (I) (16)	Excessive use of nitrogen fertiliser to grow feed for aquatic and terrestrial animals and subsequent spillover/leakage of excess fertiliser into water ways (I) (24) Inefficient and improper management of livestock manure and aquaculture waste generated by intensive production systems (I) (25)
3. Ocean acidification *(Action: reduce atmospheric carbon dioxide and waste run-off into coastal waters)*		Ocean acidification caused by global warming, biogeochemical run-off and atmospheric loading will negatively affect aquatic life and shellfish production (E) (26)
4. Land-use change *(Action: be an advocate for better use of existing agricultural and efficient use of all of the animal carcass)*	Introduction of agro-ecological/regenerative livestock and crop production systems that reduce net greenhouse gas (GHG) emissions and improve overall soil health (I) (16, 27) Greater yields per hectare into the human food chain from livestock in high-income countries – both by weight and nutrient yields – through enhancing animal genetics and husbandry practices and reducing pre-consumer losses, i.e. eating more of the animal, including offal. This leads to less land clearing and fewer flow-on effects (on the biosphere, atmosphere, etc.) (I) (28). NVS surveillance and assistance to producers to economically prevent and minimise pre-consumer losses (I) (29)	Clearing forests for livestock production (30) and coastal mangrove forests for coastal shrimp farming (31) for human and companion animal food chains (I) Arable land, particularly near cities, being built on for housing or industry and becoming urban (I) (32) Poor land/agricultural husbandry practices leading to land degradation, fertility loss (I) (33)
5. Global freshwater use *(Action: be involved in animal selection for long-term survival)*	Selection of animals for heat tolerance and efficient water use (I) (34) Efficient use of water by growing aquatic animals and sea-based food production helps to reduce freshwater footprints and the need for terrestrial animal production (I) (35)	Increased water consumption by animals due to increasing numbers of domestic aquatic and terrestrial animals, and raising animals poorly adapted to local agro-ecological conditions (I) (34)

Boundary (i.e. Earth system process) *(Possible actions by individual veterinarians)*	**Positive examples** (i.e. relieving strain on planetary boundaries)	**Negative examples** (i.e. placing strain on planetary boundaries)
6. Stratospheric ozone depletion *(Action: support and promote low methane animal production systems)*		Skin cancers in animals expected to increase until 2070, in association with ozone layer depletion due to human-made ozone-depleting substances (E) (36)
7. Atmospheric aerosol loading *(Action: consider grazing pressure, species suitability and crop types)*	Silvopasture production systems that reduce ground-level wind speed and enhance soil cover (I) (37) Production systems that conserve soil moisture, reducing the impact of bushfires (I) (38)	Overgrazing, leading to loss of vegetative cover and dust generation by wind (I) (33)
8. Chemical pollution *(Action: contribute to genetic selection of healthy, robust livestock)*	Breeding to reduce livestock pests and diseases (flystrike susceptibility/intestinal worms) and hence reduce pesticide/drench use (I) (39, 40) On-farm biosecurity measures and use of vaccines that reduce the need for veterinary medicines and pesticides (e.g. grazing management to reduce environmental worm burdens, isolating new stock to manage the risk of lice and ticks, selection of specific-pathogen-free seeds for aquaculture) (I) (41, 42) Use of organic fertilisers and soil amendments on land used to grow fodder (I) (43)	Heavy metal pollution affects animal health and the safety of aquatic and terrestrial animal-source foods (I) (44, 45) Some farmed fish have a much higher body burden of natural and human-made toxic substances, e.g. antibiotics, pesticides, heavy metals and persistent organic pollutants, than wild fish (I) (20) Antibiotic pollution of the environment including water ways (I) (46)
9. Climate change *(Action: model good environmental behaviour in transport, purchasing, dining, etc. Adopt healthy and sustainable diets for oneself and promote these to clients)*	Well-managed perennial pasture and silvopasture can sequester carbon, reducing atmospheric levels; good animal husbandry and efficient use of animal products can reduce GHG emissions per unit of production (I) (37) Companion animals with low GHG emission footprints (I) (47) Integrated aquaculture–agriculture and integrated multi-trophic aquaculture could play a significant role in sequestering carbon. Fisheries and aquaculture have a key role to play in feeding a growing world population with nutritious and low-carbon-footprint foods (I) (16)	Emissions of methane and nitrous oxide and the loss of organic carbon in the soil and biomass carbon associated with animal raising and animal feed production and supply lines. Energy consumption associated with heating and cooling intensive rearing enterprises. Transport of feed in and animals out for slaughter (I) (48) Decreased animal welfare due to increased heat stress, pathogen circulation, droughts and bushfires (E) (3)

E: effect of changing planetary boundaries on aquatic and terrestrial animals
I: impact of positive and negative contributions to processes that can result in either exceeding or staying within planetary boundaries
NVS: national Veterinary Services

The SDGs are a blueprint to achieve a better and more sustainable future for all, agreed to by 193 UN Member States (62).

So, how can NVS contribute to this endeavour? Veterinarians are respected thought leaders within their communities and NVS are policy leaders; as such, they have a responsibility to consider the sustainability of new and existing processes. The One Health approach (63) is already familiar to many governments and its application has promoted intersectoral and interdisciplinary collaboration, especially in the control of emerging infectious diseases. Nonetheless, operating effectively in the intersectoral policy space is hugely challenging. This is where communication tools, such as the PBs (4), the 'doughnut' model of social and planetary boundaries, which combines two concentric radar charts to depict both the social and ecological boundaries that underpin human well-being (8), and circular economy and food-system models based on reuse, repair, refurbishing, and recycling of existing materials and products (7), can be very helpful. The data presented in each of these models usually reflect, in a general way, the global situation. However, national data can also be used to generate country-specific illustrations that condense large amounts of data into single images. These images facilitate dialogue and can be updated, monitored over time and taken forward to identify gaps and options. The development of national models will also help to identify data gaps and cost-efficient options for obtaining the required data over time. This will assist in identifying animal systems that are well adapted to local agro-ecological conditions and can help to minimise or reduce pressure on PBs.

Given the vital role of animal-source food in nourishing people efficiently, especially women and children (64), NVS have a responsibility to engage in and contribute to national and global discussions on the transformation of food systems (65). The 2030 Agenda for Sustainable Development, which

produced the SDGs (62), demands that we work to achieve 'healthy people and a healthy planet'. There is general agreement that we should all coalesce on a food systems approach and seek to put culturally acceptable, nutritious, safe, affordable and diverse foods on the plate. National planners must seek to identify the most effective healthy diet that is affordable, accessible, convenient, and climate resilient for different wealth groups and across different geographies (65).

Innovations to accelerate the transition towards future sustainability of food systems must take into account the issues of changing diets, reducing waste and increasing productivity through the lens of PBs. National Veterinary Services have a role to play in achieving UN SDG 12, which aims to ensure sustainable consumption and production (62). For example, in fisheries and aquaculture, it is estimated that 35% of the global harvest is either lost or wasted every year (16, 48). The FAO (65) stated that, from production to wholesale and retail, food losses and waste are generally highest for more perishable, nutritious foods, including fruit, vegetables and animal products. Food loss and waste are important because a reduction in the physical quantity and/or quality of food leads to reduced remuneration from supply-chain activities, wasted energy and natural resources from inefficient food production, lost nutritional resources, pollution including greenhouse gas (GHG) emissions and the depletion of natural resources that could address ongoing chronic malnutrition and reduce pressure on the PBs (14, 65). National Veterinary Services can implement mechanisms to identify the causes of animal-source food losses in the food chain and communicate these to food producers, with advice and support as appropriate, to reduce future occurrences.

Where responsibilities for aquatic food systems lie outside the NVS, strong cooperation and collaboration with national and regional fisheries authorities are essential to promote responsible aquatic food systems transformation within PBs and in line with 'blue growth' and 'blue economy' strategies (16). In such situations, the OIE recommendation that Members nominate OIE Aquatic Focal Points can help to strengthen coordination. Precision production systems (covering a suite of digital and genomic technologies that enable increased production with fewer resources), together with the veterinary profession's enhanced understanding of the environment and human impacts on it, are likely to play a major part in achieving sustainability (16, 65).

As pressures on natural resources increase, NVS are well positioned to play an increasingly vital role in monitoring a wider range of issues relating to domestic animal-source food production, sustainable wildlife harvesting and allied value chains. In relation to food safety (i.e. freedom from biological, chemical and physical contamination), NVS must be authorised and resourced to regularly monitor, analyse and respond to food safety issues associated with production sites, abattoirs and wet markets. In terms of promoting efficient, sustainable aquatic and terrestrial animal production systems, NVS must increasingly engage in intersectoral and interdisciplinary collaboration, in order to monitor, analyse and promote systems that are appropriate to local conditions. The promotion of sustainable aquaculture (66) and soil health and biodiversity through agro-ecological and regenerative extensive and semi-intensive animal production systems on rangeland (i.e. non-arable land) (27) fits within expanded definitions of animal welfare, One Welfare (67), One Health and Planetary Health (68). In regard to intensive animal production, NVS will need to engage in tough debates that ask how food fit for human consumption should best be used. Public health nutritionists have stated that there is no nutritional case for feeding human-edible crops to farmed animals, which reduces calorie and protein supplies directly available for human consumption (69).

With increasing urbanisation and economic growth, the number of companion animals is also increasing and must be considered when assessing food security requirements (70). Companion animals such as cats (obligate carnivores) and dogs (omnivores) require meat-based diets and therefore have greater environmental impacts than herbivores (71). For example, in the United States of America, the energy consumption of companion dogs and cats is approximately 20% of the human population's energy consumption, and animal-source food consumption by dogs and cats alone is responsible for up to 58 ± 14.5 million tonnes of carbon dioxide-equivalent of methane and nitrous oxide, two powerful GHGs (47). Domestic cats and dogs also affect wildlife in multiple ways, including predation, pathogen transmission, hybridisation, competition, and the harvest of wild animals for pet food (72). In the future, NVS will probably see their regulatory role in promoting animal welfare expand to include responsible companion animal ownership that is in line with sustainable development. Beyond food security, the impact of an increasing professional focus on companion animals in high-income settings is leading to the increased use of disposable consumables, non-recyclable packaging and rapid delivery to support companion animal consumer culture. Thought leaders within the human healthcare sector note that their profession has a profound responsibility and opportunity to address climate change by reducing GHG emissions to limit the myriad associated health harms (73). Likewise, veterinarians, NVS and the OIE have an opportunity and an obligation to reduce human pressure on PBs by improving animal health, developing animal health and production systems with a lower GHG footprint, and enhancing locally appropriate wildlife biodiversity activities. These actions will contribute to animal welfare; sustainable local, national and global economies; and human well-being.

Veterinarians must be prepared and resourced to engage in evidence-based debates of the crucial issues presented above. The mandate and regulatory framework of NVS will need to change to ensure that these Services can fully participate in the transition to more sustainable ways of living on our planet.

What structural changes are required to enable efficient national Veterinary Services contributions to a healthy planet?

At present, NVS usually operate within Ministries of Agriculture, Livestock and/or Fisheries and/or Natural Resources. The performance of these Ministries is usually assessed in relation to income generation and contribution to gross domestic product, with few or no direct links to the health of the people or the environment. To increase the efficient use and safety of inputs into aquatic and terrestrial animals, in terms of the health of the planet and its people, the mandates and collaborative and institutional arrangements across sectors must also be transformed. A simple but crucial change will be a shift from measuring gross domestic product to measuring net domestic product, in which the social and environmental impacts of production are also considered. Where animals are raised for food, debates on the benefits and trade-offs in relation to scarce nutrients, land and water, with public health nutritionists within the Ministry of Health and environmental scientists and conservation biologists within the Ministry of the Environment and Forestry, would make it easier to identify production systems that can be directly aligned with human and environmental health. Where animals are kept as companions, NVS could consider collaborating with their public health colleagues to provide harmonised recommendations to consumers and human and companion animal food companies on the best use of available nutrients. For example, currently nutrient-dense pelagic fishes (74) and terrestrial animal offal (28) go to animal and pet feeds in high-income countries, both of which could very efficiently meet the nutritional requirements of humans. Engagement with public health nutrition in relation to healthy and safe animal-source food will also provide an opportunity to discuss tailoring aquatic and terrestrial animal production systems, such as changes to livestock genetics and feed composition, to achieve increased quantities of the final product (e.g. leaner meat) that are suitable for human consumption. For example, current recommendations by the Heart Foundation in Australia suggest eating poultry meat without the skin (75), presumably to reduce the overall fat content, with no mention of consuming offal. This means that significant quantities of nutrients found in the whole chicken are lost to the human food chain. Changes to chicken genetics and nutrition have also contributed to this situation. Wang *et al*. (76) report that, by comparison with the broiler chickens of the 1970s (when physicians recommended eating less fatty red meat and more poultry because it was lean), the modern broiler carcass contains more fat energy compared to protein and significantly less omega-3 fatty acid. Similar findings of the lower overall nutritional quality of farmed fish, when compared to wild fish, have been reported in Bangladesh, with a call to embrace a nutrition-sensitive approach that moves beyond maximising productivity to also consider nutritional quality (77). There are few studies that directly explore the impact of fish feed modification on the nutritional composition of farmed fish and the associated health of human consumers of fish (78). The consumption of calorie-restricted, nutrient-rich diets would also contribute to lowering obesity in humans and companion animals in many countries (79). As nutrition and health become more important to the sustainable development agenda, and as consumers become better informed, attention to feed formulations of all intensively raised animals will become increasingly urgent.

To better manage emerging and re-emerging pathogen risks, the NVS need to coordinate and collaborate with government planning agencies, environmental agencies, health agencies, food safety agencies, the forestry sector and the fisheries sector. As domesticated livestock and companion animal numbers have increased, so too has their contribution to the zoonotic disease burden (30). Pathogen spillover from wildlife is rare but when it occurs it can be very significant. Pathogen transmission from wildlife to humans appears to be influenced by extrinsic factors, such as land-use changes that cause losses in the quality and number of wildlife habitats (30), and agricultural intensification (80). Such factors play a particularly important role in driving the emergence of zoonotic diseases in biodiverse tropical forest regions (81). When human populations expand further into natural habitats (along with their associated activities, such as agriculture and hunting), this leads to increased opportunities for human-to-wildlife contact (82), and increased pathogen transmission at human–livestock–wildlife interfaces (83).

Clearly defining roles and responsibilities across all government agencies, including the NVS, is crucial to both minimising the likelihood of such events occurring and, when such an event does arise, for effective management of the incident. Making full use of the surveillance and reporting systems that NVS already have in place (including veterinary laboratories) facilitates early detection of significant diseases in wildlife, protecting human and livestock health, as well as the health of the wildlife (84). In

addition, as governments introduce agriculture biodiversity policies and programmes (85) that include new and more diverse animal breeds and variability, active collaboration by NVS in the development and monitoring of associated certification schemes involving wildlife will become increasingly important.

How might changes in planetary boundary trends influence the role of the World Organisation for Animal Health?

The OIE has rightly identified that its mandate includes working with NVS to safeguard global health security and the health of the planet (1). As we move forward, this will require expanding the OIE's range of activities to enable NVS to contribute to sustainable aquatic and terrestrial animal development and wildlife conservation. This will likely include:

– increasing veterinary literacy concerning sustainable development and associated Foresight and communication activities

– in collaboration with environmental agencies, monitoring the global biomass of domestic and non-domestic aquatic and terrestrial animals to assist in lowering disease burdens, to increase productivity and to reduce the associated environmental impacts

– the ability to monitor the efficiency of domestic animal raising and the efficient use of food animal carcasses (e.g. what proportion of the edible components of the carcass enter the human food chain)

– in collaboration with environmental agencies, monitoring wildlife health and habitat quality

– guidelines as to how to measure and classify animal species and breeds in relation to their impact on sustainable development in general, and on PBs in particular.

If we simply keep 'growing the economy' using existing structures and approaches, we increasingly risk crossing PBs. Hence, new technologies, policies and engagement processes are needed but these should recognise that the PBs are interconnected and so consideration is required to ensure that improvement in one does not result in the deterioration of others. The OIE's crucial role as a cross-sectoral champion is reflected in the One Health High-Level Expert Council, involving the OIE, FAO, World Health Organization and UN Environment Programme (86), and the active engagement of national governments through the One Health Global Leaders Group on Antimicrobial Resistance (87).

The OIE should continue to work with NVS to support their national veterinary training institutions to ensure that graduates:

a) have a basic knowledge of the status of PBs and SDGs nationally and globally

b) understand the associated impacts of and underlying processes associated with PBs in relation to animal physiology and behaviour

c) are aware of feasible adaptations

d) comprehend the implications for the profession, e.g. in terms of ethics and codes of practice

e) have a basic understanding of how to translate policy objectives into meaningful actions.

Conclusions

Intersectoral and interdisciplinary collaboration are required to achieve the transformation of the framework in which NVS operate. Such transformations cannot be driven by the veterinary profession alone. However, veterinarians have proven very effective operators in the One Health arena. By building on these intersectoral linkages, it will be possible for our profession and NVS to contribute actively to the crucial discussions and transformations required to pull Earth system metrics back within safe boundaries.

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Les frontières planétaires et les Services vétérinaires

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Résumé
Les Services vétérinaires nationaux jouent un rôle crucial dans les domaines de la santé animale, de la production animale et du bien-être des animaux. Mais ils sont aussi fortement engagés dans la protection de la sécurité sanitaire mondiale et de la santé de la planète. Le changement climatique est l'une des neuf frontières planétaires existantes, c'est-à-dire les neuf processus du système terrestre qui peuvent nous aider à surveiller les signes vitaux de notre planète vivante.
Les auteurs font le point sur les impacts positifs et négatifs de la gestion par l'homme des animaux aquatiques et terrestres dans la perspective de ces frontières planétaires. S'agissant des Services vétérinaires nationaux, les auteurs donnent un aperçu de l'impact réel des politiques des Services vétérinaires sur les systèmes terrestres ainsi que des possibilités en la matière et font quelques propositions pour que les mandats de ces Services soient repensés et modifiés et la participation des parties prenantes facilitée à la lumière des nouveaux paradigmes de durabilité. Ils évoquent plusieurs occasions au cours desquelles l'Organisation mondiale de la santé animale (OIE) pourrait contribuer aux discussions à l'échelle mondiale sur le rôle des animaux terrestres et aquatiques, tant d'élevage que sauvages, dans le développement durable. En outre, les auteurs estiment qu'un débat plus général est nécessaire concernant l'augmentation récente et significative des populations d'animaux domestiques et les frontières planétaires.
Une collaboration intersectorielle et interdisciplinaire sera nécessaire pour transformer le cadre dans lequel interviennent les Services vétérinaires nationaux. Certes, une transformation de cette nature ne peut être menée par la profession vétérinaire seule, mais les vétérinaires ont déjà fait preuve de l'efficacité de leurs capacités opérationnelles dans l'arène Une seule santé. En s'appuyant sur ces liens intersectoriels, la profession vétérinaire et les Services vétérinaires nationaux seront à même de contribuer activement aux discussions cruciales ainsi qu'aux transformations indispensables pour ramener les variables mesurables de la Terre à l'intérieur de frontières sûres.

Mots-clés
Agro-écologie – Changement climatique – Denrées alimentaires d'origine animale – Frontières planétaires – Processus du système terrestre – Production durable – Régimes alimentaires durables – Services vétérinaires nationaux – Systèmes alimentaires circulaires – Une seule santé.

Límites planetarios y Servicios Veterinarios

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Resumen
La función de los Servicios Veterinarios nacionales, además de ser crucial para la sanidad, la producción y el bienestar animales, guarda estrecha relación con la salvaguarda de la seguridad sanitaria mundial y la salud del planeta. El cambio

climático es solo uno de los nueve límites planetarios, esto es, procesos del sistema terrestre, que cabe utilizar para seguir de cerca los signos vitales del ser vivo que es nuestro planeta.
Los autores exponen los efectos tanto positivos como negativos que en relación con estos límites planetarios trae consigo la gestión antrópica de animales acuáticos y terrestres. Por lo que respecta a los Servicios Veterinarios nacionales, los autores presentan a grandes líneas las repercusiones que las políticas de estos Servicios Veterinarios tienen o pueden tener en los sistemas terrestres y proponen fórmulas para que los nuevos paradigmas de la sostenibilidad ayuden a examinar y revisar el mandato de los Servicios Veterinarios nacionales y a facilitar la participación de los demás interlocutores. También señalan las oportunidades que tiene ante sí la Organización Mundial de Sanidad Animal para contribuir a las deliberaciones mundiales sobre la función de la producción de animales acuáticos y terrestres y de la gestión de la fauna silvestre con vistas al desarrollo sostenible. Los autores, además, consideran necesario un debate más amplio en relación con el reciente y considerable crecimiento de las poblaciones de animales domésticos y los límites planetarios.
Para lograr una transformación de las coordenadas en las que operan los Servicios Veterinarios de los países se requiere una colaboración tanto intersectorial como interdisciplinar. Aunque estos cambios no pueden venir únicamente de la mano de la profesión veterinaria, la labor de los veterinarios en el ruedo de Una sola salud ha demostrado que son agentes muy eficaces. Profundizando en estos vínculos intersectoriales, será posible que nuestra profesión y los Servicios Veterinarios nacionales contribuyan activamente a las cruciales deliberaciones y transformaciones que se necesitan para que el valor de los parámetros del sistema terrestre vuelva a situarse dentro de los márgenes de seguridad.

Palabras clave
Agroecología – Alimento de origen animal – Cambio climático – Límites planetarios – Procesos del sistema terrestre – Producción sostenible – Regímenes alimentarios sostenibles – Servicios Veterinarios nacionales – Sistemas alimentarios circulares – Una sola salud.

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