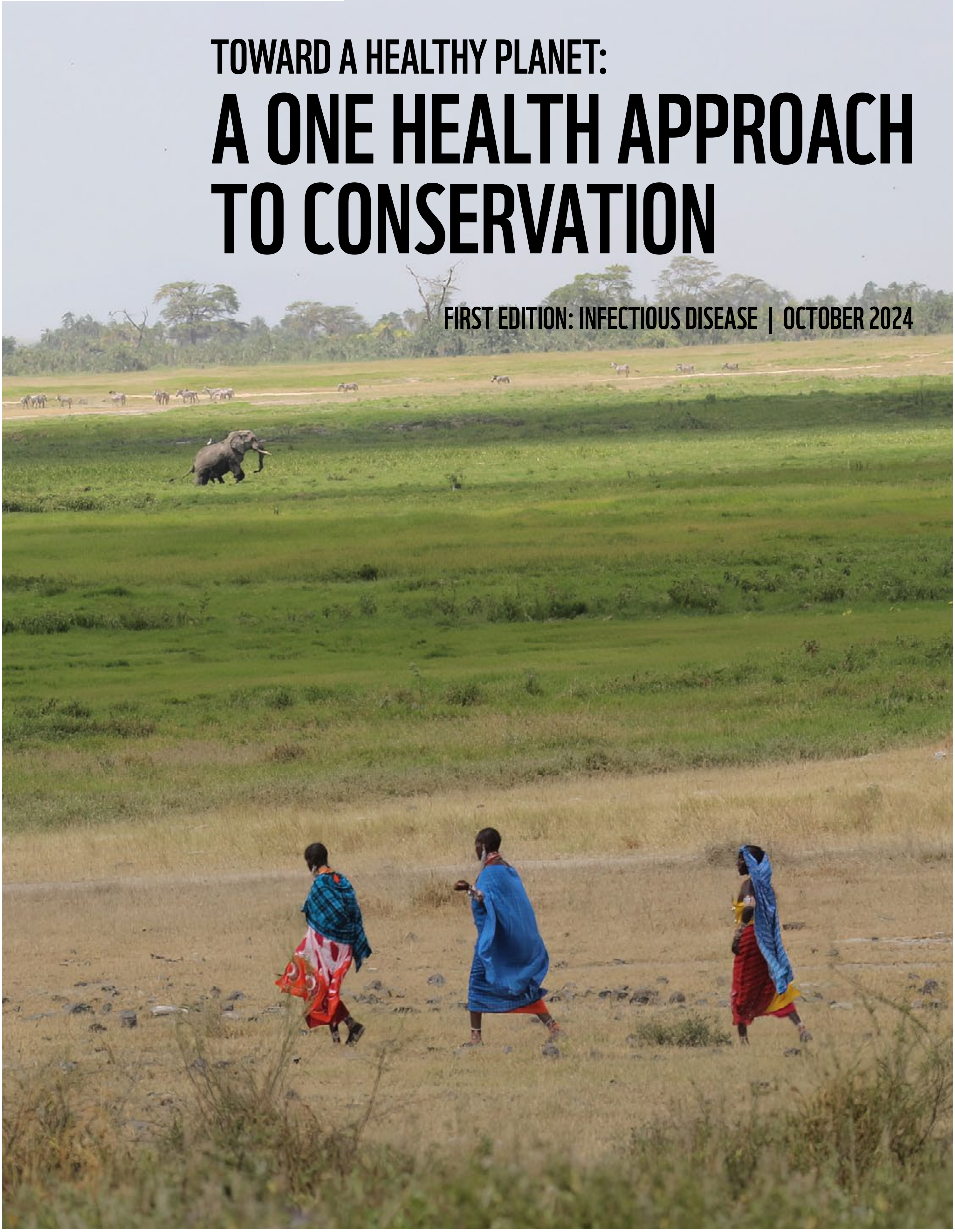
ONE HEALTH

TOWARD A HEALTHY PLANET:
A ONE HEALTH APPROACH TO CONSERVATION

FIRST EDITION: INFECTIOUS DISEASE | OCTOBER 2024



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In this report, references have been embedded as hyperlinks for easy access and convenience.

FOREWORD

We have known for decades the linkages between people, animals and the environment in terms of health, and the One Health approach has been around since 2003. But it took a global pandemic for the world to make One Health a priority.

Wendy Elliott,
Practice Leader, Biodiversity (Interim)
WWF International

Mike Ryan was Executive Director of the World Health Organization's (WHO) Health Emergencies Programme when COVID-19 hit, and led the global COVID-19 response for WHO throughout the pandemic. In 2021 he said the following: "We are pushing nature to its limit .... We are creating the conditions in which epidemics flourish ... We're taking huge risks – massive risks – with our future if we don't manage the planet in which we live."

We have seen a lot of momentum on One Health since COVID-19 changed all our lives. But, despite this momentum, what we still see in the implementation of the One Health approach on the ground is that the 'environment' pillar is often less well understood, and frequently less put into practice than the other pillars.

Given this, in 2021 we established the WWF Landscape One Health Task Force, to develop guidance and a network of experts to support WWF landscape teams to engage in the One Health approach. We brought together individuals from a diverse range of specialties who co-created the guidance. We tested the guidance in a number of landscapes in various regions and refined it based on what we learned. I am delighted that we are now able to share what we came up with.

The One Health approach in conservation doesn't always mean doing totally new things – much of existing conservation work in landscapes is also core to a One Health approach. This might include work to prevent habitat fragmentation, as fragmentation increases the human-wildlife interface and thus the risk of disease spillover; or work to strengthen regulation of high-risk wildlife trade. But importantly, we can amplify and strengthen this existing work by building it into a more comprehensive One Health approach, closely linked to animal, environmental and human health efforts. In doing so we magnify the benefits of this work for us all.

So please enjoy diving into this report. We endeavoured to make it as practical as possible, with approaches that can be applied immediately, and case studies to bring the guidance to life. Bear in mind that this guidance is very much a living organism – our collective approach to One Health must and will evolve over time as we learn and adapt, and as our planet changes. I hope our key finding of this work shines through: that no one entity can secure the health of people and planet, our only chance of success is through meaningful collaboration across organizations, sectors, landscapes and borders. Together we can achieve health for all.

EXECUTIVE SUMMARY

An integrated, unifying One Health approach recognizes the interdependence of human, animal and environmental health. Conservation efforts targeted at this intersection have the ability to improve human health by strengthening wildlife and ecosystem resilience.

However, there is limited recognition of the importance of integrated well-being between people, animals and the environment and how this affects both ecosystem services and health. A lack of early warning and monitoring systems, wildlife-specific diagnostics and treatment pathways has contributed to the poor mitigation of emerging infectious disease from wildlife. This is likely to rise due to shrinking and fragmenting natural habitats and climate change both driving the increased interface between domestic animals, humans and wildlife, reducing the resilience/adaptability of already vulnerable populations, increasing competition for limited food and water resources, and decreasing genetic diversity and resistance to disease.

The use of multisectoral, transdisciplinary conservation management techniques is necessary to prevent, predict, detect and respond to global health threats and to develop new ideas that address root causes and create long-term, sustainable solutions. This can be achieved by integrating the mandates and priorities of the environment, human health and livestock sectors. This will foster a better understanding of environmental issues in the One Health community, boost the capacity of the environmental sector to have an equal voice in decision-making, and help design interventions that best contribute to One Health outcomes (Box 1.1).

KEY ACTIONS TO SUPPORT A ONE HEALTH APPROACH:

Map the local stakeholders, to identify suitable and interested partners.

Collaborate with organizations/groups that are working in other sectors and disciplines, to share information, formulate strategies and harmonize partnerships.

Engage Indigenous Peoples and local communities (IPs and LCs) to identify their specific health needs at the human-animal-environmental interface and support the strengthening and sharing of Indigenous knowledge.

Design integrated multidisciplinary interventions using 'systems thinking' to understand and address integrated factors.

Organize specific assessment(s) to gather data and information on the procedures in place to conduct risk assessments, address gaps in data, and support surveillance, investigation, response and reporting.

Build capacity in stakeholders who work at the human-animal-environmental interface.

Box 1.1 Core components to create resilient and sustainable One Health outcomes

This report details WWF's approach to address the anthropogenic and nature-based drivers of infectious disease through guidance on implementing six key strategies (Figure 1). It also covers monitoring One Health interventions (including example indicators), and guidance on mainstreaming gender in One Health. The six strategies are governed by principles of transdisciplinary collaboration, equity, rights-based approaches, science-based learnings and gender responsiveness.

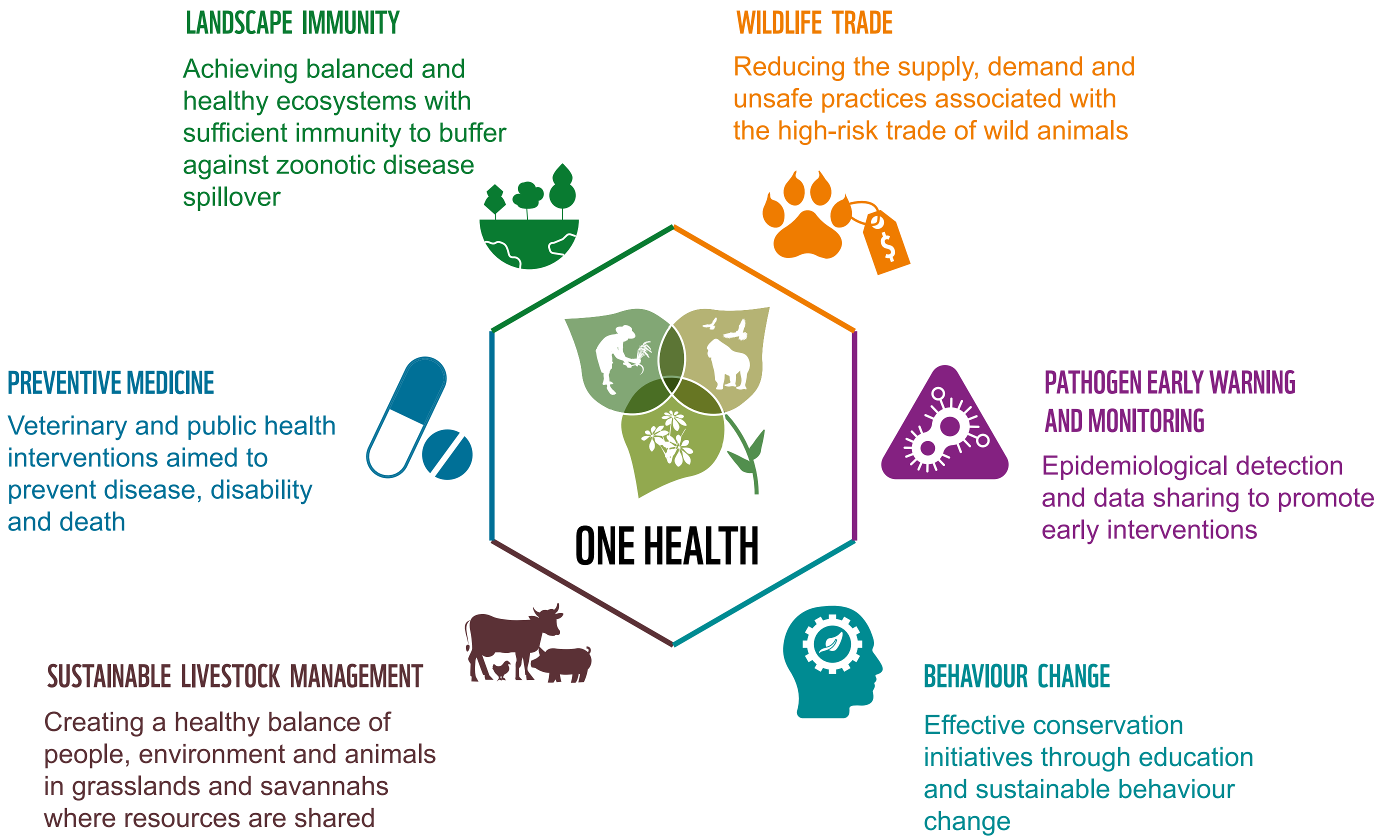


Figure 1. Six key strategies to guide the implementation of a One Health approach in conservation.

These strategies are a guide to help design and implement a One Health approach in conservation, to prevent disease emergence and spillover. They illustrate that there is no one-size-fits-all solution to interdependent health challenges. Instead, we require systems thinking and an understanding of the intricate relationships between humans, animals and the environment, as well as collaboration across multiple disciplines and sectors.

Savannah sparrow and cow, South Dakota. © WWF-US / Clay Bolt

ABBREVIATIONS

EVD	Ebola virus disease
HPAI	Highly Pathogenic Avian Influenza
HWC	Human-wildlife conflict
ILRI	International Livestock Research Institute
IP	Indigenous Peoples
IUCN	International Union for Conservation of Nature
LC	Local Communities
NbS	Nature-based solutions
OECM	Other effective area-based conservation measures
PCA	Protected and conserved areas
SARS	Severe acute respiratory syndrome
WOAH	World Organisation for Animal Health (formerly OIE)

DEFINITIONS

Animal markets	Markets where animals are slaughtered on-site for the purpose of human consumption.
Biodiversity	A contraction of 'biological diversity'. Biodiversity reflects the number, variety and variability of living organisms.
Capacity building*	The development of knowledge, skills, commitment, partnerships, structures, systems and leadership to enable effective health promotion actions.
Commodity crops	Crops that are grown, typically in large volume and at high intensity, specifically for the purpose of sale to the commodities market (as opposed to direct consumption or processing).
Disease outbreak*	The occurrence of disease cases in excess of normal expectancy. The number of cases varies according to the disease-causing agent, and the size and type of previous and existing exposure to the agent.
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
Ecosystem services	The benefits people obtain from ecosystems. These include provisioning services, or products obtained from ecosystems (e.g. freshwater, food, fuel, genetic resources, natural medicines, etc.); regulating services obtained from the regulation of ecosystem processes (e.g. water erosion, waste, climate and natural hazards); and cultural services that support people's nonmaterial well-being (e.g. cultural diversity, educational values, social relations, heritage, etc).
Health	WWF understands 'health' to be a state of complete physical, social and mental well-being, and not merely the absence of disease or infirmity. However for the purposes of this paper 'health' refers only to the absence of disease.
Human-wildlife conflict	Struggles that arise when the presence or behaviour of wildlife poses actual or perceived direct, recurring threats to human interests or needs, often leading to disagreements between groups of people and negative impacts on people and/or wildlife.

Indigenous knowledge	A network of knowledge, beliefs and traditions that preserve, communicate and contextualize Indigenous Peoples' relationships with their culture and landscape over time.
Invasive alien species	Animals, plants or other organisms that are introduced by humans, either intentionally or accidentally, into places outside of their natural range, negatively impacting native biodiversity, ecosystem services or human economy and well-being.
Nature-based solutions	Actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits. One Health interventions are a nature-based solution addressing the societal challenge of human health (Section 2.3 of the IUCN guidance).
One Health	One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes that the health of humans, domestic and wild animals, plants and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilizes multiple sectors, disciplines and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for clean water, energy and air, safe and nutritious food, taking action on climate change, and contributing to sustainable development.
Public health*	An organized activity of society to promote, protect, improve and - when necessary - restore the health of individuals, specified groups or the entire population. It is a combination of sciences, skills and values that function through collective societal activities and involve programmes, services and institutions aimed at protecting and improving the health of all people.
Refugia	Habitats that components of biodiversity retreat to, persist in and can potentially expand from under changing environmental conditions.
Sensitization	Raising awareness through various mediums and methods (e.g. door-to-door or public workshops).
Spillback	The transmission of pathogens from humans to animals.
Spillover	The transmission of pathogens from animals to humans.
Systems thinking*	An approach to problem-solving that views problems as part of a wider dynamic system. It recognizes and prioritizes the understanding of linkages, relationships, interactions and interdependencies among the components of a system that give rise to the system's observed behaviour.
Wildlife	WWF understands 'wildlife' to include all fauna, flora and fungi, including terrestrial and aquatic species. However, for the purposes of this paper 'wildlife' refers only to wild animals and wild-sourced animals.

* Definitions taken from WHO. 2021. *Health promotion glossary of terms 2021.*

THE IMPORTANCE OF THE ENVIRONMENT PILLAR

There is increasing recognition that the health of humans, domestic and wild animals, plants and the environment are closely linked and interdependent. These three elements - people, animals, environment - form the three pillars of the One Health approach. However, the importance of the environmental pillar of One Health is perhaps the least well understood and prioritized in One Health strategies. In order to address health challenges equitably and sustainably it is necessary to understand that every form of environmental degradation has direct or indirect negative consequences for human and animal health which can be prevented or mitigated with a One Health approach. In addition to the human responsibility to protect and preserve the environment, promoting environmental sustainability can significantly contribute to improving public health outcomes and creating healthier ecosystems for all living beings.

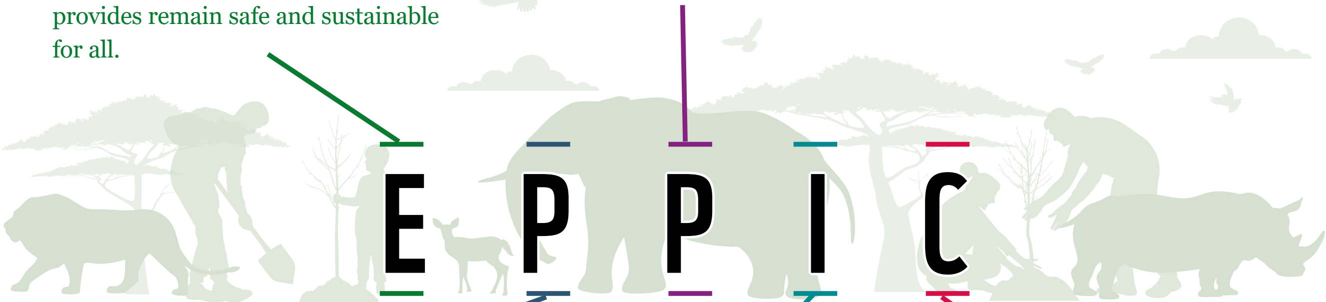
Strengthening the voice of the environmental sector in One Health is vital to health security and continued life in all its forms, and requires a holistic understanding of these relationships and coordinated actions across disciplines and sectors. The role of the environment in the One Health triad may be less visible but it is EPPIC in its contribution to health. EPPIC is an acronym that can be used to better understand the importance of environmental health for us all:

ECOSYSTEM SERVICES

Healthy ecosystems provide essential services like clean air, water filtration and erosion prevention, which are vital for human and animal health. Environmental health ensures that the shared environment and the services it provides remain safe and sustainable for all.

PATHOGEN TRANSMISSION

The majority of infectious diseases can be spread through interactions between humans, animals and the environment (e.g. zoonotic diseases like Ebola virus disease (EVD) and COVID-19 can jump from animals to humans due to environmental factors that bring them into closer contact). A healthy environment reduces the spread of diseases and contributes to the well-being of all living beings.



POLLUTION AND CONTAMINATION

Environmental pollutants such as air and water contaminants, pesticides, plastics and industrial waste can pose significant health risks to humans and animals alike. Contaminated water or food can lead to outbreaks of diseases affecting both humans and animals. Environmental health safeguards the quality of water and food sources that humans and animals rely on.

INNOVATIONS FROM NATURE

The environment plays a pivotal role in the development of new medicines, therapies and sustainable technologies that promote resilience, adaptation and transformative solutions benefiting both human and ecological systems. By integrating knowledge and efforts across disciplines – such as environmental science, veterinary medicine and public health – One Health approaches can effectively address complex health challenges

CLIMATE CHANGE

Environmental health can address some of the health impacts of climate change, such as heat-related illnesses, increased prevalence of vector-borne diseases and food insecurity. These impacts affect human health directly and can also influence animal populations and ecosystems.

Figure 2. The EPPIC role of the environment in One Health.

BACKGROUND AND SCOPE

The topic of One Health has a long history with events like the 1918 influenza pandemic (Spanish flu) highlighting the need for a coordinated approach to understanding disease transmission across the boundaries of human, animal and environmental health. Natural cycles of disease are an integral part of ecosystems, with infectious organisms and other causes of disease serving an important role in the population dynamics of animals and plants. However, threats such as climate change, land-use change, invasive alien species, wildlife trade, and rising agricultural, industrial and human population pressures can act as drivers for disease emergence and reemergence occurring beyond natural cycles and negatively impacting animal, environment and human health.

The formation of the tripartite agreement in 2010 between the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the World Organisation for Animal Health (WOAH, formerly OIE), and later the United Nations Environment Programme (UNEP) resulted in the Quadripartite which further recognized the importance of collaboration between human health, animal health and environmental sectors to address global health challenges.

More recently Ebola Virus Disease (EVD), Avian influenza (H5N1), SARS (Severe Acute Respiratory Syndrome) and in particular COVID-19 (SARS CoV2) have brought a wider recognition of One Health as a necessary framework for addressing complex health issues that transcend boundaries. Governments, international organizations, academic institutions and non-governmental organizations (NGOs) are promoting One Health as a holistic approach to improve disease prevention, surveillance, response capabilities and overall health outcomes. For nature conservation organizations, One Health is of particular interest, as the approach includes environmental health and animal health (wildlife and domestic livestock) as two of its three components, alongside human health.

WWF established the WWF Landscape One Health Task Force in 2021, bringing together 32 members of various disciplines, 5 Practices and offices from across Asia, Africa, Europe and the Americas. This task force formed to aggregate knowledge and expertise across the network, and provide the resources needed to understand how to apply a One Health approach within WWF's programmes. The task force developed the information contained in this report through an interactive internal process with external expert consultation. The approach was then trialled in a number of landscapes, with lessons learned from these practical applications fed back into the design. This report outlines the resulting approach, which will continue to evolve as practice on the ground allows for more adaptive management.

Scope

Although One Health encompasses broader health aspects beyond infectious disease such as pollutants, climate change, etc., **the scope of this report is the application of One Health approaches involving infectious diseases** in conservation landscapes.

While the marine environment is crucial to One Health, this particular report focuses on **terrestrial and freshwater environments** only.

WWF PRINCIPLES

In recognition of the importance of embracing a holistic approach for the health of nature, people and the planet, WWF promotes the integration and amplification of the One Health approach in its current and future conservation programmes, aiming to "sustainably balance and optimize the health of people, animals, and ecosystems" (Box 1.2). The following principles have been identified to guide the application of a One Health approach across landscapes.

ONE HEALTH DEFINITION

The One Health High Level Expert Panel (OHHLEP) has defined One Health as follows:

"One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilizes multiple sectors, disciplines and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for clean water, energy and air, safe and nutritious food, taking action on climate change, and contributing to sustainable development."

Box 1.2 Source: One Health: A new definition for a sustainable and healthy future

The principles are consistent with the Berlin Principles on One Health (Box 1.3), and adapted for WWF's context. In many cases, WWF already applies the Berlin Principles of One Health. Adapting them for specific landscapes, conservation objectives and strategies that respond to global trends of increasing risks to human health entails more intentional inclusion in practice and the establishment of new and deeper partnerships across disciplines to ensure their effective application on the ground.

These principles ultimately aim to help WWF identify and support:

- Credible human and animal health impacts derived from nature at a larger scale
- Effective and durable partnerships with a wider range of partners and stakeholders
- An expanded, rigorous, more well-rounded evidence base connecting nature with human and animal health
- Local, regional, and global policy tools that advance One Health goals for climate and nature.

The 10 principles are as follows:

1. **Ensure interventions are context-specific and align with the needs of local populations**. One size does not fit all and it is essential to adapt interventions to the specific needs of each situation and set of local stakeholders. Evidence-based and internationally recognized strategies (e.g. One Health Joint Plan of Action) and approaches should be analysed and adapted to the local context, to ensure they fit the specific context of the target area and respond to the needs of the relevant populations.
2. **Prioritize multidisciplinary expertise and transdisciplinary collaboration** when designing or adapting projects or strategies. Recognize the potential contributions of fields that include veterinary or medical professions, conservation and related professions, socioeconomics, anthropology and social science, among others. Partnership with organizations that have experience and expertise in different disciplines and sectors is pivotal to promote collaborative planning and ensure the engagement/ownership of all concerned ministries and departments. Transdisciplinary collaborations should be ensured by establishing an effective communication flow and maintaining a transparent sharing of information and data between partners and sectors.
3. **Promote equity among disciplines** with thorough outreach to key sectors and collaboration across stakeholders. One Health partnership should be built on the equity principle between sectors and disciplines, promoting a balanced collaboration between human, animal and environmental health, and recognizing the intrinsic value of all living things in each ecosystem.
4. **Ground progress in bottom-up approaches that extend across stakeholders and levels of government,** and prioritize co-creation, integrating traditional and scientific knowledge and ensuring the wider representation of perspectives. Transdisciplinary collaborations should be established to promote open dialogue and collaborative planning among partners at different levels, including Indigenous Peoples, local communities, civil society organizations, local authorities, decision-makers, experts and academic scientists from different disciplines. Broad bottom-up participation and co-creation is key.
5. **Decentralize** implementation where appropriate, ensuring the entities involved in the One Health approach are as broad and local as possible. Management of actions should be at the lowest level possible to promote the engagement, ownership and accountability of local actors. Decentralization of management will support the efficiency, effectiveness and equity of interventions.
6. **Follow human rights-based approaches in all efforts:** the health of nature and the planet is intrinsically linked to human health and well-being. One Health should be grounded in human rights principles; it must not infringe on human rights, but should instead respect and promote the human rights of all, while paying particular attention to the most vulnerable or marginalized groups. This includes adopting a gender-responsive lens, calling on governments to fulfil their human rights obligations, and empowering rights-holders, including human rights defenders, to actively and meaningfully participate in decision-making. The human right to health, and the right to a healthy environment, are two internationally recognized human rights which are particularly relevant for rights-based approaches to One Health.
7. **Prioritize prevention of harm to human, animal and environmental health**, and mitigate risk accordingly, reducing the occurrence of the most common and riskiest interfaces for disease emergence and spread. Preventive plans and actions should be prioritized, including measures that reduce the human-livestock-wildlife interface and support ecosystem services for health.
8. **Integrate the latest science,** ensuring the rationale for integrating nature and health is credible and inclusive of social, environmental, medical and economic sciences relevant to the current context. Preliminary assessments and anthropological studies should be planned to guide the design and subsequent revision of interventions. This will ensure that evidence-based practices, recognized and adopted at global level, are adapted to the local context and effectively respond to the needs identified and prioritized by IPs and LCs.
9. **Support evidence-based learnings for replication and scaling** of the One Health approach in practice. Several studies have been published to underline the importance of and need for the One Health approach, but only a few reflect how the approach can be operationalized at the ground level. Small-scale actions designed for a specific landscape should be carefully monitored and documented to support their replication at wider scale and inform the development of policies and guidelines for the integration of the One Health approach in conservation programmes.
10. **Focus on gender-responsive interventions** that increase the potential for success and leave no one behind (*see Chapter on Gender equity in a One Health approach*).

THE BERLIN PRINCIPLES ON ONE HEALTH

Established in 2019, the Berlin Principles on One Health are an update of the 2004 Manhattan Principles. The Berlin Principles on One Health reintegrate ecosystem health and integrity while addressing pressing challenges to global health, including pathogen spillover, climate change and antimicrobial resistance (Gruetzmacher, 2021). The Berlin Principles may also be useful to consider when building the One Health approach into conservation programmes. Developed by the Wildlife Conservation Society in partnership with the Climate and Environmental Foreign Policy Division of the German Federal Foreign Office, the Berlin Principles:

Urge world leaders, governments, civil society, the global health and conservation communities, academia and scientific institutions, business, finance leaders, and investment holders to:

1) Recognize and take action to: retain the essential health links between humans, wildlife, domesticated animals and plants, and all nature; and ensure the conservation and protection of biodiversity, which interwoven with intact and functional ecosystems provides the critical foundational infrastructure of life, health and well-being on our planet;

2) Take action to develop strong institutions that integrate understanding of human and animal health with the health of the environment and invest in the translation of robust science-based knowledge into policy and practice;

3) Take action to combat the current climate crisis, which is creating new severe threats to human, animal and environmental health, and exacerbating existing challenges;

4) Recognize that decisions regarding land, air, sea, and freshwater use directly impact health and wellbeing of humans, animals and ecosystems and that alterations in ecosystems paired with decreased resilience generate shifts in communicable and non-communicable disease emergence, exacerbation and spread; and take action accordingly to eliminate or mitigate these impacts;

5) Devise adaptive, holistic and forward-looking approaches to the detection, prevention, monitoring, control and mitigation of emerging/resurging diseases and exacerbating communicable and non-communicable diseases, that incorporate the complex interconnections among species, ecosystems, and human society, while accounting fully for harmful economic drivers, and perverse subsidies;

6) Take action to meaningfully integrate biodiversity conservation perspectives and human health and well-being when developing solutions for communicable and non-communicable disease threats;

7) Increase cross-sectoral investment in the global human, livestock, wildlife, plant and ecosystem health infrastructure and international funding mechanisms for the protection of ecosystems, commensurate with the serious nature of emerging/ resurging and exacerbating communicable and non-communicable disease threats to life on our planet;

8) Enhance capacity for cross-sectoral and trans-disciplinary health surveillance and clear, timely information sharing to improve coordination of responses among governments and NGOs, health, academia and other institutions, industry and other stakeholders;

9) Form participatory, collaborative relationships among governments, NGOs, and Indigenous Peoples and local communities while strengthening the public sector to meet the challenges of global health and biodiversity conservation; and

10) Invest in educating and raising awareness for global citizenship and holistic planetary health approaches among children and adults in schools, communities, and universities while also influencing policy processes to increase recognition that human health ultimately depends on ecosystem integrity and a healthy planet.

Box 1.3 Source: The 2019 Berlin Principles on One Health


Women go to work in Mahila Jagaran Community Forest, a community forest run solely by women, Karnali corridor, Nepal. © James Morgan / WWF-US

A ONE HEALTH APPROACH TO CONSERVATION

RESULTS CHAIN

The interdependencies between environmental, animal and human health are complex. Developing an effective, integrated approach to addressing the underlying challenges consequently also involves a wide range of strategies and interventions. Building on a series of analyses conducted by WWF and partners, we investigated the various angles of One Health challenges, and developed a results chain of actions needed to achieve the goal of "healthy ecosystems, healthy animals and healthy people" (*Figure 2*).

This results chain coalesced around the six strategy areas of:

- Landscape immunity
- Wildlife trade
- Preventive medicine
- Pathogen early warning and monitoring
- Sustainable livestock management
- Behaviour change.

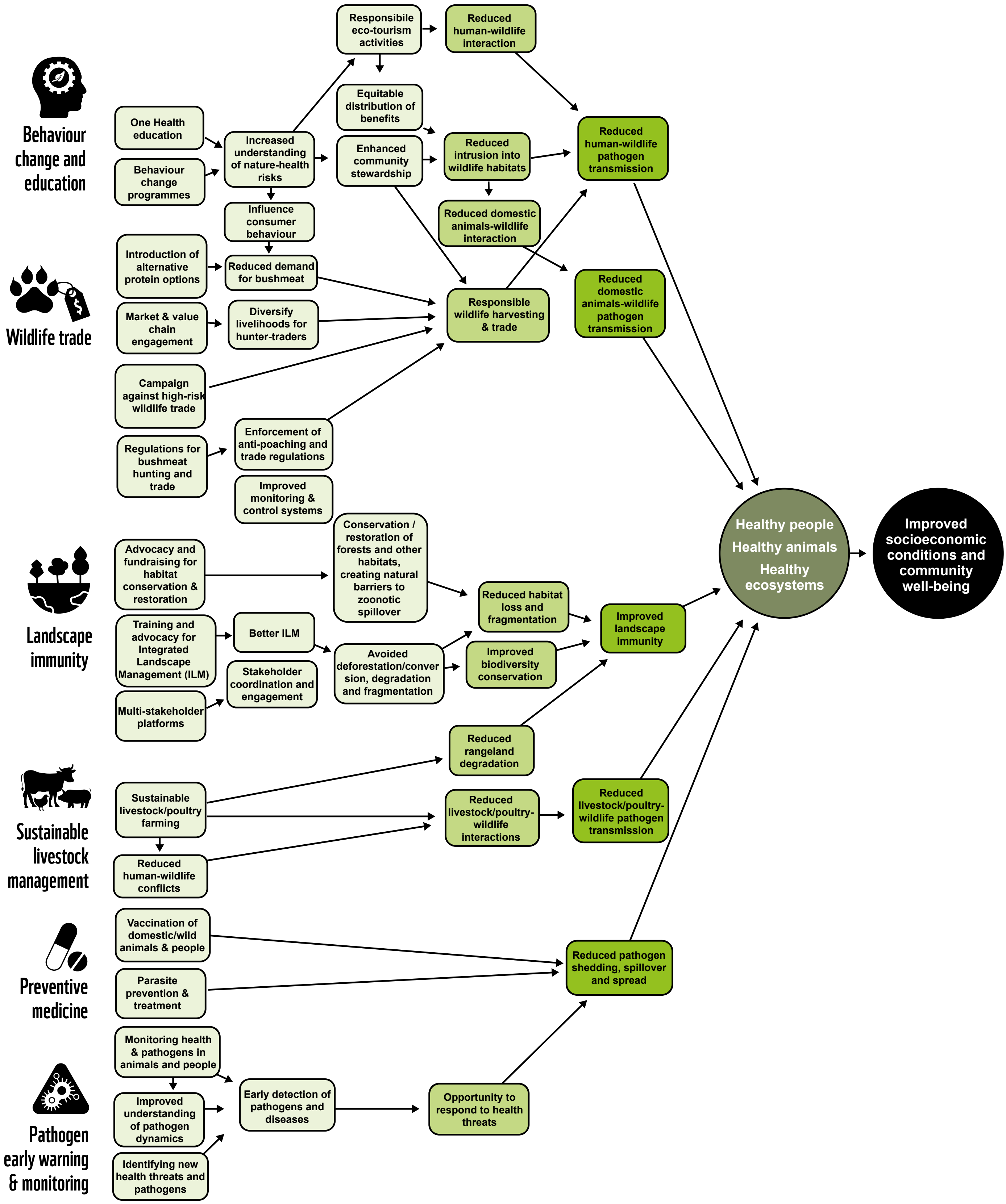


Figure 3. Results chain resulting in six strategic areas of One Health implementation in conservation.

1. LANDSCAPE IMMUNITY

Women of the Mtangawanda Mangrove Restoration Women Group planting mangroves in Lamu County, Kenya. © Kent Andreasen / WWF-Germany

WHAT IS LANDSCAPE IMMUNITY AND HOW DOES IT LINK TO ONE HEALTH?

Land use and land-use change that causes deforestation/conversion and fragmentation can force wildlife into closer proximity to humans and livestock, introduce stress that leaves wildlife more vulnerable to infection, increase the likelihood that wildlife 'shed' pathogens, and change the distribution and density of pathogens across the environment. The practice of ensuring 'landscape immunity' aims to achieve the opposite: sustainable and healthy ecosystems in which animal-pathogen-human interactions are in balance and neither wildlife nor humans are overly stressed or forced to aggregate by land use-induced changes.

While deforestation/conversion and fragmentation are widely linked to infectious disease dynamics, many land-use changes play a role, including infrastructure development (roads/rail, dams, irrigation, mining etc.), coastal zone degradation, wetland modification and the concentration or expansion of urban environments - urbanization (Table 1.1.). Beyond the more direct impacts, these changes can also drive a cascade of factors including pollution and human migration that exacerbate disease emergence and transmission.

Table 1.1. The effect of 'unhealthy' and 'healthy' landscapes on infectious disease dynamics (derived from Plowright et al., 2021).

	'UNHEALTHY' LANDSCAPE	'HEALTHY' LANDSCAPE (i.e. landscape immunity)
Infect/shed	• Wildlife populations stressed by land-use-change-driven factors (loss or fragmentation of habitat, inability to access food or water resources or move to meet needs) decline in overall health, becoming more susceptible to pathogen *infection*. • Increased stress can increase the likelihood that wildlife will *shed* pathogens, leading to the infection of other animals of the same or different species. • Highly modified and disturbed land areas can provide the ideal habitat for pathogen hosts.	• Pathogen populations are kept in balance by sufficient numbers of predators and competitors, reducing *infection*. • Wildlife, livestock and humans can access the resources they need to remain healthy and with sufficient immunity to respond to pathogen *infection*. • Healthy wildlife, with lower stress levels, *shed* fewer pathogens.
Spill/spread	• The increased shedding noted above can also increase the likelihood of transfer to humans - *spillover*. • Land-use change and development of linear and other forms of infrastructure can cause ecosystem fragmentation, i.e. where remaining areas of natural habitats are increasingly divided into smaller areas, increasing the length of the human-wildlife interface or 'edge' between human-dominated areas and natural habitats. The longer the edge, the higher the likelihood of interactions between wildlife and people, and/or wildlife and livestock, which could lead to *spillover* of infectious diseases. • Land-use change that forces wildlife, people and/or livestock to aggregate together (e.g. to access dwindling resources) increases the potential for pathogen *spread*.	• Less shedding from wildlife also reduces the likelihood of *spillove*r to humans. • The human-wildlife interface or edge is limited, meaning less interaction between wildlife and people/livestock, reducing the risk of *spillover*. • Wildlife, people and livestock have sufficient space and resources, limiting the need for aggregations and decreasing potential for pathogen *spread*.

The health of a landscape will determine the impact of the infect-shed-spill-spread cascade and the transmission of infectious disease. Both 'spillover' (from animals to humans) and 'spillback' (from humans to animals) are crucial to consider. A spillover event can lead to an emerging infectious disease in humans while a spillback can cause wildlife morbidity and mortality, with the risk being particularly great at close interfaces between humans, domestic animals and wild animals, such as habituated great apes and avian influenza in poultry.

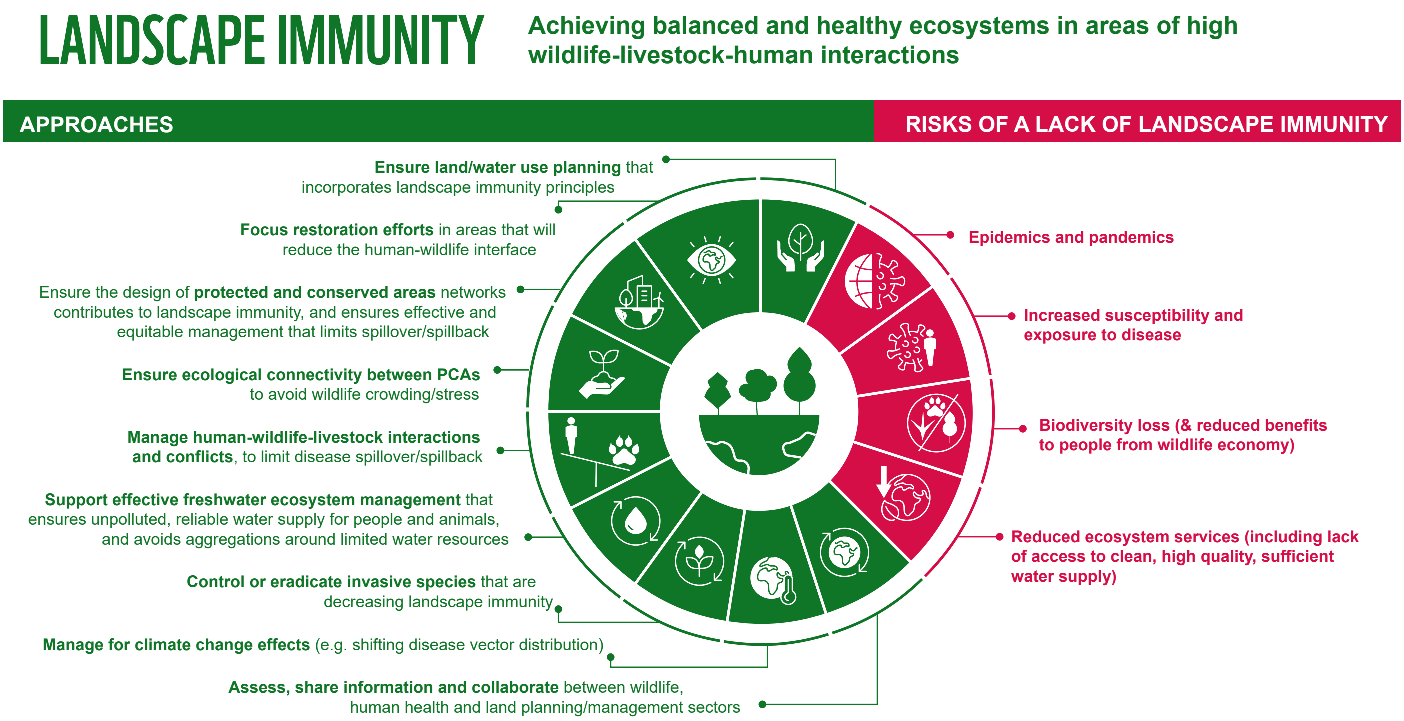
Land-use changes that impact **ecosystem services** (e.g. water quality, quantity, flow and access) can also have severe consequences for human health, as well as increasing stress levels in wildlife populations, making them more susceptible to pathogen infection and increasing likelihood of shedding. Additionally, changes or reductions in freshwater flows and resources will increase proximity between people, domestic animals and wildlife as all three congregate to access the limited water resources that remain.

Although land-use change is often thought of as large-scale ecological destruction, even more subtle changes such as ecosystem degradation and the invasion of **non-native plants** can impact human health, reduce animal fitness and modify/ impact ecosystem services, decreasing landscape immunity. The loss or decline of particular species or taxa providing important ecological roles can also impact disease dynamics; for example, the loss of vultures from an ecosystem can decrease carcass decomposition rates, increasing the number, time spent at carcass and contacts between other mammalian scavengers and thus the risk of disease transmission.

EXAMPLES OF LAND-USE CHANGE DRIVING INFECTIOUS DISEASE DYNAMICS:

- Deforestation-driven loss of winter nectar resources in Australia caused flying foxes to feed on fruit and other food in agro-urban landscapes, increasing the risk of Hendra virus spillover.
- The index cases of EVD outbreaks (i.e. first case of disease noticed by health authorities) occur mostly in hotspots of forest fragmentation. EVD has caused major die-offs of gorillas, including 5,000 in one study area over a two-year period.
- Intensification of farming in Malaysia resulted in the direct overlap of mango production and livestock rearing and produced a pathway for a virus circulating in flying foxes to infect an intensively managed commercial pig population. No human cases have occurred in Malaysia since policies were put in place regulating the minimum distance between fruit trees and pigsties.
- Poultry farms close to wetlands and on wild bird migration routes increase the potential for highly pathogenic avian influenza (HPAI) to be introduced to commercial poultry.

WHAT APPROACHES CAN WE TAKE TO SECURE LANDSCAPE IMMUNITY?



Improvements in landscape immunity can be explored via the following actions:

Land-use planning can play a crucial role in achieving landscape immunity. Land-use planning should consider infectious disease dynamics by prioritizing the reduction of fragmentation of natural habitats, reducing the extent of the human-wildlife interface. Access provided by roads, railways, pipelines and other linear infrastructure, regulations around natural resource use and access, and the spatial dynamics of food production all play a role in the degree of contact between humans/livestock and wildlife.

Effective freshwater ecosystem management: Access to clean water (for people, wildlife and domestic animals) is ultimately driven by the availability and health of freshwater resources, along with surface water and groundwater. Safeguarding water sources and environmental flows is essential to ensure human and animal access to clean and safe water supply, to avoid pressure on freshwater biodiversity and increased stress on wildlife populations (with resulting increases in infection and shedding). It also helps avoid competition for limited freshwater resources, which results in the clustering of wildlife, domestic animals and humans around the same dwindling water sources, increasing risk of spillover and spread.

Establish and effectively and equitably manage protected and conserved areas (PCAs):[1] Considering the spatial arrangement of PCAs during their establishment can help ensure PCA networks make a significant contribution to landscape immunity (e.g. new PCAs could be established to connect existing ones, reducing the human-wildlife interface). Alternatively, new PCAs could be established in areas most at risk of fragmentation, that are emerging hotspots for zoonotic spillover. However, for these benefits to be realized, PCAs need to be effectively and equitably managed, ensuring they retain a full complement of native species and their inter-relationships. The role of Indigenous Peoples and local communities as crucial stakeholders must be considered, particularly where customary rights/tenures may not be formalized. PCA management should be designed to limit risks both of pathogen spillover from wildlife to humans, and spillback from humans to wildlife through zoning and other regulations/rules. Zoning of PCAs can reduce zoonotic disease risk by reducing the likelihood of contact between wildlife hosts and people (e.g. concentrating human facilities and infrastructure away from the reserve boundaries). Measures to prevent wildlife being drawn toward people are also important. These include prohibiting wildlife feeding, making sure that human food waste is not accessible to wildlife, planting crops unattractive to wildlife closest to PCAs, and potentially fencing wildlife out of agricultural, business and dwelling areas.

Fencing of protected areas (rather than fencing human facilities) can have both pros and cons for zoonotic disease management. Some fences function as environmental stressors (e.g. when they prevent wildlife accessing resources they need to remain healthy). In other situations, they may be an effective approach to mitigating zoonotic exposure risk from large mammals and livestock (e.g. veterinary fences which keep livestock and wildlife separate from one another), but other approaches (e.g. netting, chemical and biological control) will be needed to prevent vectors not limited by fences (e.g. insects and birds). IUCN guidelines are available on the prevention, detection, response and recovery from disease risks in and around PCAs, and One Health principles for sustainable tourism in PCAs.

Ensure connectivity between PCAs: While some PCAs are large contiguous areas sufficient to maintain wildlife populations, most PCAs are smaller, meaning wildlife and ecological processes need to flow between them. When land around PCAs is converted, and/or when PCAs are fenced, intra- and inter-species competition and crowding of wildlife within PCAs can increase the potential for the emergence and transmission of pathogens. Such risks can be reduced by restoring the ecological connectivity which would allow wildlife to move to meet their resource needs, including in response to climate change. However, in some circumstances, increasing connectivity may increase potential for the spread of pathogens due to the increased mobility of hosts and vectors (e.g. the removal of veterinary fences in Southern Africa designed to keep cattle separate from wildlife will increase connectivity for wildlife populations, but will also increase the potential for disease spread between wildlife and livestock). It is crucial that connectivity conservation planning considers the full range of potential positive and negative impacts of various connectivity scenarios on the infect-shed-spill-spread cascade.

Manage human-wildlife and livestock-wildlife interactions: Design and manage holistic systems to manage conflicts between humans, livestock and wildlife, and reduce risk of spillover/spillback. The C2C: Conflict to Coexistence approach provides a framework and methodology through which a tailormade human-wildlife conflict (HWC) management strategy can be developed based on the local cultural, environmental and social context.

Manage invasive species: Invasive alien plant species may provide optimal habitat for zoonotic pathogens, hosts and vectors, and invasive animal species can act as hosts or vectors of pathogens. In addition, invasive alien species that degrade natural ecosystems can increase stress in native wildlife populations (e.g. due to resource competition), increasing potential for pathogen infection and shedding. Measures to prevent the introduction of invasive species, and to control or eradicate invasive species already established, will therefore contribute to landscape immunity. If the level of invasiveness has already passed a certain threshold, eradication is unlikely to be feasible, and only containment may be possible in order to reduce the risks of further invasion. (*See 'Additional resources' for tools on invasive species prevention and management*).

Manage for climate change: Climate-induced stressors on both animals and humans can exacerbate effects of diseases and their transmission. Climate change is already shifting the distributions of pathogen vectors such as mosquitos, and is likely to increasingly influence pathogen dynamics. Climate change can also facilitate alien plant species invasions. Climate adaptation approaches that address and mitigate climate-related changes in the infect-shed-spill-spread cascade will be essential for landscape immunity to be achieved in the long term.

1 Protected and conserved areas (PCAs) is shorthand for protected and conserved areas, including Indigenous and Community Conserved Areas and effective area-based conservation measures (OECMs)

Focus restoration efforts in areas that will increase landscape immunity: Reduce the human-wildlife interface by focusing restoration in ecological corridors, where restoration efforts most contribute to reducing fragmentation. Restoration also has the potential to reduce stress in wildlife populations, reducing susceptibility to pathogens and shedding. It is important to note that restoration may benefit some zoonotic pathogen hosts and/or vector populations by providing them with increased preferred habitat (e.g. Tsetse flies have a higher abundance in intact vs. fragmented natural habitats). Thorough consideration of potential unintended consequences should be part of pre-restoration planning.

CASE STUDY: NIPAH VIRUS AND BAT HABITAT PROTECTION

Indian flying fox, also known as greater Indian.fruit bat, Badul, (*Pteropus medius*, formerly *Pteropus giganteus*) in Pench Tiger reserve, India.
© WWF-Sweden / Ola Jennersten

In September 2023, the Indian Ministry of Health and Family Welfare reported the sixth outbreak of Nipah virus in India since 2001. Nipah virus is a zoonotic illness that is transmitted via direct contact with infected people or animals (e.g. bats and pigs) or their body fluids, or via consumption or handling of contaminated products. It was suspected that patients became ill through living or working in close proximity to bats, which resulted in eating or touching contaminated fruit or direct contact with an infected bat's saliva, urine, excrement or blood.

State and national authorities activated a multisectoral coordination and response mechanism to contain the spread of the outbreak, including enhanced surveillance and contact tracing, laboratory testing of suspected cases and high-risk contacts, hospital preparedness for case management, infection prevention and control, risk communication and community engagement.

India's national government also recognized the need to conduct careful monitoring of high-risk zones and consider ecological protection of bat habitats in areas where spillover risk is high. An analysis was conducted to compare ecological conditions from 2002-2020 with those that existed at the time of past spillovers to identify high-risk areas. A 2022 study recommended preserving the large trees that provide food and shelter for bats in Kerala's midland region and planting more native fruit trees to address the loss of bat habitat to development and quarry mining. In one village the outbreak prompted village officials to ban the removal of flying fox roosting trees on public property.

GUIDING QUESTIONS

The following table provides some indicative (but not comprehensive) guiding questions which can be asked when thinking about how to ensure landscape immunity.

	DOMESTIC ANIMALS (INCLUDING LIVESTOCK)	WILDLIFE	HUMANS	ENVIRONMENT
General	How can the human-animal-environment interface be decreased? What are the potential unintended consequences of landscape management in relation to infectious disease dynamics?			
Land-use planning	Will a proposed land-use change increase the length of the 'edge' of the wildlife-domestic animal interface, contributing to higher spillover risk?	Will a proposed land-use change increase stress in wildlife and potentially increase shedding of pathogens? Are pathogen populations in wildlife kept in balance by sufficient numbers of predators and competitors?	What are the infectious disease dynamics associated with this use of land? Will a proposed land-use change increase the length of the 'edge' of the human-wildlife-domestic animal interface, contributing to higher interactions and spillover risk?	Has ecological integrity been maintained? Are modified land areas providing a habitat for pathogen hosts? Does road/railway access contribute to habitat fragmentation/ increased access?
Freshwater ecosystem management	Do livestock have access to sufficient, high-quality water supply?	Do wildlife have access to sufficient, high-quality water supply? What is the status of freshwater biodiversity?	Do humans have access to sufficient, high-quality water supply? What is the relationship between upstream and downstream water users?	Are flows of water clean and reliable? What are the seasonal patterns? What are the most crucial water source areas (e.g. water towers) and are they safeguarded?
Design and management of PCAs, ensuring their connectivity, and managing human-wildlife-livestock interactions	Can livestock access appropriate areas required for nutrition and health? Can livestock-wildlife conflicts be more effectively managed with holistic approaches? Are fences an effective barrier to disease between wildlife and livestock?	Are wild animals being forced to aggregate, either with each other and/or with livestock/humans? What is driving that and how can it be rectified?	How can human-wildlife contact be reduced or risks of contact minimized (e.g. mask wearing and distancing regulations for wildlife viewing activities)? Can communities access the resources they need to remain healthy and with sufficient immunity to respond to pathogen infection? What is the role of Indigenous Peoples and local communities in management of landscapes? Can HWC be more effectively managed with holistic approaches?	How can the PCA network be modified to reduce fragmentation/ decrease the human-wildlife interface?

	DOMESTIC ANIMALS (INCLUDING LIVESTOCK)	WILDLIFE	HUMANS	ENVIRONMENT
Ecological restoration	Where could restoration efforts be focused to have maximum impact on reducing the wildlife-domestic animal-human interface? What kind of restoration is likely to increase resource availability for domestic animals and humans?	Where does restoration have the greatest potential to reduce wildlife stress (and thus pathogen infection and shedding)? Do wild animals require improved access to food, water resources or movement to meet needs, and can these needs be met with restoration?	Do humans have sufficient space and access to resources, limiting the need for aggregations and decreasing potential for pathogen spread? If not, can restoration fill this gap?	Where will restoration efforts most contribute to reducing fragmentation? Will restoration benefit zoonotic pathogen hosts and/ or vector populations by providing them with increased preferred habitat?

A FOCUS ON WETLANDS


Setiu Wetland is one of WWF-Malaysia's project sites in West Malaysia. © WWF-Malaysia / Mazidi Abd Ghani

Integrated landscape management often focuses on forests and grasslands, with freshwater systems such as wetlands often not getting the priority they deserve. However, wetlands are crucially important, particularly from a One Health perspective. Humans, plants and wildlife need water for survival, but degraded wetlands can be sources of disease outbreaks. Too much water (e.g. extreme flooding) causes the conditions that can potentially result in outbreaks of water- and vector-borne diseases and loss of wetlands can concentrate wildlife, livestock and people, increasing spillover risk. The following subsection provides a deeper dive into the issues of wetlands and One Health, within the broader strategy of landscape immunity.

Why is wetland management important for landscape immunity?

Wetlands provide essential ecosystem goods and services for human well-being, health and survival, inclusive economic growth, and climate mitigation and adaptation. As people desperately seek relief from extreme climatic events, including too much or too little water for survival, there could be mass migrations within and between national boundaries, which could eventually lead to regional and national instability. Coastal wetlands protect shorelines and immediate inshore infrastructure and communities from storms, storm surges and extreme tides. Wetlands help to make cities and settlements safe and resilient from floods and droughts, and are important natural carbon stores that contribute to climate mitigation.

Unfortunately, wetlands and the services they provide are grossly undervalued, which encourages unchecked conversion to other land uses. Estimates suggest that over 70% of the world's wetlands may have been converted, but conservation remains a low priority, despite their importance. Most drivers of wetland degradation and conversion are anthropogenic, and include conversion to agriculture and aquaculture; alteration of hydrologic regimes in the upper watersheds by dam-building, water extraction and diversion; inundation to create artificial ponds and reservoirs; invasion by exotic species; siltation and erosion due to deforestation, sand mining reclamation and land-use change; accumulative water demand; and global climate change. Most major rivers are now dammed, with more planned, and the water is diverted or stored, altering instream environmental flows that prevent adequate recharge of wetlands in the lower reaches.

Polluted and degraded wetlands affect the well-being, health, survival and socioeconomic security of human communities; especially the local communities who remain largely dependent on the natural resources and ecosystem services provided by the wetlands, including water, fisheries, non-timber natural products and recreation. Wetlands also support important ecosystem services that benefit society at regional and even global scales, including carbon sequestration, flood control, groundwater recharge, nutrient removal, toxin retention and scrubbing; for example, the extensive tidal wetlands in the Yellow Sea that are critically important habitats for migratory water birds also provide ecosystem services worth an estimated US$30 billion annually by buffering one of the most densely populated coastal areas in the world from storms and sea-level rise.

Wetlands and migratory birds: conserving a natural phenomenon

Wetlands are also important for the millions of birds that undertake arduous transcontinental journeys along the long-distance migratory routes, the flyways, from their northern nesting grounds to overwintering grounds in the south during the winter, and back during the spring. Along the way, many species use staging areas to stop to rest and refuel before flying on. For hundreds of species of waterbirds that use the flyways, these nesting grounds, overwintering habitats and staging areas are usually wetlands, from rivers and streams, to lakes, ponds, marshes, swamps, mangroves and coastal tidal flats. The flyways can be considered 'avian landscapes' of transcontinental scale, and the staging areas are stepping-stone corridors that provide ecological connectivity for migrant birds.

But the ecological functionality of the flyways is in great and imminent danger. The stopover habitats that migrating birds use are being drained and filled for urban, industrial and agricultural uses (e.g. over 80% of East and Southeast Asia's wetlands are now classified as threatened and nearly half of all intertidal mudflats have been lost). Without these refuelling sites, the migrating birds will be unable to reach their eventual destinations.

This is particularly relevant for One Health as migratory waterbirds (e.g. cranes and seabirds) are known to be reservoirs of various strains of avian influenza due to their aggregating behaviour, and can be long-distance carriers, including after becoming infected from reservoirs of domestic poultry. At the same time, migratory birds are also victims. Conversion of natural wetlands drives birds to congregate in the few remaining suitable habitats, which increases risk of avian influenza outbreaks, further impacting populations of globally threatened species (e.g. white-naped cranes and hooded cranes, both classified as vulnerable, died of HPAI in Izumi, Japan). Additionally, the use of wetland resources by people places additional physiological stress on migrating birds that usually arrive at wetlands already debilitated, making them even weaker and susceptible to disease, and increasing shedding of pathogens that could cause outbreaks with spillover potential.

The impacts of wetland conversion and degradation are already being manifested. The East Asian-Australasian Flyway has seen a significant decline in waterbirds. Bird populations along the Central Asian Flyway are also declining at a rapid rate. In fact, over 60% of waterbird populations in Asia are now showing signs of decline or have become extirpated in just the past two decades.

Wetlands, water quality improvement and aquatic biodiversity conservation

Pollution impacts on freshwater biodiversity can be profound and can reflect direct toxicity or disruption to ecosystem processes. Pollutants significantly impact human and wildlife populations and contribute to the extinction of wetland species (e.g. microplastics have been found to make amphibian larvae more susceptible to the fungus that causes chytridiomycosis disease).

Policy and management options include improved wastewater treatment or reuse, regulation of polluting industries, market instruments that reflect downstream pollution costs, improved agricultural practices, and nature-based solutions (NbS) such as floodplain wetland restoration or riparian buffer zones. Globally, 80% of sewage enters surface waters without adequate treatment and in Latin America, Africa and Asia, approximately 15% of river lengths are severely polluted organically which can contribute to the spread of infectious disease. Improved wastewater treatment, water quality monitoring and better farm management in combination with market mechanisms should therefore be a priority for many countries.

Wetlands and climate change

Climate change will cause degradation and shifts in wetlands across landscapes. Changes in rainfall patterns, frequency of intense precipitation events, prolonged droughts, extraction and storage of water for anthropogenic uses and conversion of natural wetlands into reservoirs, fishponds and other artificial wetlands, changes to landforms and land use in the supporting watersheds all contribute to these changes. Climate change will also compel people to move, and even migrate across large areas as they search for suitable places to settle. These areas will usually be adjacent to or with ready access to water and wetlands, because water is vital for human survival. The range of ecosystem services wetlands provide are important for water and food security, and also determine health, livelihoods, and economic benefits for the well-being of human communities.

These dynamics are bound to result in greater contact between migratory waterbirds and people, their poultry and other livestock that will also rely on wetlands and wetland resources, increasing the risks of disease spillover, especially of avian influenza. Since October 2021, a strain of H5N1 has caused about 3,000 outbreaks in poultry in several countries, and over 77 million birds have been culled to stop the spread. Over 400,000 fatalities in wild birds have also been documented in over 2,600 outbreaks, which is more than the total outbreaks in 2016-2017. Researchers say that the virus seems to be spreading in wild birds more easily than ever before, making outbreaks particularly hard to contain. Wild birds help to transport the virus around the world, with their migration patterns determining when and where it will spread next. The wide range of wild birds affected by H5N1 includes wildfowl, waders, gulls, cranes, grebes, herons, pelicans, gamebirds, corvids and raptors (diurnal and nocturnal). Cases have also been detected in mammals such as red foxes, Eurasian otters, harbour seals, grey seals, tigers, leopards, mountain lions and grizzly bears, indicating the potential for spread among wide taxonomic groups, including top predators, across disparate geographic regions that can have severe ecological impacts.

In addition to the health and ecological concerns, these outbreaks can have significant economic and livelihood-related consequences. In 2020 and 2021, an outbreak of avian influenza subtype H5N8 occurred at poultry farms and among wild bird populations in several countries, from Europe to South Asia and East Asia, leading to the subsequent culling of millions of birds to prevent a pandemic similar to the H5N1 outbreak in 2008.

Infected birds are found at sites that include wetlands of international importance and other protected wetlands, and the scales of mortality can pose threats to population survival. Authorities responsible for monitoring animal health should apply a One Health approach to controlling avian influenza by recognizing the connections between the health of humans, domestic and wild animals, plants and the wider environment. This should include coordinated actions through a holistic approach, including intensifying monitoring and biosecurity measures to reduce spillover risk between poultry and wild birds, avoiding use of disinfectants in wetlands since they could affect ecosystem and community health, city planning on drainage design, and adherence to international obligations to ensure that the responses do not include lethal actions against wild birds.

Strengthening wetland conservation for One Health through integrated landscape management

The following considerations can inform actions to bring wetland conservation into integrated landscape management for One Health:

- The basis of wetland conservation is protection and restoration. This includes ensuring the presence of corridors/areas for wildlife and people who depend on the wetland, reconnecting floodplains and protecting headwaters.
- Regular monitoring of wetland ecosystem services and biodiversity is essential to ensure wetland health. Assessment tools should follow international guidelines and standards such as those of the Ramsar Convention (example) and IUCN (example) or national guidelines.
- To protect waterbird-rich areas, poultry farms should not be located nearby. Where there are already poultry farms in close proximity, poultry should be vaccinated against HPAI and a reduction of farm size and density is recommended.
- Because wetlands will be affected by climate change, climate impact analyses should be conducted to develop adaptation plans for managing the wetlands and configuring corridors in the landscape, based on probabilities of change.
- Clusters or networks of wetlands should be identified to ensure a functional stepping stone corridor system along flyways to allow birds to continue their migrations. These wetlands should be given international recognition through Ramsar, using a wetland network paradigm, rather than as individual sites, as a proactive and pre-emptive planning strategy.
- The values of wetland biodiversity, and ecosystem goods and services, largely depend on where they are found in the landscape and their ecological connectivity as clusters or networks. Wetlands perform multiple functions at various scales, so valuations should be conducted through a hierarchy of scales, from the wetland as a site, to the value of a wetland network and contribution to the landscape and biosphere.
- Fully engaging IPs and LCs in wetland management is crucial. Businesses can also play a role through innovative approaches which include ensuring corporates that are dependent on wetland resources, especially water, pay for the ecosystem services they receive; developing business models based on the 'Bankable Nature Solutions' paradigm; and investing in conservation outcomes that can support global conservation targets and corporate ESG targets.
- NbS offer opportunities for collaboration between IPs and LCs, public and private sector. For instance in the Mara Triangle in Kenya, tourist hotels are collaborating with conservation organizations to construct wetlands to manage wastewater and other effluent to reduce pollution and impacts on people and wildlife.
- Policies that relate to wetland management should include steps to minimize contact between wild birds and bats, and humans, poultry and domestic livestock. This may necessitate climate change-integrated zoning plans and working with IPs and LCs on husbandry practices.
- A well coordinated and communicated capacity-building and monitoring programme, including along the flyways (which should be treated as a landscape), can help to detect potential disease outbreaks early and prevent epidemics and pandemics. Existing partnerships, such as the East Asian-Australasian Flyway Partnership can be leveraged for this, or similar ones built.
- Predictive models should be developed to identify potential viral hotspots to stop the spread of avian influenza by migratory birds.

Kuching Wetland National Park, located near to the capital city of Sarawak, Malaysia. © WWF-Malaysia / Mazidi Abd Ghani

2. WILDLIFE TRADE

A channel-billed toucan (*Ramphastos vitellinus)* and a squirrel monkey (*Saimirisciureus*) tied to a cage at Belsen market in Iquitos, Peru. © Brent Stirton / Getty Images / WWF

WHAT ARE THE LINKS BETWEEN WILDLIFE TRADE AND ONE HEALTH?

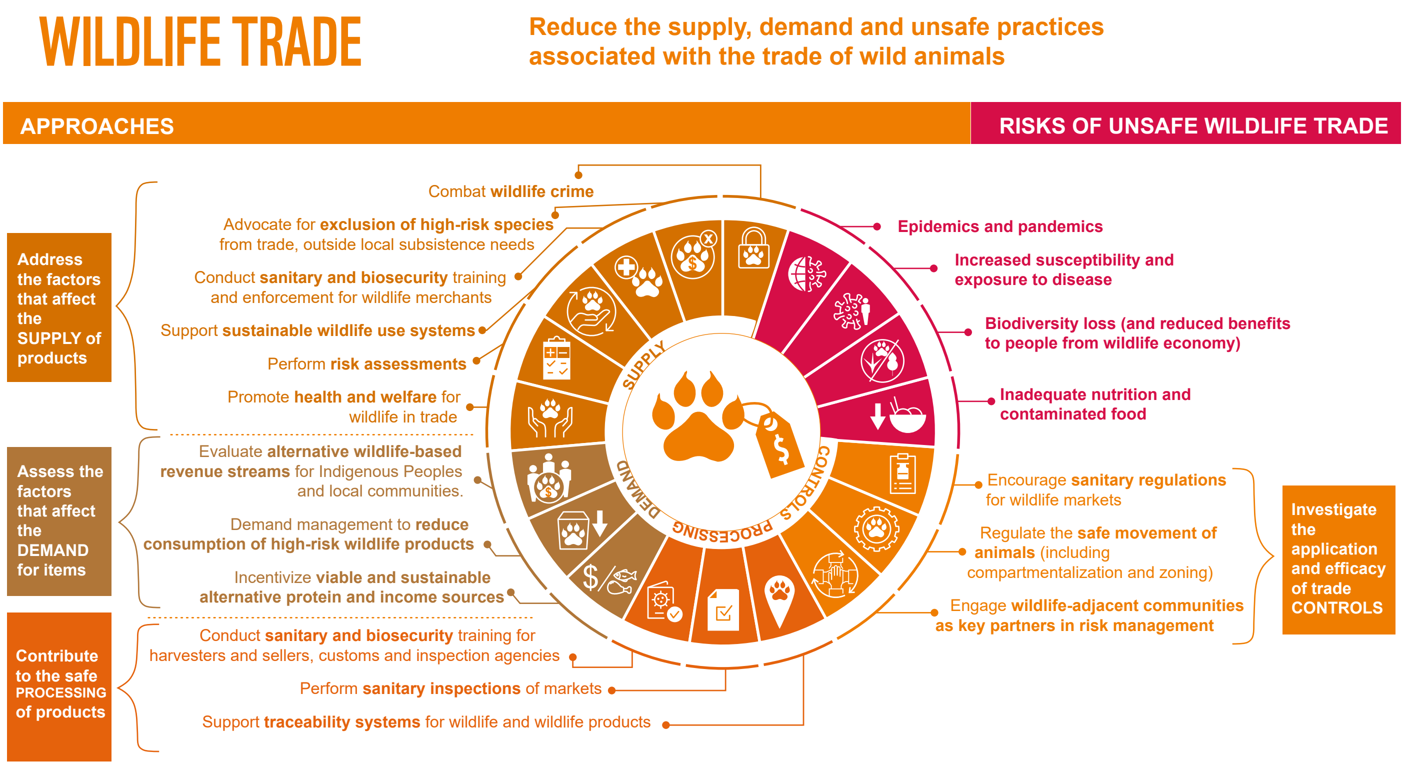
Tens of millions of wild animals and their parts are traded each year, nationally, regionally and across the world for food, the pet trade, biomedical research, use in traditional medicine or other purposes, such as cultural and recreational uses. The trade and farming of wild-sourced animals contributes in many countries to increased food security (e.g. wild meat) and income generation; however, the demand for wildlife poses a threat to the persistence of viable wild populations targeted for trade, and potentially to human health.

Wildlife trade increases the risk of the spread of vector-borne diseases and spillover of zoonotic diseases through intensified human-animal contact created during farming, hunting, butchering, storage, transport, and at markets and restaurants or when interacting with domesticated or wild animals. The trade involves an estimated one-quarter of all mammal species, including high percentages of bats, rodents and primates which are known to host a high diversity of zoonoses. The level of risk of infectious disease through pathogen spillover/spillback depends on pathogen prevalence along the trade chain which is affected by taxa, types of trade (i.e. live or as partly processed products), trade magnitude and any mixing of taxa, sanitation and human behaviours at various interfaces including farms, transport, markets, slaughtering and end-use.

Wildlife trade - legal or illegal - can contribute to the removal of threatened and at-risk species and can increase the risk of local and global extinction. The trade in wildlife depletes and disrupts natural ecosystems through the removal of wild species that perform important ecosystem functions. The demand for larger or more robust specimens often removes the fittest individuals from the breeding population and can further reduce the resilience and health of subsequent generations. Environmentally destructive practices employed to remove wildlife can also contaminate and damage habitats, further compromising human and animal health (e.g. cyanide and dynamite fishing practices which destroy coral reefs). Land conversion for agribusiness can also remove wildlife through direct exploitation and commercial trade as new routes and areas are opened up.

Wildlife trade has far-reaching implications beyond the scope of this chapter. A comprehensive approach should include poverty eradication, food security measures, demand reduction and the integration of One Health principles as a vital element of sustainable development.

WHAT APPROACHES CAN WE TAKE TO WILDLIFE TRADE FROM A ONE HEALTH PERSPECTIVE?



A starting point for using the One Health concept to develop work on wildlife trade is to conduct a risk analysis that considers animal welfare, health, conservation and socioeconomic values, then identify proportionate risk-management or risk-reduction measures.

WOAH has compiled an overview of the main approaches to manage the risk of disease emergence in wildlife trade. These approaches are depicted in slightly adapted form below (Table 2.1), with additional guidance and examples provided.

One of 16 tigers cubs seized from smugglers. A veterinary team from the wildlife forensic unit takes blood samples to trace the DNA. Chaiyaphum, Thailand.

Table 2.1 Approaches to reduce the health risks from the supply, demand and unsafe practices associated with the trade of wild animals

AREAS OF POTENTIAL RISK AND INTERVENTION	APPROACHES	GUIDANCE AND TOOLS FOR THE APPROACH	EXAMPLES
Supply: Factors affecting the entry of products into the market	Responding to illegal trade of wildlife through supporting crime prevention, community engagement and enforcement	UNODC Wildlife and Forest Crime Toolkit UNODC SAFE Project Spatial monitoring and reporting tool (SMART) ASEAN Handbook on Legal Cooperation to Combat Wildlife Crime Tackling Tiger Trafficking Framework - provides best practice and case studies addressing trafficking of tigers and other species Problem-oriented wildlife protection and 55 steps to addressing wildlife crime problems WWF Zero Poaching Toolkit	Nepal's application of the Zero Poaching Toolkit to achieve multiple years of zero poaching of rhino and tiger Restorative justice to understand why the crime has taken place and provide an avenue to address this. Focus on victims and the community: applying restorative justice principles to wildlife crime offences in South Africa Community-driven solutions to manta ray hunting in Indonesia (problem-oriented approach) Conservation healthcare exchange to prevent illegal logging (problem-oriented approach)
	Advocacy for banning the trade of wildlife for food and medicines outside of local subsistence needs		WWF Ivory Initiative
	Advocacy for exclusion of high-risk species from wildlife trade	Frameworks for assessing high-risk species: • WWF global risk framework • Asia-Pacific framework • IUCN/WOAH Guidelines for Wildlife Disease Risk Analysis	
	Sanitary and biosecurity training and enforcement for wildlife market merchants and along the supply chain	FAO's Joint Risk Assessment Operational Tool	Options for managing and tracing wild animal trade chains to reduce zoonotic disease risk (TRAFFIC)
	Sustainable wildlife use systems	Sustainable Wildlife Management programme guidance Global review of wild meat trade with recommendations and proposed approaches Decision-making system that embraces ecological, social and economic realms of the bushmeat trade (in French)	CBD Congo bushmeat programme The collaborative partnership on sustainable wildlife management (CPW)
	Risk assessment methods adapted to the wildlife trade, including the use of hazard analysis and critical control point and decision analysis methods	Frameworks for assessing high-risk species: • WWF global risk framework • Asia-Pacific framework • TRAFFIC Review: Options for Managing and Tracing Wild Animal Trade Chains to Reduce Zoonotic Risk	Case study from the Laos application of the Asia-Pacific framework in this paper
	Promoting health and care for animals involved in wildlife trade to ensure highest animal welfare standards (including transport) through education and improved regulation		Extending food safety systems to the wildlife trade (kangaroos)

AREAS OF POTENTIAL RISK AND INTERVENTION	APPROACHES	GUIDANCE AND TOOLS FOR THE APPROACH	EXAMPLES
Demand: Factors affecting the demand for items in the market	Supporting alternative wildlife-based revenue streams for local communities	Livelihood alternatives for the unsustainable use of bushmeat Wildlife economy reports Nature Pays Hub: Guidance to accelerate market access for community enterprises to promote livelihoods and conservation	The CarBi project in the Central Annamites in Laos promotes village development funds in priority villages
	Demand management to reduce consumption of high-risk wildlife products	(See *Chapter 6: Behaviour change*) Frameworks for assessing high-risk species: • WWF global risk framework • Asia-Pacific framework • TRAFFIC Five-Dimensional Sustainability Assessment Framework (5DSAF). The '5D' tool adds animal welfare and human health to the conventional ecological, economic and social aspects	Laos, Viet Nam, Cambodia bushmeat demand reduction behavioural change programme WWF-South Africa's SASSI programme to encourage consumers to make sustainable and informed seafood choices
	Supporting and incentivizing viable and sustainable food supplies to reduce reliance on wildlife as protein and income sources	WWF Positive food production practices	
Process: Actions taken by suppliers affecting the added value of products	Sanitary and biosecurity training for harvesters and sellers, customs and inspection agencies	WOAH publications on biosecurity issues and safe transport of animals Biosecurity training for farmers and vets	
	Sanitary inspections of markets	A guide to healthy food markets	Application of a healthy food markets guide in Indonesia
	Traceability systems for wildlife and wildlife products	TRAFFIC report on options for managing and tracing wild animal trade chains to reduce zoonotic risk	TRAZAPP in Peru for traceability of fisheries
Controls: Rules and procedures that govern activities in the supply chain	Sanitary regulations for wildlife markets	A guide to healthy food markets	Application of a healthy food markets guide in Indonesia
	Facilitating safe international movement of animals including compartmentalization and zoning	Safe transport of animals WOAH zoning standards ASEAN Strategy for Preventing Transmission of Zoonotic Diseases from Wildlife Trade WOAH Standards: Codes and Manuals	African swine fever zoning
	Engaging rural communities that neighbour or live with wildlife as key partners in risk management	Sustainable Wildlife Management programme guidance	iNaturalist tool to harness citizen science to monitor wildlife markets
Environment	Enhanced capacity for wildlife disease surveillance, investigation, response and reporting	WOAH Guidelines for Addressing Disease Risks in Wildlife Trade	Wildlife Health Surveillance Network in Southeast Asia
	Management of the livestock-wildlife interface		Regenerative cattle ranching in Peru with a One Health approach

CASE STUDY: DEVELOPMENT OF A REGIONAL TOOL TO ASSESS RISK IN WILDLIFE MARKETS

Macaques (Macaca sp.) for sale on an Indonesian market. © Traffic SE Asia / Chris R. Shepherd

In Asia-Pacific, WWF developed a rapid assessment tool for stakeholders and government authorities in the public health and wildlife sectors to assess wildlife trade situations for risks of potentially serious zoonoses. The tool provides a snapshot of a trade situation that can be used to inform policies to regulate and control the trade, or to take action at specific locations of particularly high risk to public health.

The tool is based on available knowledge of wildlife taxa traded in the Asia-Pacific region known to carry highly virulent and transmissible viruses, combined with a qualitative assessment of relative risks associated with broad categories of market types and trade chains. When using the tool, the numbers of wild animals for sale in a specific market are estimated. These numbers are converted into qualitative threat categories. Information on traded taxa and numbers of animals of each taxon can be derived from snapshot surveys and estimates from several site visits. The risk situation is assessed using three variables: transmission risk, spread potential and zoonotic virus risk. These variables classify risks of potential zoonoses based on market size, crowding of wildlife, hygiene conditions, number and turnover of people through the market, distances buyers may travel after visiting a market, and points along trade chains that could allow viruses to accumulate and amplify the potential for zoonoses. Taxon and market risk assessments are combined in a risk matrix that provides an assessment of disease risk associated with specific wildlife markets. Risk levels for a given location may vary over time as different combinations and numbers of taxa are traded and the tool can be used to monitor these changes.

GUIDING QUESTIONS

The following table provides some indicative (but not comprehensive) guiding questions which can be asked when planning wildlife trade interventions related to One Health.

	DOMESTIC ANIMALS (INCLUDING LIVESTOCK)	WILDLIFE	HUMANS	ENVIRONMENT
General	Are up-to-date assessments of wildlife trade procedures in place and how often are they reviewed? Do regulatory authorities/officers responsible for checking and inspecting products and facilities used in processing, handling and transportation of wildlife and wildlife products receive adequate training and guidance? Is this training in line with technological advancements in wildlife trade? Could technology be used to reduce the human-animal-environment interface?			
Supply: Factors affecting the entry of products into the market	What wildlife management and biosecurity measures can reduce the risks of pathogen spillover from wildlife trade?	How big is the wildlife trade problem? Can you quantify it? What role does gender play in the trade? In a given context, are wildlife trade restrictions capable of delivering benefits to both wildlife and people?	Ethically, should law enforcement be a preferred course of action relative to community engagement, behaviour change and other preventative measures? What role is there specifically for women in enforcement or community outreach? How are legal and illegal trades associated with disease risk, and can sustainable wildlife production systems reduce the risks?	What wildlife management and biosecurity measures can reduce the risks of pathogen spillover? Can habitat preservation and other NbS affect the wildlife trade?
Demand: Factors affecting the demand for items in the market	Has increased livestock demand outweighed supply and resulted in increased wildlife trade? Has domestic pet ownership increased, leading to increased contact with wildlife? Is gender a factor influencing demand?	Is there an increasing trend in wildlife trade? What is the sustainability of offtake for threatened species? Has increased extinction risk resulted in some species becoming more highly valued?	What influences the effectiveness of communications campaigns and behaviour change strategies and how can this be measured? How can lasting behaviour change be measured beyond intentions or self-reporting? How can local cultures, practices and traditions related to wildlife trade be respected while also protecting wildlife and reducing zoonosis risks?	Which factors influence whether synthetic or alternative products can effectively replace or substitute wildlife products? Are the alternatives ethically appropriate and sustainable?

	DOMESTIC ANIMALS (INCLUDING LIVESTOCK)	WILDLIFE	HUMANS	ENVIRONMENT
Process: Actions taken by suppliers affecting the added value of products	How are domestic animals affected by disease transmission from wildlife trade?	How can technology or other developments support traceability and contribute to reduced zoonosis risks from traded wildlife?	How can corruption or lack of capacities be addressed to avoid problems in the detection, traceability, management and use of wildlife? What financial (or other) incentives/costs can encourage sustainable wildlife use systems and discourage illegal and risky ones?	Which environmental processes influence risk from zoonosis?
Controls: Rules and procedures that govern activities in the supply chain	Which measures can be taken to monitor and respond to the emergence of disease at the interface between domesticated animals and wildlife?	How can protocols and treaties be better implemented to regulate and control the trade in wildlife? Are there any loopholes to address when implementing controls/regulations on wildlife trade? Is corruption an issue in the control of wildlife trade? If so, how can it be addressed?	How can local customs be incorporated into wildlife trade controls by engaging local communities? Can the community be engaged to support rules/ regulations?	Who governs the landscape and source population ecosystem (Indigenous Peoples, government, stewards)? How can ecosystems be better protected through strengthened rules and procedures?

Rescued pangolin released into the wild by Wildlife Reserves Singapore. © K. Krishnasamy / TRAFFIC

3. PREVENTIVE MEDICINE

Vaccine-laden pellets in Montana, United States. © Conservation Media / WWF-US

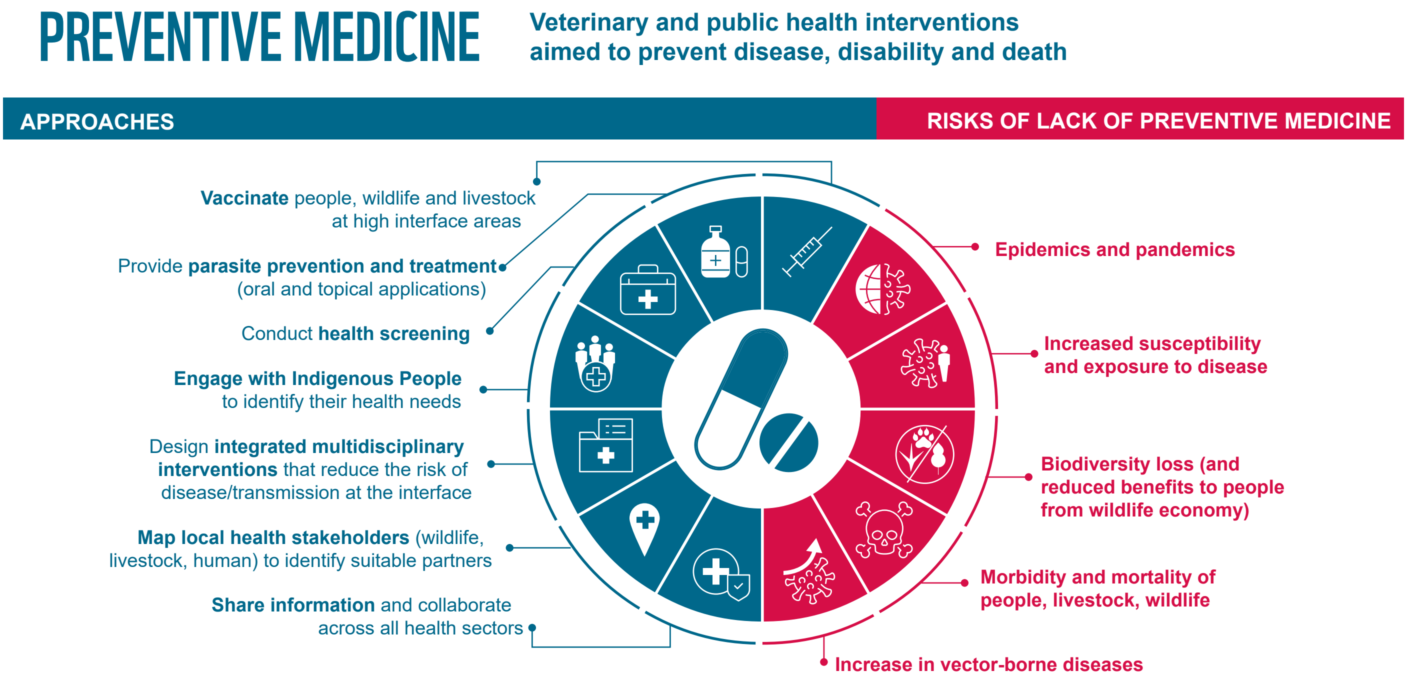
WHAT ARE THE LINKS BETWEEN PREVENTIVE MEDICINE AND ONE HEALTH?

Preventive medicine is the practice of promoting veterinary and medical activities that support the health and well-being of an individual or population with the aim to prevent disease, disability and death. This includes prophylaxis, early detection efforts (e.g. screenings) as well as strategies for appropriate management of existing diseases and related complications.

Management of global health risks requires multisectoral, collaborative partnerships across the animal, human and environmental health sectors. A risk assessment of socioeconomic, environmental and ecological factors can provide a basis for identifying areas where infectious disease risks are most likely to occur, and where preventive medicine interventions can be targeted by key health stakeholders.

Preventive medicine plans and actions should be prioritized, and work alongside measures that reduce the human-animal-environmental interface and support ecosystem services for health (*see Chapter 1: Landscape immunity*). This will aid in decreasing emerging/resurging, communicable and non-communicable diseases that occur at this interface. These interventions can improve health and well-being, reduce disease emergence/spread, reduce the risk of species extinction and reduce the cost of outbreak mitigation. A targeted transdisciplinary approach that incorporates the complex interconnections that exist among humans, animals (domestic and wildlife) and ecosystems is required for this work to be effective.

HOW CAN WE APPLY PREVENTIVE MEDICINE IN A ONE HEALTH APPROACH?



Key areas of intervention include:

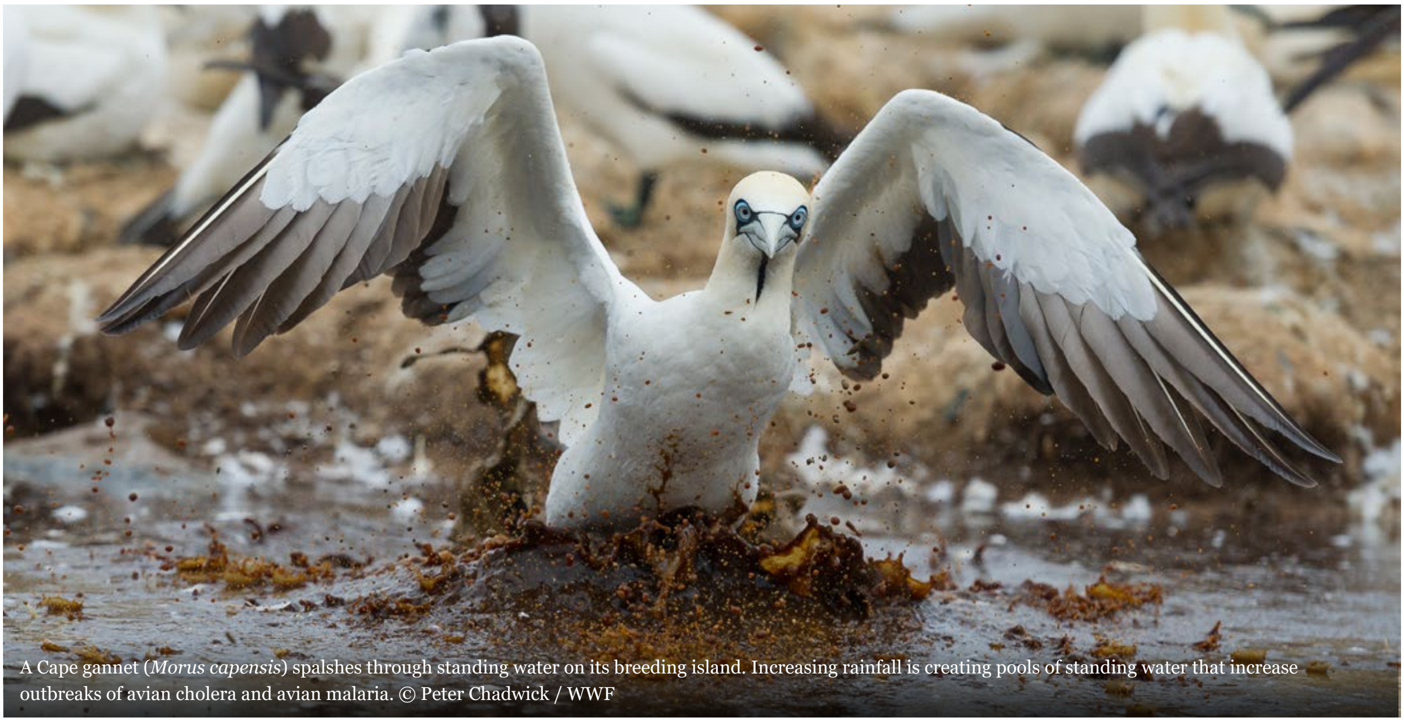
Vaccination can protect both humans and animals from disease before they become ill, minimize their suffering, and create more resilient populations. Wildlife vaccination has potential to reduce disease-induced extinction and zoonotic spillover events (e.g. oral rabies vaccination in wildlife). However, administering vaccines to wildlife brings practical, epidemiological, ecological and evolutionary challenges. Overall, vaccination protocols should always consider appropriate epidemiological (and mechanistic) modelling tools, and use methods to assess vaccine safety in the community and ecosystem.

Parasite prevention and control is often overlooked in favour of addressing bacteria, viruses or prions which represent the majority of the 75% of emerging infectious diseases which are zoonotic. Although parasites (helminths and protozoa) represent only around 13%, they are important in terms of One Health as an approach to disease mitigation and control (e.g. Chagas disease increases susceptibility to MERS-CoV). For animals, parasites can be an important part of their 'biological package', and loss of genetic diversity, environmental pollution, habitat loss, climate change, contact with domestic livestock, and invasive species can increase the impact of parasites on populations. The translocation or movement of animals also accelerates/amplifies dispersal of pathogens and the associated stress can increase their susceptibility to disease and make latent agents of disease pathogenic. Models that guide an understanding of the host-pathogen interaction can aid in determining if a particular release site poses a high level of risk, and whether specific release strategies or preventive medication could be applied. An ecosystem-centred conservation strategy (rather than species-centred) also includes methods for the assessment and conservation of threatened parasites that are integral to the functioning and survival of global ecosystems.

Health screening is one of the most important healthcare strategies to prevent transmission, facilitate early diagnosis and treatment, improve quality of life and prevent premature death. It should provide information on both the benefits and harms associated with preventive health screening strategies and knowledge translation tools to support shared decision-making. Wildlife health assessments can vary broadly according to context, and can be built into wildlife population monitoring. Common assessment methods for wildlife are blood analysis, body composition assessment, physical examination, and fecal analysis (mainly used to detect enteric parasites but also for endocrinological analysis, e.g. cortisol levels.) (*See Chapter 4: Early pathogen warning and monitoring* for more information).

Risk-based approaches are valuable to identify the most rewarding areas for intervention, especially when data and/or resources are scarce. Risk assessments (*see Additional resources on Disease risk analysis*) can be used to establish surveillance and monitoring plans or to rank the relative importance of many hazards/pathogens present. All zoonotic diseases have a reservoir host species, and it is often most effective to prevent disease in other species by controlling it in the preferred host - e.g. control/elimination of brucellosis in livestock populations is the most effective way to prevent infection with brucellosis in humans and some wildlife species (*see Chapter 1: Landscape Immunity for further information on spillover/spillback*). In other cases, wildlife species may be the reservoir host, and prevention of disease in domestic animals or humans depends on reducing the disease burden in wildlife and/or minimizing interactions with those wild species.

Preventive medicine is crucial for humans and livestock; while it is used less commonly for wildlife, conservation should be conducted with the understanding that health in all sectors is interconnected. Building partnerships with the human and veterinary health sectors to focus on human and livestock preventive medicine is crucial for a holistic One Health approach. In addition, conservation risk mitigation strategies should consider how rangers or field operatives are exposed to pathogens and infection and include appropriate preventive measures, guided by veterinary and public health practitioners.



A Cape gannet (*Morus capensis*) spalshes through standing water on its breeding island. Increasing rainfall is creating pools of standing water that increase outbreaks of avian cholera and avian malaria. © Peter Chadwick / WWF

CASE STUDY 1: KOALA CHLAMYDIA VACCINATION PROGRAMME TO REVERSE POPULATION DECLINES

Chlamydia ("Chlamydiosis") is the most common and well-known disease of wild koalas. It is estimated to be found in up to 48% of the population and in some parts of Australia, koala infection rates are as high as 90%. The disease is exacerbated by the stress that koalas feel from ongoing deforestation, drought and the recent bushfires. It is one of the key threatening processes contributing to koalas being listed as vulnerable in Queensland, New South Wales, and the Australian Capital territory. Clinical disease causes keratoconjunctivitis, urinary tract infection, and/or reproductive tract infection. Chlamydiosis has the potential to cause significant population declines, when combined with other pressures, particularly in koala populations which lack immunity, is often fatal and requires an extensive treatment period between 4-10 weeks.

However, computer modelling suggested that vaccinating as low as 10% of the breeding population annually could be enough to reduce chlamydial infection significantly to lead to a population rise. In 2021 WWF and Currumbin Wildlife Hospital, in collaboration with the Queensland University of Technology initiated a programme to deliver a vaccine to 30 koalas from a closed population to determine the level of vaccination required within an infected koala population to reduce the overall incidence of chlamydia, improve population numbers and reduce koala admissions from disease. The vaccine was administered in two separate doses, four weeks apart, with the patients housed and monitored in a holding facility until their release. Upon release, they were fitted with a radio collar to track their health for three years, recapturing every six months to check their general health assessment, reproductive status assessment and vaccine immunity (from a blood sample). In addition to the research cohort, all koalas admitted to Currumbin Wildlife Hospital were vaccinated prior to release.

The programme has currently vaccinated more than 350 koalas and confirmed immunity in all 30 koalas in the monitored group after 12 months.

Male koala with severe case of chlamydia. © WWF-Australia/Free Vreman

CASE STUDY 2: EDIBLE BAIT DELIVERY SYSTEM PREVENTS SYLVATIC PLAGUE IN PRAIRIE DOGS TO PROTECT ENDANGERED BLACK-FOOTED FERRETS

Black-footed ferret (*Mustela nigripes*) emerging from a prairie dog burrow © Clay Bolt/WWF-US

Sylvatic plague is caused by a zoonotic bacteria that can be transmitted between animals and humans by the bite of infected fleas, direct contact with infected tissues, and inhalation of infected respiratory droplets. If left untreated it can be rapidly fatal in humans and cause mortality rates as high as 95-99% in prairie dog populations. Both black-footed ferrets and prairie dogs are highly susceptible to sylvatic plague. In the Great Plains of North America, endangered black-footed ferrets rely on prairie dogs for food and use their burrows for shelter and raising young. As there are fewer than 400 black-footed ferrets in the wild, and at least 3,000 breeding adults are needed to achieve national recovery goals, plague abatement in black-footed ferrets and prairie dogs is key to the survival and persistence of both species.

An injectable vaccine is available to protect black-footed ferrets from plague, which with a booster is effective for an individual's lifetime. Vaccination is conducted by live-trapping wild-born kits (young of the year) and inoculating them with the plague vaccine, before releasing them. The mitigation of plague in prairie dogs is reliant on a flea-suppressing dust insecticide instilled in their burrows or an insecticide delivered in a grain or bait form (e.g. fipronil grain or fipronil peanut butter-flavoured baits). These plague abatement tools are effective for a minimum of 10 months, so they are proactively used annually. Although the dust is effective in prairie dog populations, it is labour-intensive to distribute and fleas can develop resistance when it is applied in the same burrows consecutively for six years or more. Many black-footed ferret reintroduction sites rotate tools annually or use a combination.

In 2016, WWF, the US Fish and Wildlife Service and Model Avionics developed a mechanized bait delivery system that dropped three plague protecting baits simultaneously from a drone and an all-terrain vehicle. The prototype was tested across several thousand acres of prairie dog colonies in Montana, South Dakota, Wyoming, Colorado and Arizona. In 2019, the system was patented and is now part of an effective approach that delivers edible baits to protect prairie dogs from this deadly non-native disease.

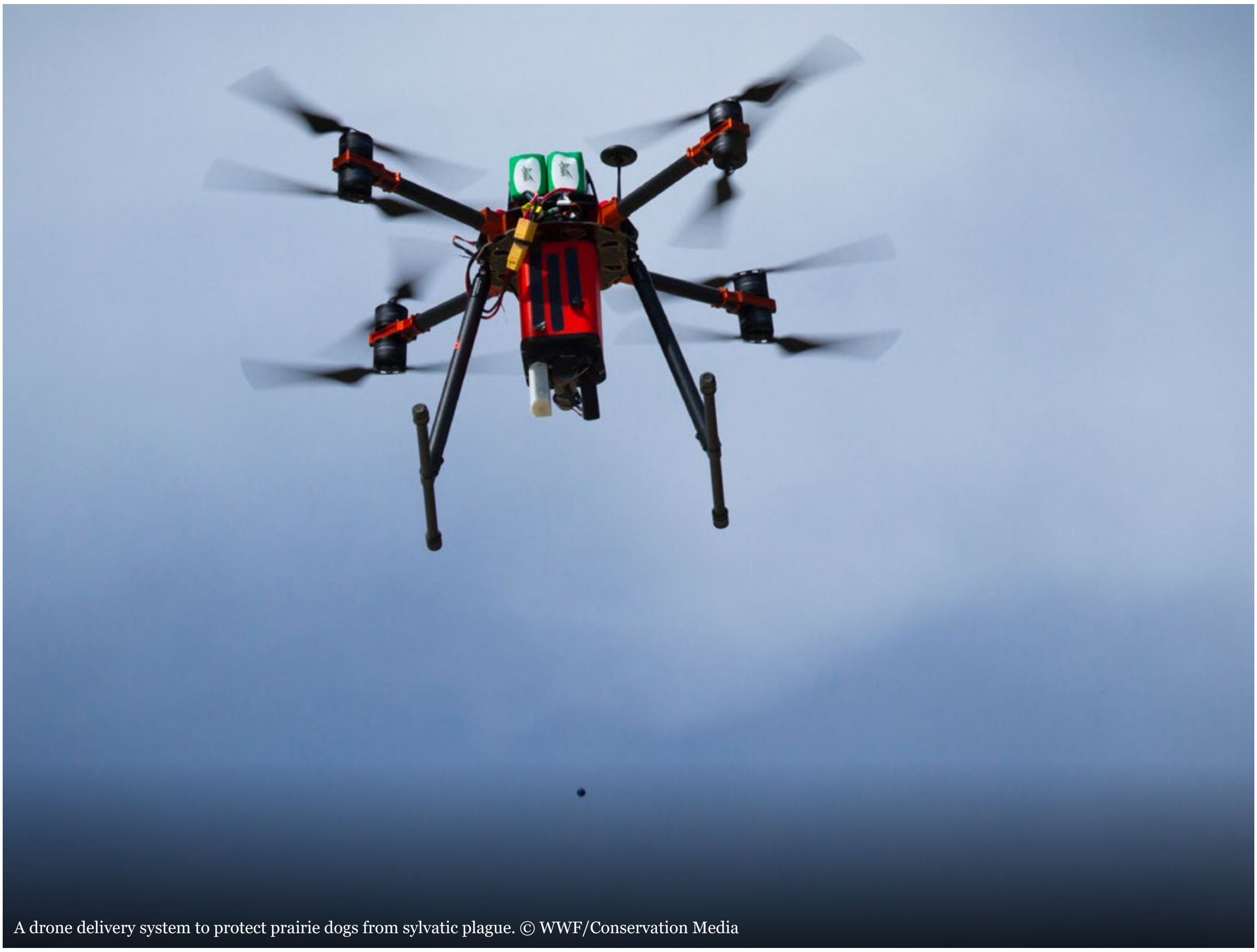
GUIDING QUESTIONS AND EXAMPLES

The following table provides guiding questions which can be asked when planning preventive medicine work in a landscape. It also contains examples of existing work that contributes to One Health preventive medicine initiatives.

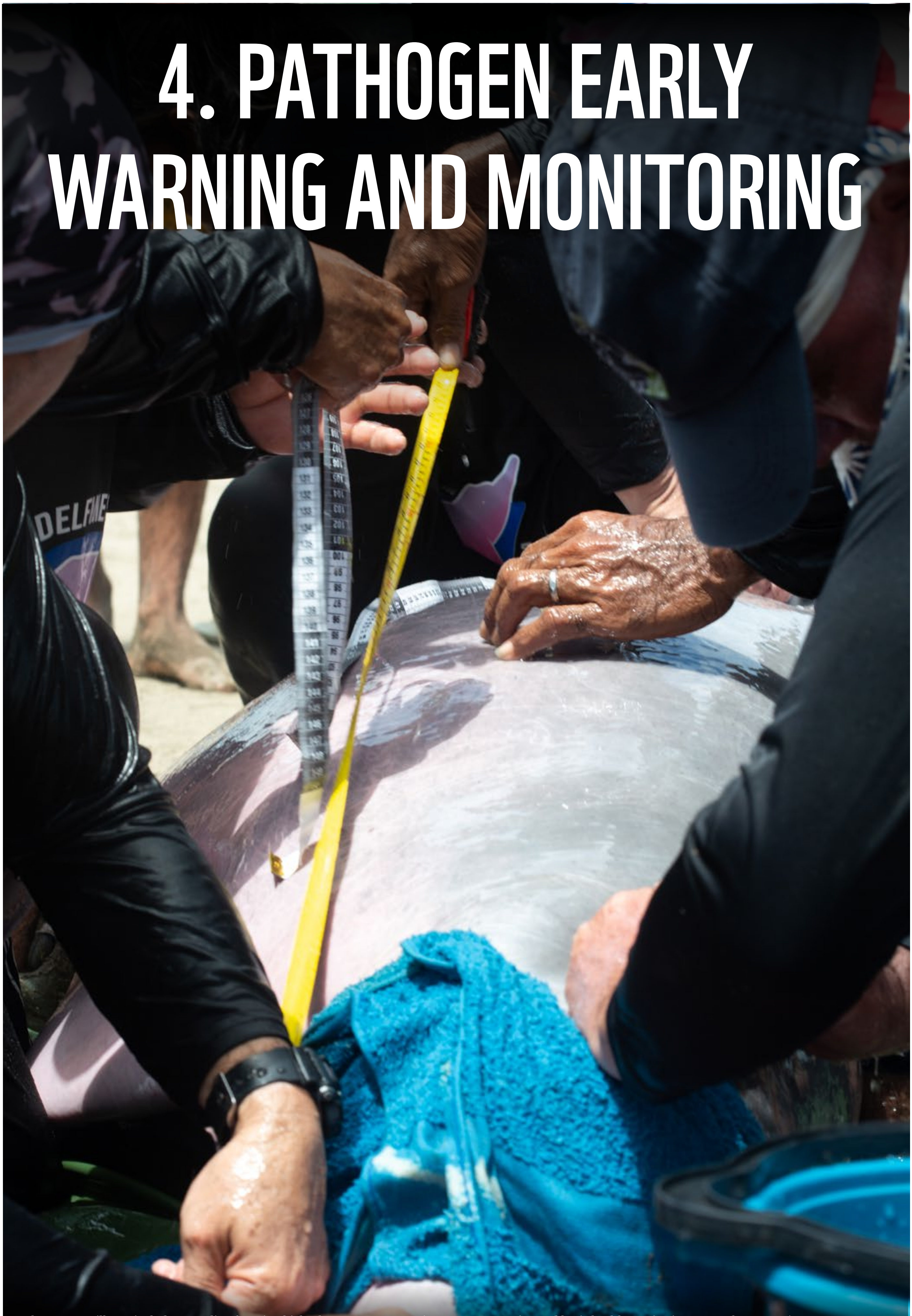
	DOMESTIC ANIMALS (INCLUDING LIVESTOCK)	WILDLIFE	HUMANS	ENVIRONMENT
General	Are infectious diseases considered as a threat in national or species strategies and action plans? If yes, which diseases are considered to be of greatest risk? If no, consider the priority of not yet recognized disease risks. Has a risk assessment been conducted and if so, what were the learnings? Have there been any disease outbreaks in humans or animals in the landscape/country that could have been prevented? Do disease mortality events occur and are they followed up/diagnosed? Do interventions conflict with other One Health pillars (e.g. excessive dipping/spraying to prevent tick-borne diseases in livestock may impact oxpeckers, birds which feed on ticks)?			
Health screening	Are they healthy? What are the (un) known diseases? Are there any preventive health programmes (e.g. vaccinations, dipping, deworming)? Is there disease screening (ongoing or previous)?	Are they healthy? Is there any health monitoring conducted during handling/ immobilization (clinical examination, parasitic, haematology, clinical chemistry, etc.) or during observations (e.g. with habituated animals)? Are there any opportunities to collect samples for health screening (e.g. blood/faeces for serology and parasitology)? Is wildlife mortality monitored (necropsy, disease)?	Do people have access to health services, including vaccination? Are there any known health issues/diseases in the communities and can they pose a threat to wildlife in the area (e.g. tuberculosis, COVID-19)? Are there any activities where people come close to wildlife (e.g. tourism)? Is there any wildlife handling/immobilization by WWF staff and partners (e.g. collaring or translocation)?	Is it healthy? Are there known risks present (contamination, soil reservoir of disease)? What are the pollution levels? Are microplastics, toxins or persistent organic pollutants present? Are biodegradable waste/ chemicals present?
Example	Bovine tuberculosis (*Mycobacterium bovis*) screening for spread from livestock to humans and wildlife, such as buffalo, lions	COVID-19 testing for potential transmission to great apes during tourist-related viewing of habituated groups	What is the risk of latent bovine tuberculosis which if activated can spread to other people and animals (e.g. elephants, primates)?	Testing radiation at Chernobyl nuclear exclusion zone prior to animal translocations

	DOMESTIC ANIMALS (INCLUDING LIVESTOCK)	WILDLIFE	HUMANS	ENVIRONMENT
Vaccination	Which diseases could occur in domestic animals and pose a threat to wildlife species? Have there been any disease outbreaks in the area/country that could have been prevented by vaccination?	Which diseases are known to occur in the various wildlife species in the area? Is vaccination feasible and economically viable?	Have there been any disease outbreaks in the area/country that could have been prevented by vaccination? Are staff vaccinated appropriately to participate in projects?	Is the environment contaminated by pathogens in human/ animal waste as a result of lack of vaccination? Is the environment becoming polluted by waste related to preventive medicine campaigns (e.g. syringes, biological material)?
Example	Canine distemper virus (CDV) in dogs can spread to lions, tigers, leopards and African wild dogs and cause high mortality Brucellosis can spread from livestock to humans, mainly through consumption of unpasteurized milk. Vaccination of livestock thus also protects humans	Anthrax vaccination of Indian rhinos and lowland gorillas after diagnosed mortalities Oral rabies vaccination baits for wildlife, e.g. foxes in Germany, to locally eradicate disease	Tuberculosis (*Mycobacterium tuberculosis*) vaccination in high risk/high prevalence cases Coronaviruses vaccination (SARS-CoV 2), reducing spread from people to animals, e.g. big cats, primates -Q Fever vaccination *(Coxiella burnetii)* for humans working with farm animals	Biodegradable efforts for medical, plastic and microfibre waste from mass vaccination
Parasite prevention and treatment	Are there any vector-borne diseases, carried by ticks, flies, mosquitoes, in the area? Has the incidence of vector-borne diseases risen? Is the method of prevention/treatment unsafe or outdated? Have there been any disease outbreaks in the area/country that could have been prevented by parasiticides?	Has the prevalence of vector-borne diseases risen? Are there any spillover/spillback risks in high interface areas with livestock? Will susceptibility to infection and disease be affected by translocation and are translocated wildlife treated with appropriate preventives prior to introduction to a new population? Will the frequency of contact between hosts and, thus, pathogen exposure change?	Is the method of prevention/treatment unsafe or outdated? Have there been any disease outbreaks in the area/country that could have been prevented by parasiticides?	Is the environment an important route of transmission for a suspected parasite (water, soil, food)? Is the environment contaminated with a larval/nymph/egg stage of a parasite? Is there a symbiotic or parasitic relationship between the host and the environment? Is parasite prevention contaminating the environment (e.g. DDT)?
Example	Vector-borne diseases can be prevented/ minimized by dipping of livestock or biological (vs. chemical) control of ticks	Health checks and preventives at translocation quarantine check points	Tick tracker app reports areas of ticks to contribute to combating infection from ticks (Lyme disease)	Cats at home programme reducing *Toxoplasma gondii* oocysts shed from feline faeces into drinking water


A koala receiving treatment for chlamydiosis. © Currumbin Wildlife Hospital


A drone delivery system to protect prairie dogs from sylvatic plague. © WWF/Conservation Media

4. PATHOGEN EARLY WARNING AND MONITORING



Pathogen surveillance includes sampling for microbial cultures, mercury testing, DNA sequencing and basic health monitoring. © Esteban Fong / WWF-Peru

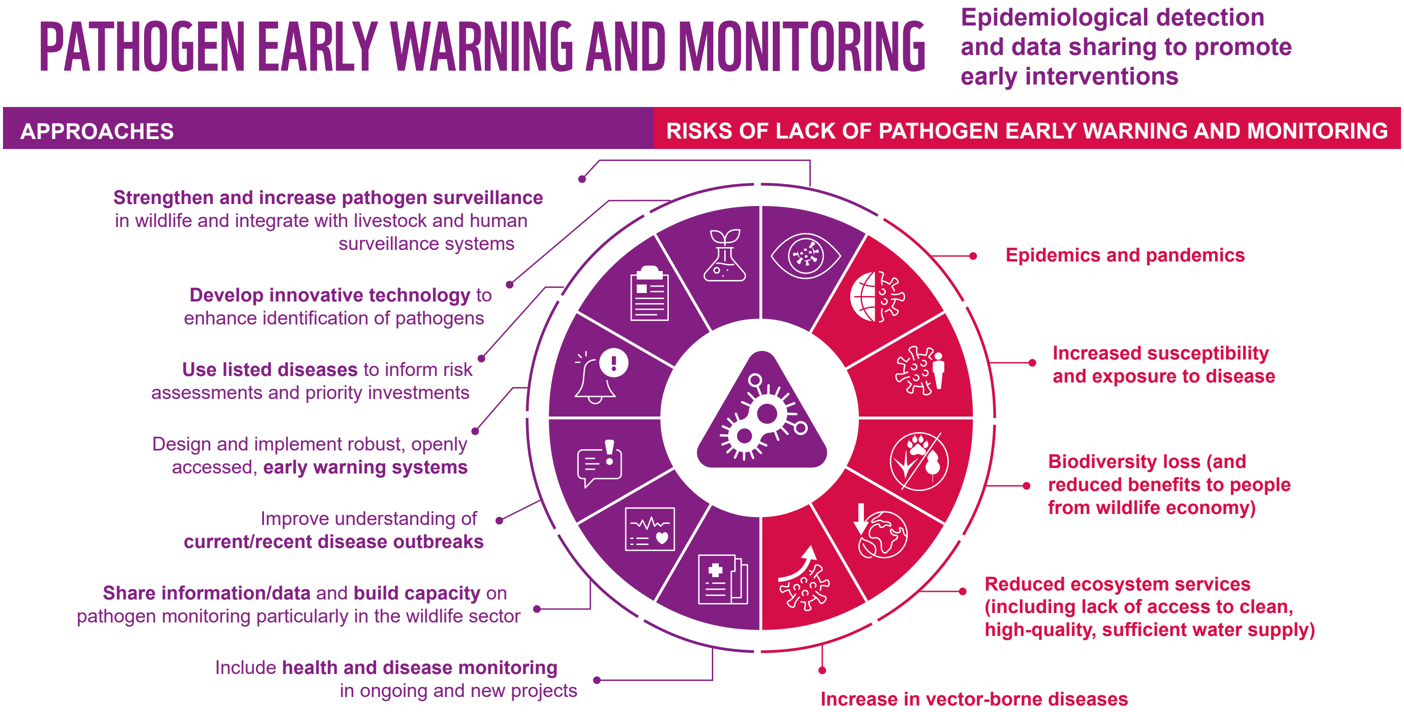
WHAT ARE THE LINKS BETWEEN PATHOGEN EARLY WARNING AND MONITORING, AND ONE HEALTH?

Zoonotic pathogens can emerge at any time, threatening all societies' health, well-being and economies. Collecting and sharing of epidemiological data and information across a broad range of sectors and borders can aid early detection of pathogens and enable early warning of emerging threats through an effective One Health intelligence framework. This can promote methods of intervention to respond to plant, animal and foodborne outbreaks, ultimately reducing the impact of disease.

Monitoring can improve our understanding of existing host and pathogen dynamics, drivers of disease, and disease transmission in animals and humans in the environment they share. Monitoring the origin, spread and patterns of new pathogens in geographical regions and interfaces can form part of a surveillance strategy which can potentially anticipate and prevent pandemics. Effective monitoring and early warning systems can:

- Prevent large-scale propagation of acute epidemic outbreaks and potential pandemics
- Improve health of Indigenous Peoples and local communities
- Prevent humans spreading disease to wildlife, ensuring secure income sources for IPs and LCs from the wildlife economy
- Improve biodiversity, ecosystem health and resources

WHAT APPROACHES CAN WE TAKE TO PATHOGEN EARLY WARNING AND MONITORING FROM A ONE HEALTH PERSPECTIVE?



The key areas where support for pathogen early warning systems and monitoring can be directed are:

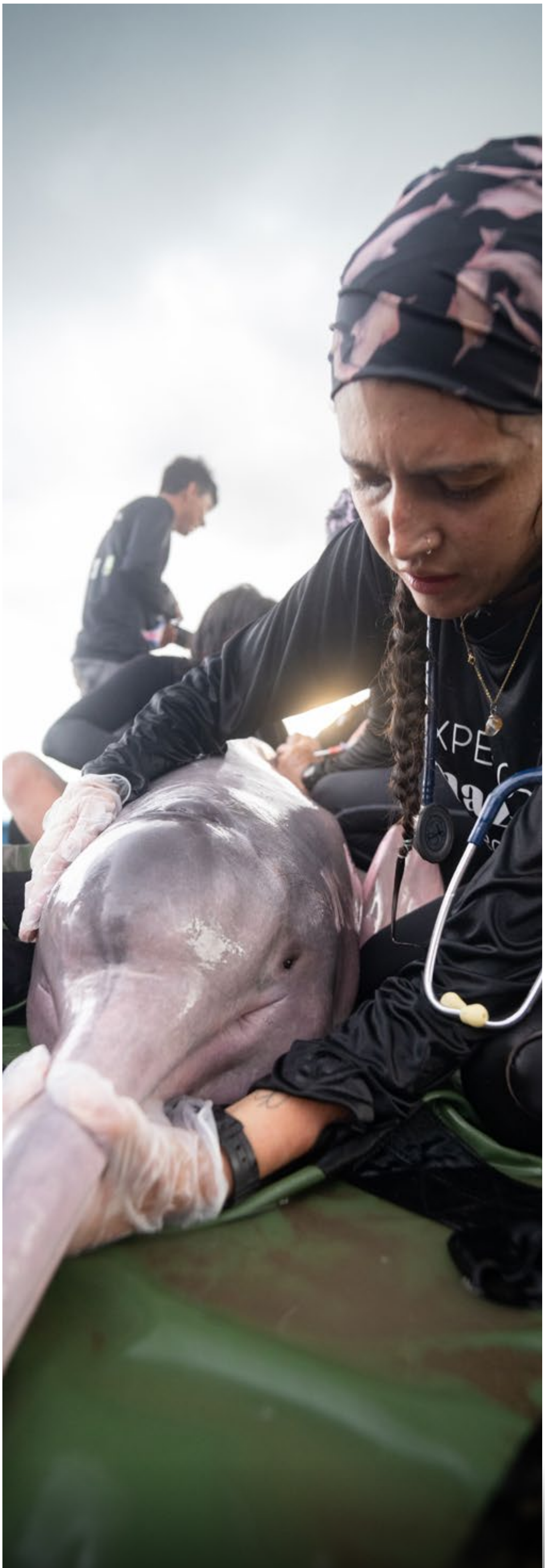
Pathogen surveillance: Surveillance of novel threats arising at the human-animal interface is essential to the One Health approach. Effective methods of monitoring infectious diseases in wildlife and livestock in particular need to be scaled up, along with improved training and capacity. New One Health platforms that integrate human, wildlife and livestock surveillance systems are needed to identify linkages in health risks. Surveillance systems also need open-access data platforms for more effective and real-time monitoring.

Innovative technological advancements: New mathematical modelling, diagnostic, communications and informatics technologies (e.g. electronic health records) can identify and report on previously unknown pathogen risks. Improvements in diagnostic platforms have the potential to enable targeted global surveillance through enhanced pathogen discovery and detection with increased sensitivity and specificity.

Listed diseases: A list of terrestrial and aquatic animal diseases notifiable to WOAH has been established to promote transparency on the world animal health situation. Such lists can be used to inform risk assessments and direct investment for warning and monitoring systems. The World Animal Health Information System (WAHIS) portal provides access to all listed diseases as well as other important diseases not listed by WOAH, including several emerging diseases and more than 50 wildlife diseases which may have a serious impact on global health and conservation.

Pandemic or outbreak investigation: Understanding the ecological, behavioural and socioeconomic drivers around recent pandemics (e.g. COVID-19, HIV/AIDS, SARS and influenza) caused by viral zoonotic pathogens requires increased and integrative health monitoring.

Climate change: Climate change may alter the range of global pathogens, allowing infections, particularly vector-borne infections, to expand into new locations (e.g. dengue fever). Early warning systems and monitoring of vector distribution, directed by risk assessments in key priority regions, will aid with understanding drivers and implementing mitigation pathways.



As bio-indicators and a sentinel species of water health, changes in river dolphins are assessed as early warning signs indicating ecosystem degradation and human health risk. © Gustavo Carrasco / WWF-Peru

CASE STUDY: GORILLA TOURISM AND DISEASE MONITORING AND EARLY WARNING

WWF in collaboration with the Helmholtz Institute for One Health (HIOH, Greifswald, Germany) initiated a continuous human and wildlife health monitoring and early warning system in Campo Ma'an Landscape, Cameroon, and Dzanga Sangha Protected Areas complex, Central African Republic. Both sites have been close to epicentres of EVD outbreaks in humans, and disease outbreaks had been noted in wildlife due to spillback from humans (respiratory diseases) or through naturally occurring disease (anthrax). As local livelihoods depend on tourism incomes in these sites, healthy habituated gorillas and other wildlife are crucial for the local economy.

The early warning and monitoring system includes:

- Long-term veterinary capacity on site; continuing education and collaboration with the local, national and international veterinary communities. Veterinarians manage mobile field laboratories to investigate suspected pathogens.
- A database to support digitalized data collection from examinations, necropsies and non-invasive sample collection (urine, faeces) of habituated animals and unhabituated wildlife populations.
- An employee health programme, in collaboration with human health infrastructure: regular and specific health screening, disease treatment and vaccination programmes for all project staff and their immediate families, ecoguards, interns and tourists.
- Clear emergency communication protocols in case of disease outbreaks from local to national and international level to avoid pathogen spread.

This has resulted in a 70% decrease in frequency of respiratory disease outbreaks in the gorilla population. It has also contributed to the improved general health of all staff and a better understanding of disease dynamics.

The work has included continuous capacity building on best practice standards and secure procedures including laboratory diagnostics, field techniques, data collection and administration at both project sites, led by national veterinary staff, supported by international PhD students from collaborating laboratories. Learnings have been shared through peer-reviewed journals and virtual workshops on epidemiological modelling.

For more information, see this case study on the Panorama Solutions site and this story.

Non-invasive sampling (urine) in habituated gorilla groups.
© Kim Grützmacher / WWF

Preparing for a necropsy of a young elephant. © Tobias Grässle, WWF

GUIDING QUESTIONS

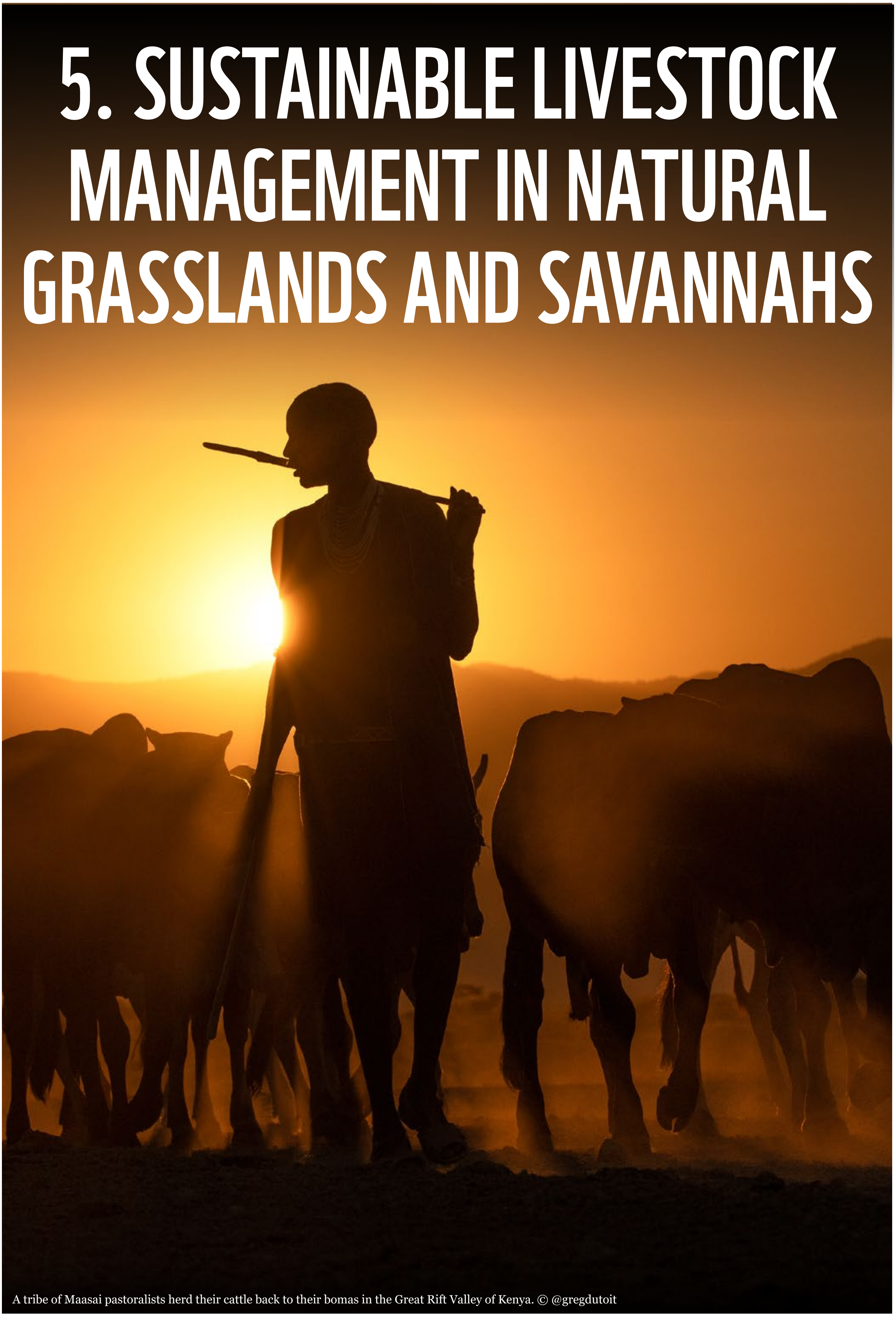
The following table provides guiding questions for planning early warning and monitoring interventions. It also contains examples of existing work that contributes to One Health and early warning and monitoring initiatives.

	DOMESTIC ANIMALS (INCLUDING LIVESTOCK)	WILDLIFE	HUMANS	ENVIRONMENT
General	How can IPs and LCs be involved in the monitoring and early warning systems? What is the capacity on site for continuous health monitoring of domestic, wild animal and human health? Can real-time investigation of disease and death in wild and domestic animals and humans be established on site? Which local, national and international partners need to be involved in the establishment of emergency communication protocols in case of disease outbreaks? How will the data be managed effectively?			
Early warning and monitoring systems	Are domestic animals in the area affected by listed diseases? Is there a direct connection with wildlife? What can be learned from current or recent disease outbreaks? Does standard treatment mask warning signs/symptoms?	Are wildlife affected by notifiable or emerging infectious disease? What can be learned from current or recent disease outbreaks? Can standardized monitoring be included in wildlife research, rescue and rehabilitation? Can sentinel species or biomagnification pathways promote improved understanding?	Is there sufficient capacity for training on safety and needed procedures and can this be maintained over time? Can human and animal warning systems be integrated? What can be learned from current or recent disease outbreaks?	Is this a high priority area for climate change (e.g. identified climate change refugia)? Are there any compounding factors of disease e.g. contamination/ pollution, fragmentation?
Examples	FAO and WOAH have collaborated to develop a network of Expertise on Animal Influenza (OFFLU 2013)	Global Early Warning System for Major Animal Diseases (GLEWS), developed by FAO, WOAH and WHO (GLEWS 2013) Global Alert and Response Operations of WHO	USDA Early Warning System for SARS-CoV-2 One Health Intelligence Scoping Study (OHISS) rapid alert system will allow the capture of real-time data and better protect global health security against emerging threats PREDICT programme of USAID's Emerging Pandemic Threats has the potential to detect spillovers of pathogens from wildlife using its SMART method	Strengthening Climate Information and Early Warning Systems (SCIEWS) project

Blood sampling are conducted as part of health assessments for river dolphins in the Amazon. © Gustavo Carrasco / WWF-Peru

Team members undertaking snow leopard measurements and health checks. © DNPWC/WWF Nepal

5. SUSTAINABLE LIVESTOCK MANAGEMENT IN NATURAL GRASSLANDS AND SAVANNAHS



A tribe of Maasai pastoralists herd their cattle back to their bomas in the Great Rift Valley of Kenya. © @gregdutoit

WHAT ARE THE LINKS BETWEEN SUSTAINABLE LIVESTOCK MANAGEMENT AND ONE HEALTH?

Animal, human and environmental health are closely linked, and livestock systems are no exception. Livestock are often the predominant and most culturally embedded form of land use within natural grasslands and savannahs. These systems are often where the One Health triad of people, the environment and animals are most intertwined, with herders, livestock and wildlife all living together and sharing the resources of the same natural ecosystems.

Livestock play a major role in sustainable global food systems and are a contributor to poverty reduction, food security and agricultural development. In drylands, livestock is often the only way to sustainably convert natural resources into food, fibre and work power for local communities. Well-functioning rangelands[2] have the potential to contribute a wealth of ecosystem services such as the preservation of biodiversity, prevention of soil erosion, carbon sequestration in soils and biomass and plant nutrient availability for animal feed. Rangelands constitute 54% of the Earth's land cover, provide food security for 1-2 billion people and support 78% of global grazing.

However, up to 50% of rangelands are degraded. This is driven largely by converting pastures to cropland and other land-use changes due to population growth and urban expansion, rapidly rising food, fibre and fuel demands, excessive grazing, and policies that incentivize overexploitation. Unsustainable livestock management can also have negative impacts on wildlife (e.g. HWC) and can increase the potential for transmission of diseases among humans and wildlife and domestic animal species, something that is exacerbated by poor hygiene and poor animal husbandry (e.g. high stocking density, effluent management). Increasing incomes, changing diets and population growth have led to increased demand for livestock-derived products and made the livestock sector one of the fastest-growing agricultural sub-sectors in middle- and low-income countries. If not properly managed, this growth risks accentuating sustainability issues with equity, environmental and public health impacts.

Cattle are raised in diverse geographies and systems from intensive to extensive, each with its own challenges and opportunities from a One Health perspective. The keeping of livestock may be influenced by many complex factors including tenure issues and political, social, cultural and ecological changes. Effective and sustainable livestock management requires cross-sector approaches adapted to the local context in order to reduce the unintended negative impacts on human, environmental and/or animal health (e.g. the impact of veterinary fences and nearby farms on wildlife migration, the impact of antibiotic use in livestock on antimicrobial resistance).

Given the conservation focus of this report, this chapter focuses on sustainable livestock management for natural grasslands and savannahs only. There are many other facets of livestock health and management that intertwine with ecosystem and human health but do not fall within the scope of this guidance, including:

- Antimicrobial use, residues and resistance (AMR)[3]
- Foodborne disease, food safety and occupational hazards
- Disease transmission and risk in peri-urban environments
- Intensive farming methods

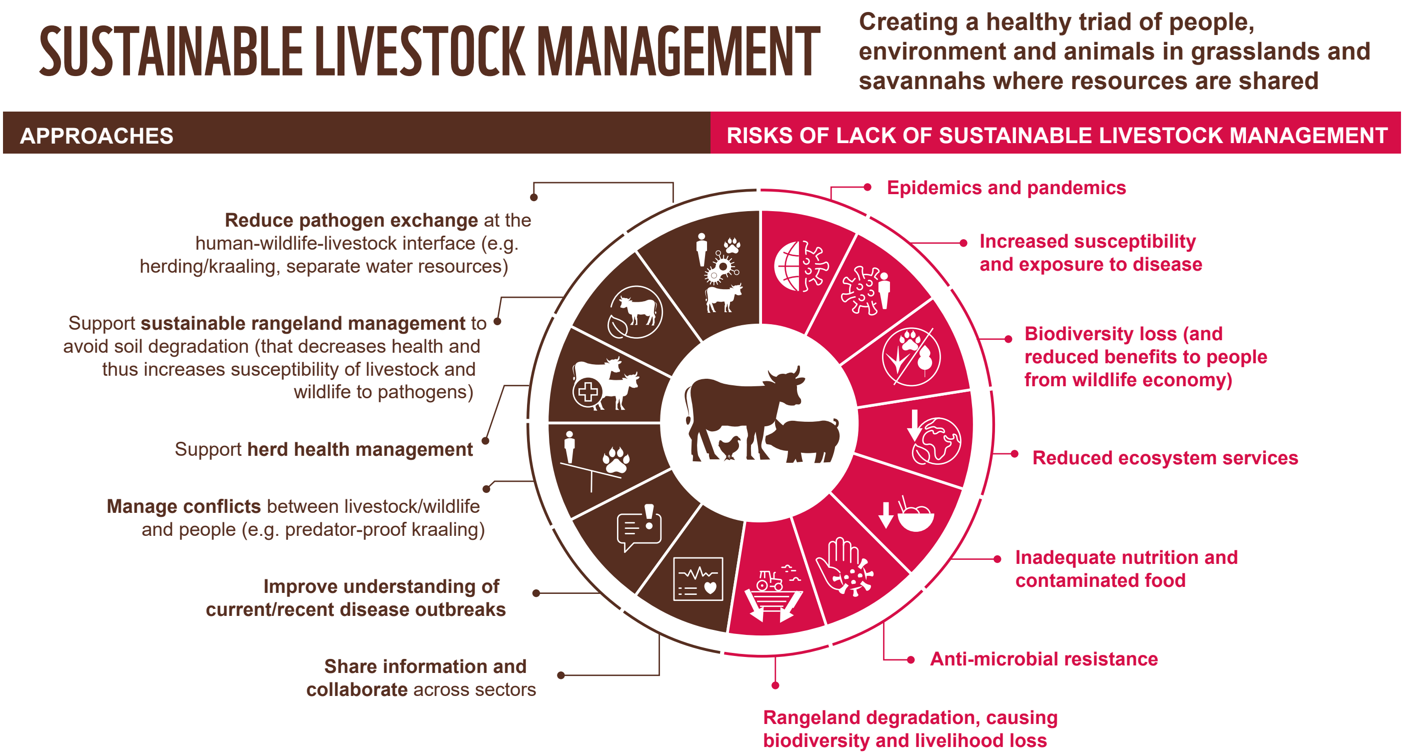
These issues highlight the need to address entire food value chains in dealing with the One Health nexus across the livestock sector.

Effective One Health strategies for sustainable cattle management in natural grasslands, including the prevention, control and elimination of livestock-associated zoonoses (e.g. vaccination against brucellosis, leptospirosis, Q fever), have the potential to improve human health, livestock productivity and equitable benefits particularly in low- and middle-income countries. Holistic rangeland management avoiding soil degradation and the reduction of the human-wildlife-livestock interface are crucial approaches to complement actions to reduce zoonoses.

2 Land cover which consists mostly of the natural grasslands and savannahs used by livestock and wild animals to graze and forage.

3 Antimicrobial treatment of free-ranging livestock can expose wildlife to resistant genes/organisms in the shared environment; however, this is not considered a primary health concern for wild animals in grasslands and savannahs at this time.

HOW CAN WE APPLY A ONE HEALTH APPROACH TO LIVESTOCK MANAGEMENT IN NATURAL GRASSLANDS?



There is wide scope to improve livestock sector practices so that they are more sustainable, more equitable, pose less risk to animal (livestock, wildlife) and human health, and reduce adverse impacts on land, water and the environment. The International Livestock Research Institute (ILRI) has identified seven key areas important for a One Health approach with the livestock sector (Figure 2). We suggest using these briefs as guidance when considering One Health approaches to sustainable livestock management.

Training in regenerative livestock farming for cattle ranchers in Madre de Dios, Peru. © Pierina Bellota / WWF-Peru

Figure 4. The seven key areas for livestock sector investment using a One Health approach (Source: International Livestock Research Institute)

The following actions can be useful in sustainable livestock management for One Health:

Organize assessment(s) to gather data and information (based on the guiding questions below and key data gaps) to understand health and disease trends, and minimize the contribution of livestock production to the degradation of ecosystems and wildlife health. The impact of livestock on local species and ecosystems is contextually specific and an impact assessment can help to map and prioritize the material impacts for a particular production system and region.

Collaborate between sectors: Share information and *"join up multi-sectoral health investments to reduce health risks and burdens to people, livestock and ecosystems"* (ILRI brief).

Reduce human and animal disease: *"Prevent and control human (and animal) diseases transmitted by animals to save millions of lives and livelihoods"* (ILRI brief). This is of particular importance in areas where the eradication of disease in wildlife and/or prevention of contact between wild and domestic species is of economic and political importance and when disease forms a barrier to trade (e.g. foot and mouth disease in Africa). Reducing zoonotic diseases requires the prediction, early detection, prevention and mitigation of pathogen impacts utilizing experts from medicine, public health and veterinary/wildlife services (see *Chapter 3: Preventive medicine* and *Chapter 4: Pathogen early warning and monitoring*). It is important to consider interventions that benefit all One Health pillars (humans-animals-environment) and reduce the risk of conflict and unintended consequences (e.g. excessive dipping/spraying to prevent tick-borne diseases in livestock may impact oxpeckers - birds which feed on ticks).

Manage livestock-nature interfaces: "*Manage the interfaces between livestock and nature for win-win-win outcomes for nature, people and animals"* (ILRI brief). Transmission of viruses, bacteria, and other pathogens (such as prions or fungi) may occur between livestock and wildlife species and cause disease outbreaks in either population. Many diseases that cause devastating impacts for animal health, producer livelihoods and food security when they infect the livestock population are also found in wildlife (e.g. foot and mouth disease, African swine fever, avian influenza). Conversely, diseases that are endemic and established in livestock can be introduced to vulnerable wildlife species that would not otherwise maintain the disease in their population (e.g. brucellosis) and result in new and emerging infectious diseases. Robust biosecurity practices and veterinary/animal health capacity can aid in detection, disease response and the creation of a barrier against disease transmission. Typical biosecurity measures include an awareness of high-priority diseases (with trained professionals in animal health who are able to inform, detect and respond when a disease outbreak occurs), record-keeping to understand health and disease trends over time, disinfecting tools and vehicles that are shared between herds, quarantine and appropriate fencing.

Local context and cross-sector approaches are imperative, considering that interventions meant to prevent and control animal disease, such as fences and pharmaceuticals, can also have negative impacts on wild species and habitats.

Effective and holistic approaches to manage HWC are also critical from a One Health perspective (e.g. integrating One Health and HWC mitigation measures in India).

Support equity: Empower IPs and LC to act for better health outcomes for people, animals and the environment (ILRI brief). It is also important to recognize the intersections between gender and health in livestock-keeping communities (e.g. how gender roles influence disease exposure, access to vet services and decision-making regarding One Health investments) (see *Chapter on Gender equity in a One Health approach*).

Examples of work on One Health with sustainable livestock management include:

- *Herd management:* Predator-proof corrals, herd health management, vaccinations, wildlife contact management, planned grazing, destocking, (mobile) abattoirs, working collaboratively on surveillance and disease monitoring, technological innovation to support sustainable productivity where possible (e.g. drone monitoring, precision farming).
- *Markets:* Addressing commodity-based trade to include aspects of food safety, traceability and One Health in value chains.
- *Research*: Investigating gender issues in disease prevention and control mechanisms, developing evidence on the contribution of livestock to zoonosis, understanding the One Health dynamics in specific landscapes.
- *Knowledge:* Developing One Health wildlife and livestock vet teams, creating awareness through formal and informal trainings on One Health.
- *Policy:* Working with partners to develop policy frameworks on One Health.
- *Partnerships:* Collaborating with livestock experts to create greater impact, including the private sector involved in the food market system.

CASE STUDY: HOLISTIC CATTLE HERDING IN KAZA

In 2022, WWF together with its partners the Victoria Falls Wildlife Trust (VFWT) and Herding for Hope (H4H) began testing a holistic cattle-herding approach applying One Health principles in the Zimbabwean part of the Kavango-Zambezi (KAZA) landscape. The approach aims to reduce rangeland degradation and HWC while at the same time improving animal health.

More than 160 community members in the project area have so far participated in the theory of change study. As a result and thanks to the support of VFWT, a hundred households with a total of over 1,000 livestock are now using mobile bomas (livestock enclosures), while also tagging their cattle to track their health history. Cattle health is examined during general vet health checks every two weeks and guides which cattle can be selected for sales. Cattle are also vaccinated against lumpy skin, black leg and brucellosis anthrax and dipped to prevent disease transmitted via ectoparasites. The use of the mobile bomas and ensuring that livestock are not left unattended in the grazing areas has reduced predation, thus lowering HWC. In a next phase of the project the aim is to transition to planned grazing with professional and trained herders to improve rangeland conditions.

The strategy used by H4H addresses the challenges and risks that livestock holders are experiencing by simultaneously strengthening animal health services and support; strengthening animal conditions through improved rangeland conditions and herd health management; increasing animal safety by reducing predation, stock theft and accidents; strengthening market access and trade support through compliance, including participation in tourism enterprises; improving support for water infrastructure; and increasing employment through professionalizing livestock herding.

Cattle sharing grazing land with wildlife in Zambia.
© Martin Harvey / WWF

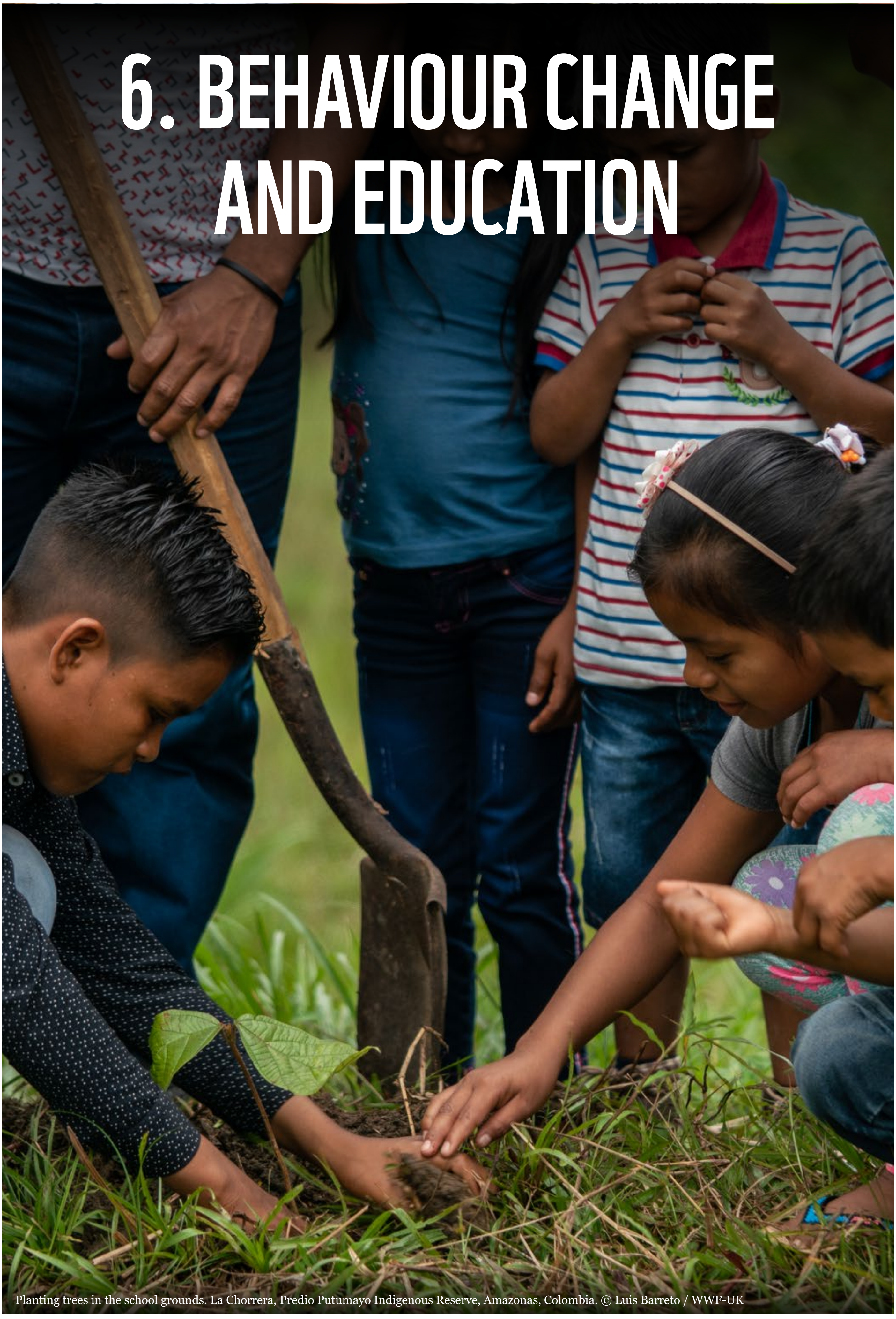
Cattle in boma being examined by a vet and vaccinated. © VFWT

GUIDING QUESTIONS

The following table provides some indicative guiding questions for planning sustainable livestock interventions.

	HUMAN-ANIMAL-ENVIRONMENT INTERFACE
Organize assessments	What are the contributing pressures from livestock on environmental, wildlife and human health (e.g. overgrazing, waste products, disease spillover)? What are the disease trends in the landscape? Are frameworks in place to guide prevention/control of disease?
Reduce human and animal disease	Have there been any disease outbreaks in humans or wildlife in the landscape/country that could have been prevented by better livestock management? Are wildlife and livestock vet teams integrated? Are there mechanisms in place for sharing disease surveillance data between wildlife, livestock and public health sectors?
Manage livestock-nature interfaces	Are biosecurity measures in place? Have protocols and procedures been created with veterinary and public health involvement? Are there endemic diseases or high-risk diseases present?
Ensure equity	Are IPs and LCs involved? Have gender roles that are critical to the project outcome been integrated? How do gender roles influence disease exposure, access to vet services, and decision-making regarding One Health investments? What specific strategies are in place to ensure that marginalized groups, including women and Indigenous communities, are actively involved in decision-making processes?
Collaborate between sectors	How are livestock partners connected to wildlife managers? Is there any policy in place to support sustainable livestock management and does it link to a One Health framework? Would project impact be improved with strengthened collaboration between livestock experts and the private sector?

6. BEHAVIOUR CHANGE AND EDUCATION



Planting trees in the school grounds. La Chorrera, Predio Putumayo Indigenous Reserve, Amazonas, Colombia. © Luis Barreto / WWF-UK

WHAT ARE THE LINKS BETWEEN BEHAVIOUR CHANGE AND EDUCATION, AND ONE HEALTH?

For nearly every environmental challenge, humans are both the problem and the solution. Human behaviour - collective or individual - and how we understand and interact with nature is complex. Our behaviour is influenced by many different social, cultural and economic factors unique to individuals, communities and nations.

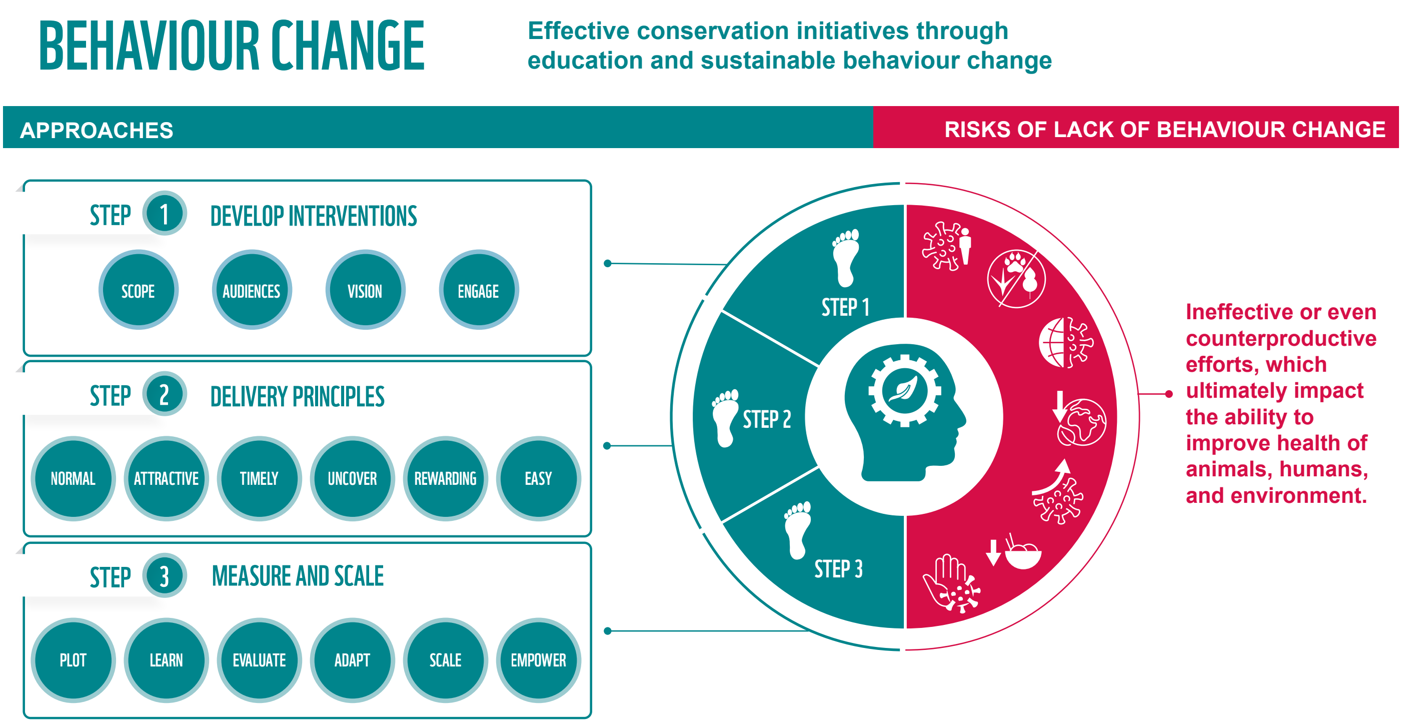
Behaviour change has been recognized by governments, corporates and civil society alike as a crucial solution to addressing climate change; One Health is no different. To achieve the changes needed to ensure healthy people, animals and ecosystems, behaviour change and education will be essential as part of a coordinated, collaborative, multidisciplinary and cross-sectoral approach, and the growing body of knowledge on behavioural science is an invaluable tool.

Many One Health initiatives require or would benefit from a behavioural change approach. One obvious example is in efforts to reduce **demand for wildlife products** considered 'high risk' from a disease perspective. However, challenges in documenting the direct behavioural or biological impacts of behaviour change in relation to wildlife trade continue and there remain substantial gaps between best practice in social marketing and current practices in the design of demand reduction campaigns. It is clear that there is scope to increase the sophistication and impact of such activities in the One Health space.

Other behaviour change efforts that are crucial to One Health include initiatives relating to hygiene and sanitary practices, handling of animal products, food preparation and consumption, and waste management. Behaviour change requires a broad-spectrum approach, from working with herders to ensure more **sustainable livestock practices** (see *Chapter 5: Sustainable livestock management*), to ensuring government land-use planning practices support landscape immunity (see *Chapter 1: Landscape immunity*).

More traditional educational efforts are also important in One Health, given the interdisciplinary nature of One Health approaches. Embedding animal and/or ecosystem health education within the human health curriculum, and vice versa, is necessary to build the foundation on which interdisciplinary collaboration can be effective. Also, improving our understanding of human behaviour and how this impacts **gender**, the **economy**, **social structures** and **politics** is necessary for conservation practitioners to direct behavioural change and education initiatives.

WHAT APPROACHES CAN WE TAKE TO BEHAVIOUR CHANGE AND EDUCATION FROM A ONE HEALTH PERSPECTIVE?



WWF's Save Nature Please Framework (Figure 5) is a simple way to apply behaviour change strategies within any conservation-based programme. The framework proposes a three-step process - each comprising a flexible menu of subsidiary components - for applying behavioural science to the development, delivery, evaluation and scaling of behaviour change interventions.

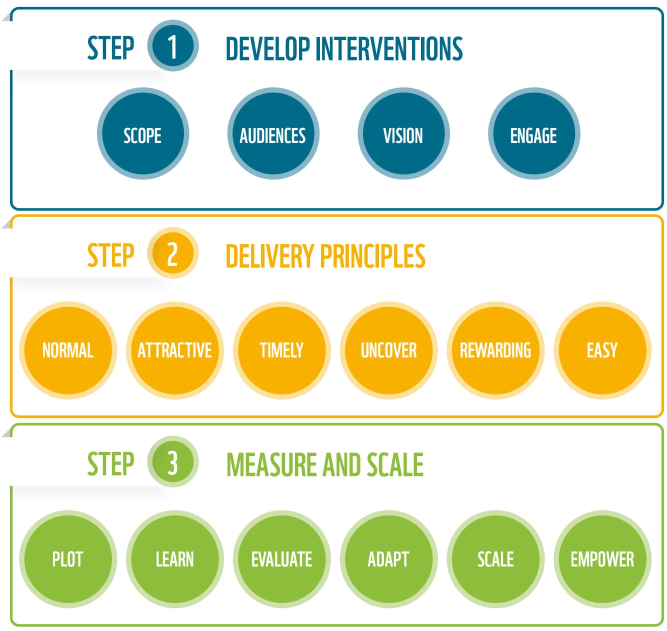


Figure 5. WWF Save Nature Please framework

Step 1: Develop interventions (Scope, Audiences, Vision, Engage) is about researching, gathering evidence, and understanding the problem and objective, the target audience, and vision of the future that inform development of behaviour change strategies and interventions. Interventions to change behaviour can be both 'downstream', such as education, communication and campaigns, as well as 'upstream', such as policy, regulatory or business change - where best to focus is decided during this development stage. Key interventions in this step are:

- **Organize assessment(s)** across different audiences to better understand what behaviours and educational gaps pose greatest risk for One Health (e.g. zoonotic transmissions). Identify or conduct baseline and impact surveys to understand the local context, identify motivators/barriers to behaviour change, and guide the planning of suitable context-specific interventions. This will help tailor messages and approaches to the target population in a specific context. When possible, surveys should be conducted in a collaborative manner with actors from other disciplines/sectors to ensure the design and adoption of a multidisciplinary approach from the planning phases.

- **Understand and engage with IPs and LCs** to identify their specific need at the human-animal-environmental interface; this includes baseline assessments/research methods being adapted as needed for specific contexts and communities.

- **Build capacity** by introducing/training key stakeholders in One Health and behaviour change. This should ensure basic principles, scope and intervention strategies on social and cognitive behavioural sciences are well understood and appreciated before planning for specific actions in the community.

Step 2: Delivery principles (Normal, Attractive, Timely, Uncover, Rewarding, Easy) are the principles that should guide interventions, including social norms, timeliness and context, and reward. Develop and refine messages and strategies to suit the local needs and context. Leveraging the evidence and good practices tested at regional/global level, messages and approaches should be adapted/tailored to target groups and countries as one size does not fit all.

Step 3: Measure and scale (Pilot, Learn, Evaluate, Adapt, Scale, Empower) is about piloting activities, measuring success, adapting and improving, and scaling for impact through collaboration. Key interventions in this step are:

- **Pilot** the identified strategies (e.g. mass awareness campaigns, community dialogue days, facility-based health talks) in small groups to assess their effectiveness and impact, before planning for their implementation with a broader audience. Pilot activities should be monitored carefully to allow for possible revision and adjustments should these be needed. Adopt empirical methods widely practised in development economics to rigorously identify whether, how and why interventions work.

- **Collect and share** challenges and lessons learnt to promote the development of best practices and their adaptation and replication in other landscapes and projects.

- Integrate with the policies, institutions and systems to facilitate learning and **scaling** informed by a rigorous evidence base. Lessons on scaling can be learnt from other fields.

All steps require collaboration with other organizations/groups to share information and build sustainable networks. Mapping stakeholders across sectors and disciplines that are already engaged or interested to support a behaviour change programme on One Health issues will aid in this process.

CASE STUDY 1: ZERO WILD MEAT

Zero Wild Meat was an innovative campaign launched by WWF in 2022 in the Mekong (Viet Nam, Cambodia, Laos) that spotlighted two serious threats of wild meat trade - risks to public health and risks to nature.

We used a behaviour change approach and deep research into our target audience: launching a pre-campaign survey into the motivations and eating habits of wild meat consumers to guide our creative design; testing messages and visuals with members of our target audience; and further revising these visuals based on feedback before the campaign launch. At the end of our campaign, a survey was conducted to compare against our baseline pre-campaign survey.

During this campaign, we used tactics such as:

- Recruiting influential messengers like doctors, celebrities and restaurant owners
- Seeking public pledges from consumers not to eat wild meat
- Asking restaurant owners to pledge not to serve wild meat and publicly promote the campaign in their establishments
- Partnering with key government agencies and their outreach channels

Campaign visuals and messages were deployed in physical and online locations where wild meat consumers spend time, and we varied our visuals and messages throughout the campaign.

This report illustrates the campaign design, implementation and evaluation through a behaviour change lens, provides insights from its pre- and post-campaign surveys among wild meat eaters, and summarizes key learnings for future interventions.

Key outcomes in terms of reach include over 18 million total impressions on WWF social media channels, more than 4,000 online pledges by individuals committing to #ZeroWildMeat, coverage in over 200 media outlets following press conferences with national-level government partners, and billboards and adverts displayed in nearly 200 locations including government buildings, office buildings, shopping malls, restaurants and markets.

Key impacts, illustrated from the pre- and post-campaign survey results, show an additional 7% of wild meat eaters surveyed in Vietnam and 15% of eaters surveyed in Laos are likely to reject eating wild meat after being exposed to our campaign, compared against the baseline. Although these numbers may not seem large, given the modest scale of this pilot campaign and how deeply consumption is embedded into the culture, it is in fact a significant outcome with great promise for public health efforts.

Key visual showing the zoonotic disease risk of consuming wild meat. © WWF-Viet Nam

CASE STUDY 2: BEHAVIOUR CHANGE TO COMBAT EPIDEMIC OUTBREAKS

Dzanga-sangha landscape with herd of African forest elephants, Central African Republic. © Meg Gawler / WWF

From 2017-2021 a One Health behavioural change programme was implemented in two ecotourism sites in the Congo Basin: Campo Ma'an National Park (CMNP), Cameroon and Dzanga-Sangha Protected Areas (DSPA), Central African Republic. The major challenge addressed by this programme was the outbreak of epidemics such as EVD, anthrax or respiratory diseases transmitted between humans and wildlife in and around the protected areas. The behavioural change strategy was multifaceted, aiming to engage the local population through culturally relevant and participatory activities. This was not only about teaching people what to do, but about helping them understand why these changes were necessary and how they could implement them in their daily lives.

The campaign conducted 62 proximity sensitization activities, reaching 6,330 people including Indigenous communities. These activities were designed to be interactive and engaging, using methods such as theatre campaigns and educational films performed by members of the community in local languages. Outbreak simulations provided hands-on experience in responding to potential health crises, while school activities engaged the younger generation, and discussion forums allowed community members to voice their concerns and questions. Additionally, 31 radio broadcasts reached up to 290,000 Indigenous People and local communities in the project area.

To measure the impact of these efforts, a sociological study was conducted, comparing knowledge, perception and attitude toward zoonotic disease risks at the beginning and the end of the project, revealing the following results:

- In DSPA, awareness of contagious diseases between humans and wildlife rose from 78% to almost 95%, while in CMNP, it rose from only 25% to reach 85%. Additionally, a large majority (95-98%) correctly identified infection pathways.
- The number of people understanding the importance of thoroughly cooking meat before consumption increased markedly - from 25% in 2018 to 47% in 2021 in DSPA, and from 22% to 59% in CMNP during the same period.
- There was also a significant rise in the proportion of respondents taking precautions to avoid zoonotic disease infections, with DSPA seeing an increase from 50% to 91%, and CMNP from 31% to 86%. The range of hygiene measures cited by respondents expanded, indicating a broader understanding and adoption of protective behaviours.

GUIDING QUESTIONS

The following table provides guiding questions which can be asked when planning interventions. Once the specific behavioural change required is identified, the Save Nature Please framework can be used to develop the appropriate approach.

STEP 1: **Develop interventions** S A V E	What specific change in human behaviour is essential to achieve your One Health objectives? Who is the target audience and what assessments are required to best understand them and their needs? What gaps are there in your existing knowledge of the driving behavioural forces between human-animal-environment interactions, and how will they be filled? Can you define a Specific, Measurable, Achievable, Realistic and Timebound behavioural objective for your target audience? What datasets or research are required to adopt a baseline of behaviour/education? How will you sensitively engage citizens, influencers, stakeholders and collaborators to build understanding? Which local, national and international partners need to be involved in the behaviour change intervention? Have all stakeholders been mapped to create a collaborative network? What are the needs of Indigenous Peoples and local communities and how can they be involved in behaviour/educational initiatives? How can the initiative empower women to produce better health outcomes?
STEP 2: **Delivery principles** N A T U R E	How can you make the behaviour change as easy as possible for your target audience? How can the desired behaviour change be attractive or rewarding for the target audience? Does your intervention adequately overcome barriers to change (as identified in initial assessments)? Is there a moment in time that your target audience will be most receptive to changing their behaviour? Are there social norms that can be leveraged or need to be shifted in order to achieve the target change? Do strategies suit the local needs and context? Is there a role model who can influence the change in behaviour? How do cultural beliefs, traditions and local contexts influence the feasibility and acceptance of the proposed behaviour change?
STEP 3: **Measure and scale** P L E A S E	Has a pilot project been conducted? If not, is one useful in this context? How can you measure success? Is there an informational feedback loop in place? Is scaling possible? Is sustained funding secured? Is there capacity on site for monitoring of domestic animal, wild animal and human health? Is there sufficient time to allow change to be monitored? What mechanisms will be established to ensure continuous stakeholder engagement and feedback throughout the intervention process?

Laxmi Paudel in Dhikurpokhari VDC, ward no - 5 in the Bhakarjung area of Nepal. She is a female Community Health Worker, member of the Women's Group and member of the Community Forest Users Groups. She is also a member of Hariyo Ban and Anti-Poaching Group. © Karine Aigner/WWF-US

GENDER EQUITY IN A ONE HEALTH APPROACH

In social sciences, gender is defined as the roles, behaviours, characteristics and attributes socially constructed and culturally seen as appropriate for women and men. A recent compilation by the Network for Ecohealth and One Health listed "Social, cultural, and gender equity and inclusiveness" as a key value, emphasizing the importance of considering gender in One Health.

Population growth, land-use change, unsustainable agriculture and the loss of traditional ecological knowledge are challenges impacting ecosystem health that are directly linked to gender equality. For example, in developing countries, women represent 43% of the agricultural workforce and are therefore a critical stakeholder group in terms of more sustainable agricultural practices. Yet they face barriers to land tenure, new technologies and in controlling household resources. While women in Indigenous Peoples and local communities play a vital role in the conservation and management of natural resources, they experience disproportionate social costs and health burdens in comparison to men.

One of the main challenges in incorporating gender considerations into the One Health approach is the broad and complex nature of the field. For instance, limited access to and control over land for women or poorer individuals may expose them to environments with a higher risk of zoonotic diseases, increasing their chances of infection. Gender plays a role in socioeconomic issues, human-wildlife conflict, vulnerability to zoonotic diseases and access to natural resources. Women suffer disproportionately from infectious diseases and natural disasters, particularly in developing countries. Studies show that women during their child-bearing years are more vulnerable to disease outbreaks due to immunosuppression during pregnancy, increased exposure due to distribution of labour or family roles, and/or deleterious pregnancy outcomes. Gender and the distribution of labour and resources play important roles in the control and prevention of zoonotic diseases. The prominent role of gender in the frontline defence against the spread of avian influenza in Southeast Asia in 2008 was evident, as women were the primary caretakers of both poultry and their families. Women also have less access to disease prevention and treatment, are more at risk of sexual and reproductive health issues, and suffer greater lack of access to healthcare than male counterparts. The COVID-19 pandemic has deepened gender inequities by impacting women disproportionately, through an increased burden of unpaid care work, losses of jobs and livelihoods, an escalation in gender-based violence and an increasing risk of child marriage.

ONE HEALTH THROUGH A GENDER PERSPECTIVE

Including gender in a One Health approach helps to better understand risks at the human-animal-environment interface. It also helps identify potential benefits, such as improving the detection of emerging zoonotic diseases by providing better access to veterinary services for previously underserved groups of livestock keepers.

A One Health approach should ideally be gender-responsive in every programme and landscape.

This section primarily follows recommendations deriving from the workshop Women and One Health, organized in 2016 by the University of Wisconsin-Madison in collaboration with the United States Department of Agriculture. This workshop brought together experts working in fields related to One Health, women and agriculture, gender and development, and aimed to have wide cultural and geographic diversity of participation.

Some generic steps for One Health approaches with a gender perspective follow. Partnerships will be invaluable for these activities:

Organize assessment(s) to gather data and information on the drivers of disease from a gender perspective, paying attention to women's voices in the following areas:

- Agricultural production
- Natural resource management
- Income
- Leadership
- Time use, and other community-based participatory methods

Collaborate with other organizations/groups to share information, and work together to reduce vulnerability and increase resilience to emerging diseases for women and vulnerable groups.

Train regulatory officers/authorities (especially in agriculture and health programmes) on gender inclusivity (how to avoid gender bias, teach and empower female students, and prepare all students for a professional life that is inclusive and free of gender bias).

Improve educational and training opportunities for women especially in technical and leadership programmes so women can be sustainably influential at local, regional and national levels. Develop visual, multilingual, and low-literacy learning materials to be more efficient. Supporting a gender-balanced teaching environment can also improve equitable accessibility.

Ensure that participants and trainers with **parenting responsibilities are able to participate** when training is offered, by paying attention to wrap-around services (e.g. daycare and transportation).

CASE STUDY: GENDER-RELATED TRANSDISCIPLINARY APPROACH TO CHAGAS DISEASE IN GUATEMALA

"Approximately 6 million people, mostly in Latin America, are estimated to be infected with *Trypanosoma cruzi*, the parasite that causes Chagas disease, which can lead to life-threatening heart failure if left untreated. An insect vector commonly referred to as the "kissing bug" carries the parasite and can transmit it to humans, particularly those living in adobe huts with cracks and crevices where bugs can hide during the day and emerge at night to feed. Other modes of transmission include blood transfusions or organ transplants from infected donors, consumption of food contaminated with *T. cruzi*, and passage from an infected mother to her baby during pregnancy or childbirth. Effective treatment can only happen during the acute phase of infection, which often goes unnoticed due to its mild symptoms. The onset of clinically noticeable disease usually occurs many years later, and specific treatment at that stage is largely ineffective.

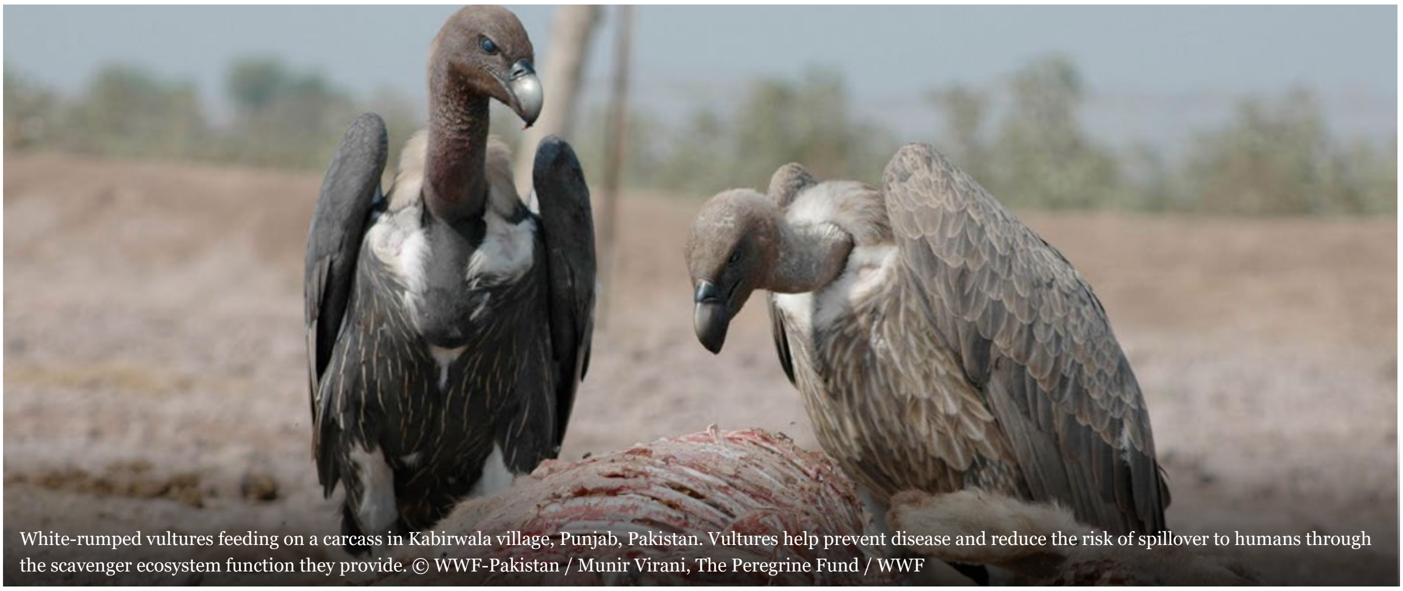
"Conventional approaches to vector control have relied on spraying dwellings with residual insecticides and repeated spraying is often necessary due to reinfestation from bugs living in the surrounding areas. An alternative, ecohealth approach was implemented with substantial success in Guatemala. A multidisciplinary team consisting of scientists, community leaders and government representatives designed a gender-sensitive approach that combined community education, community participation, and home improvements - particularly of the walls and floors - to make homes less habitable for the parasites. Importantly, an anthropological survey to understand women's traditional roles in wall plastering for home improvement was critical to the successful implementation of this community-level intervention. The efficacy of the home improvement technique relied on three key elements: (1) the expertise of the team of engineers who tested and selected the best combination of local materials to make a cost-effective mixture; (2) building local capacity for remediation by training community leaders, vector control specialists, and ministry of health representatives in home improvement; and (3) reducing the burden on women in home improvement duties by adopting new plastering techniques that last five times longer than traditional approaches. Additional keys to success were keeping farm animals outside the home, and supporting and empowering women through entrepreneurship programmes to improve household economies. Future efforts are being discussed to promote ecological restoration of deforested areas surrounding the communities in this project, which may provide habitat for the insect vectors and physical barriers to prevent house infestations."

Gender-related transdisciplinary approach to Chagas disease in Guatemala

GUIDING QUESTIONS

The following table provides some indicative (but not comprehensive) guiding questions which can be asked when planning gender and One Health interventions to support conservation.

DOMESTIC ANIMALS (INCLUDING LIVESTOCK)	WILDLIFE	HUMANS	ENVIRONMENT
What are the gender-based differences for tasks involving domestic animals?	Do women have access to knowledge concerning zoonoses during wild animal-sourced food preparation and sale?	Do women have power/ voices during meetings/ decision-making moments in the community?	Are women performing tasks that require them to spend time in natural habitats (e.g. wood, water collection)? What animal taxa do they come into contact with?
What are the barriers for women to control livestock assets?	Do men have access to knowledge concerning health risks during sourcing wild animals (hunting)?	What women's groups exist in the community?	Is there planned training on water- or soil-related pathogens, for both women and men?
Do women have access to veterinary knowledge and medicines?	What are the gendered sociocultural roles and responsibilities concerning wildlife?	Is there a programme on training and leadership for women and vulnerable people?	Do women have access to land for agriculture and house building?
Do women handle uncooked meat?	Do women handle uncooked meat?	Are women more involved in higher-risk tasks (washing soiled clothes, taking care of sick family and friends, cleaning latrines etc.)?	Do women tend to harvest more plants/insects?
Is there planned training on domestic animal-associated pathogens, for both women and men?	Do women have contact with rodents/bats or other high-risk taxa?	When planning activities that involve women, is there a budget for daycare?	Is there a gender-based division for collecting wood/water?
Are the voices of women incorporated into planning and implementation of new policies/programmes related to domestic animals?	Is there planned training on wildlife-associated pathogens, for both women and men?	Are the voices of women incorporated in the planning and implementation of new policies/programmes related to leadership, healthcare and economy?	Are women empowered in agriculture-related work?
	Are the voices of women incorporated into planning and implementation of new policies/programmes related to wildlife interactions?		Do women have the ability to control/contribute to their environment?
			Are the voices of women incorporated in planning and implementation of new policies/programmes related to environment and land-use plans?


White-rumped vultures feeding on a carcass in Kabirwala village, Punjab, Pakistan. Vultures help prevent disease and reduce the risk of spillover to humans through the scavenger ecosystem function they provide. © WWF-Pakistan / Munir Virani, The Peregrine Fund / WWF

MONITORING ONE HEALTH INITIATIVES

WHAT TYPES OF INDICATORS SHOULD BE USED?

Three main types of indicators are important:

1) Outcome indicators

2) Process indicators

3) Value-add indicators of One Health vs. working in a single discipline alone.

Outcome indicators and process indicators are both essential. To assess 'value-add' it's likely that a collaboration with a research institution would be necessary (where a government is not leading) as it's a complex aspect to assess, so value-add type indicators are optional.

All indicators should be identified/defined through a participatory approach with all actors involved in the project. As with all project activities, the development of the monitoring framework and indicators should involve conservation and development partners, institutional counterparts and local communities.

1. Outcome indicators

These are indicators that measure the outcome of the intervention. Ideally a One Health initiative would have both **disciplinary indicators** that are measurable within one discipline (i.e. animal health, ecosystem health and human health) and **interdisciplinary indicators** that measure the outcomes in at least two disciplines simultaneously.

- Examples of disciplinary indicators: access to health services or vaccination coverage (human health); habitat fragmentation (ecosystem health); vaccination coverage, mortality rates (animal health).
- Examples of interdisciplinary indicators: number of spillover events from wildlife to people or vice versa; number of zoonotic outbreaks that are jointly identified and managed (across human and animal health sectors).

The interdisciplinary indicators should be the focus, and will be the most interesting and important from a One Health perspective, but it may be difficult to show consistent causal links between the different disciplines given the complexity of factors and confounding or unknown variables. Interdisciplinary indicators that have a more robust scientific foundation for causality for a specific place should be used when possible - although focusing just on the indicators where attribution can readily be assessed may mean it's more likely to miss *how* things happen or do not happen. For example, forest fragmentation is associated with increased malaria incidence in some geographies. Within this relationship it might be difficult to conclusively link when one drives the other; however, where the association is more evident and the impact of malaria is costly and burdensome to people, including malaria rates as an indicator alongside forest fragmentation change indicators can deepen understanding of the linkages.

Outcome indicators will be context-and intervention-specfic. It's impossible to have one set of indicators that would fit every circumstance or every geography.

Often, One Health interventions will be oriented around reducing risk of zoonotic spillover. Measuring risk in itself is tricky, particularly change in risk over time. Risk may also be different for different people and can manifest in different ways within an individual (e.g. via trade-offs between risks). However, it may be possible to measure factors that would increase or decrease risk, and measure change over time in those factors to approximate the change in risk level.

2. Process indicators

Process indicators measure 'how' we implement One Health initiatives, and would normally be standard questions related to governance of processes, actors, how they worked together, if there is a shared responsibility/governance etc.

Process indicators (or questions) can cover the following areas:

- Operations
- Infrastructure
- Resources
- Common data sharing platform
- Integrated learning

There are a number of frameworks for process indicators, including the One Health Assessment for Planning and Performance (OH-APP) framework. As an example, the process indicators under the prevention of zoonotic diseases include aspects such as:

- Engagement of concerned stakeholders in multisectoral coordination mechanisms
- Procedures in place for sharing surveillance information, and for notifying international organizations
- Access to laboratory diagnostic facilities
- Existence of a shared database system
- Database and procedures for risk analysis in place
- Procedures in place for joint investigations
- Policies in place for intersectoral collaboration and funding mechanisms

Process indicators should be embedded within process evaluations that use quantitative, qualitative and mixed-method approaches to get to questions of 'how' and 'why' in these areas.

3. Added value of a One Health approach

Assessment of the added value of One Health is complicated. Added value usually refers to health, financial and environmental benefits. Indicators on added value would explore why a One Health approach brings more benefit than working within disciplinary silos. As noted above, this is likely only possible through collaboration with a research entity, as it is complex (and often done on a cost-benefit ratio). Solid research of this type is important as cross-disciplinary working will always be more expensive and time-consuming, and the information provided by these added-value indicators provides crucial justification for the application and scaling of the One Health approach.

WHAT ARE SOME EXAMPLE INDICATORS?

This section provides some example indicators, which can inform the participatory process of selecting suitable indicators. These example indicators are not intended to be comprehensive or even the best indicators to use, just ideas to start the thought process.

1. Landscape immunity

Ecological-based prevention of zoonotic spillover

- Rate of land-use change/deforestation
- Length of forest/ecosystem edge and ecosystem integrity (e.g. high-integrity forest)
- Indicators of community ecology, trends of keystone species (e.g. predator/scavenger populations)
- Disease risks in PCAs (sample indicators are available in this IUCN guidance)

River basin indicators

- The river basin scorecards practitioner's guide (example here) is useful for setting outcome indicators in consultation with communities. Disease burden is an example indicator, with a representative disease determined by relevance, incidence, and where there is a clear and most direct relationship to fragmentation and habitat conversion.

2. Wildlife trade

- Number of carcasses of species X (particularly of species with high zoonosis risks) on the market per period of time
- Percentage of a given population (ideally segregated by gender, age, educational level) who consume, own or trade in wild animals in a defined period of time
- Estimated total supply of wildlife meat in markets
- Prevalence of taxonomic risk categories of key faunal groups in trade
- Market trade risk could be defined as a composite indicator of welfare conditions of wildlife in trade (health and stress indicators); farms and markets with proximity between domestic animals and wildlife; existence and effective implementation of adequate regulations controlling trade in species with high zoonosis risks
- Number of rangers per hectare of forest
- Number of veterinary health control staff per administrative unit

3. Preventative medicine

- Rate of mortality/new cases (epidemic curve)
- Total dose of vaccines administered/% of population vaccinated
- Health screening diagnostic records for preventable diseases
- Prevalence of vector-borne disease

4. Pathogen early warning and surveillance

- Number of (wildlife) carcasses sampled
- Number of recorded pathogens entered into cross-disciplinary data sharing platform(s)
- Number of disease outbreaks in wildlife, human and livestock populations
- Number of cases of human and livestock infections linked to zoonoses of wild origin

5. Sustainable livestock

- Number of livestock successfully vaccinated
- Adoption of sustainable livestock practices
- Livestock density on forage area
- Use of local knowledge in feed production
- Livestock production units that have adopted good animal husbandry practices

6. Behaviour change and education

Outcome indicators:

- Measured change in target behaviour
- Change in attitudes/intentions toward a specific behaviour
- Improved knowledge on a specific topic (e.g. knowledge on the risk of zoonotic disease)

Process indicators:

- Number people reached in education sessions
- Number people engaged in community dialogues

CASE STUDY: BENGO ONE HEALTH PROJECT

From 2017-2021, a One Health behavioural change programme was implemented in two ecotourism sites in the Congo Basin: Campo Ma'an National Park in Cameroon and Dzanga-Sangha Protected Area in Central African Republic. The following indicators were used:

- Number of participants directly sensitized
- Number of participants trained in outbreak response
- Number of visual health checks of gorillas
- Number of disease outbreaks
- Number of faeces/urine samples collected and analysed
- Number of carcasses sampled
- Number of blow flies captured and sampled
- Number of capacity building measures

The above indicators allowed the following types of impacts to be measured, following baseline assessments and post-intervention assessments:

In 2018 only 31% of respondents in Campo Mann National Park and 50% in Dzanga-Sanga Protected Area took precautions against zoonotic disease infections; in 2021, 86% of respondents in Campo Mann and 91% in Dzanga-Sanga stated they did so. The number of mitigation measures known by respondents also increased from six to nine.

In 2018 only 25% of Dzanga-Sanga respondents recognized the need to cook meat well before consumption, while 47% did so in 2021; in Campo Mann understanding of the risks of wildlife consumption increased from 22% in 2018 to 59% in 2021.

Samples of 73 carcasses from deceased wildlife and 244 samples from diseased gorillas and employees active during respiratory disease outbreaks were tested and diagnosed.

Between 2017 and 2021, six respiratory disease outbreaks were observed in habituated gorillas, a 70% decrease from the previous period.

Western lowland gorilla (*Gorilla gorilla gorilla*) juvenile males, Dzanga Sangha Special Dense Forest Reserve, Central African Republic.
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ADDITIONAL RESOURCES

1. LANDSCAPE IMMUNITY

Reducing land use-induced spillover risk by fostering landscape immunity: Policy priorities for conservation practitioners

Land use-induced spillover: A call to action to safeguard environmental, animal and human health

Ecological Countermeasures for Preventing Zoonotic Disease Outbreaks: When Ecological Restoration is a Human Health Imperative

Unhealthy Landscapes: Policy Recommendations on Land Use Change and Infectious Disease Emergence

Boosting One Health in Africa by bringing water, sanitation and freshwater conservation together: A One Health WaSH partnership with CARE, WaterAid, IRC, Water.org

'Fencing for Conservation: Restriction of Evolutionary Potential or a Riposte to Threatening Processes?'

Addressing ecological connectivity in the development of roads, railways, and canals: Practical, feasible, science-based strategies to confront the impacts of infrastructure on the environment

Sustainable Wildlife Management Programme:

- Role playing game user guide: An instrumental data-collection tool for resource monitors
- Animal factsheets describe the animal's behaviour, the places of conflict, mitigation tools, approaches and strategies (elephant, hyena, lion, hippopotamus, baboon, crocodile)

Protected and conserved areas (PCAs):

- Healthy people and wildlife through nature protection: IUCN guidelines for prevention, detection, response, and recovery from disease risks in and around protected and conserved areas
- One Health principles for sustainable tourism in protected and conserved areas: accompanying principles to the guidelines for prevention, detection, response and recovery from disease risks in and around protected and conserved areas

Human-wildlife conflict/coexistence:

- IUCN Species Survival Commission guidelines on human-wildlife conflict and coexistence: first edition

Invasive species:

- WOAH Guidelines for assessing the risk of non-native animals becoming invasive
- IUCN Guidelines for the prevention of biodiversity loss caused by alien invasive species

Wetlands:

- EMPRES-i+: Global Animal Disease Information System
- East Asian-Australasian Flyway Partnership (EAAFP): A flyway-wide framework to promote dialogue, cooperation and collaboration to conserve migratory waterbirds and their habitats
- Ramsar Wetland Disease Manual Technical Report no. 7: Guidelines for Assessment, Monitoring and Management of Animal Disease in Wetlands

2. WILDLIFE TRADE

Additional resources are included in Table 2 within the wildlife trade section above.

3. PATHOGEN EARLY WARNING AND MONITORING

Developments in Animal Health Surveillance: An overview

Development of methodology to prioritise wildlife pathogens for surveillance: An example of pathogen ranking for a wildlife surveillance strategy

USAID PREDICT: Pandemic preparedness for global health security

Best Practice Guidelines for Health Monitoring and Disease Control in Great Ape Populations. IUCN Primate Specialist Group

Toward a global pathogen early warning system: Building on the landscape of biosurveillance today

WOAH Guidelines for Addressing Disease Risks in Wildlife Trade

WOAH General Guidelines for Surveillance of Diseases, Pathogens and Toxic Agents in Free-ranging Wildlife

4. PREVENTIVE MEDICINE

IUCN/WOAH Guidelines for Wildlife Disease Risk Analysis

Wildlife Population Health: Core competencies, tools and perspectives to manage free-ranging animal population health

Essential Wildlife Health Monitoring: Disease Risk Analysis and Health Surveillance

5. SUSTAINABLE LIVESTOCK MANAGEMENT

The International Livestock Research Institute: Livestock pathways to 2030: Seven ways to invest in One Health

Video: LRI speech on One Health

Herding 4 Health: Video example Limpopo National Park

6. BEHAVIOUR CHANGE

Behavior Change for Wildlife Conservation e-Library of resources (e.g. Change Wildlife Consumers toolkit, reports, case studies, webinars, booklets, courses)

Save Nature Please Framework: Using behavioural science for conservation

United Nations' Practitioner's Guide to Getting Started with Behavioural Science

The Behaviour Change Module of the One Health Courses developed by AFROHUN and SEAOHUN. Direct links here and here

SBCC (Social Behaviour Change Communication) I-Kit: A step-by-step guide to integrating gender into social and behavioural change

Behavioural Insights Team: EAST: Four simple ways to apply behavioural insights

The COM-B Model for Behavior Change - The Decision Lab

Educational resources (non-exhaustive list):

- Behaviour Change for Conservation: Online course to guide behavioural change for conservation.
- One Health Connecting Humans, Animals and the Environment: Online short course (six weeks) from the University of Basel, provided on FutureLearn platform
- One Health for Global Health Security: Course Series by Open WHO
- HORN Curriculum: Series of online eLearning modules, residential summer schools and residential masterclass events by the One Health Regional Network for the Horn of Africa (HORN)
- AFROHUN One Health Modules: Sixteen online modules organized by the Africa One Health University Network (AFROHUN) aimed at training and educating the current and future One Health workforce
- SEAOHUN One Health Modules: Fourteen online modules organized by Southeast Asia One Health University Network (SEAOHUN) aimed at training and educating the current and future One Health workforce
- One Health (online learning) MSc, PgDip, PgCert - University of Edinburgh (part-time, one to six years depending on programme)
- MSc One Health: London School of Hygiene and Tropical Medicine (one-year residential)

7. GENDER AND ONE HEALTH

AFROHUN course on Gender, One Health and Infectious Disease: Application of gender analysis tools to disease surveillance, response, and control (facilitator guide here)

Gender considerations in One Health: A framework for researchers

WWF Gender and illegal wildlife trade: Integrating gender into illegal wildlife trade thinking and responses

8. ONE HEALTH POLICY

Food and Agriculture Organization of the United Nations (FAO) - One Health: Agrifood system transformation

European Union - One Health

One Health Commission: Resources/Services

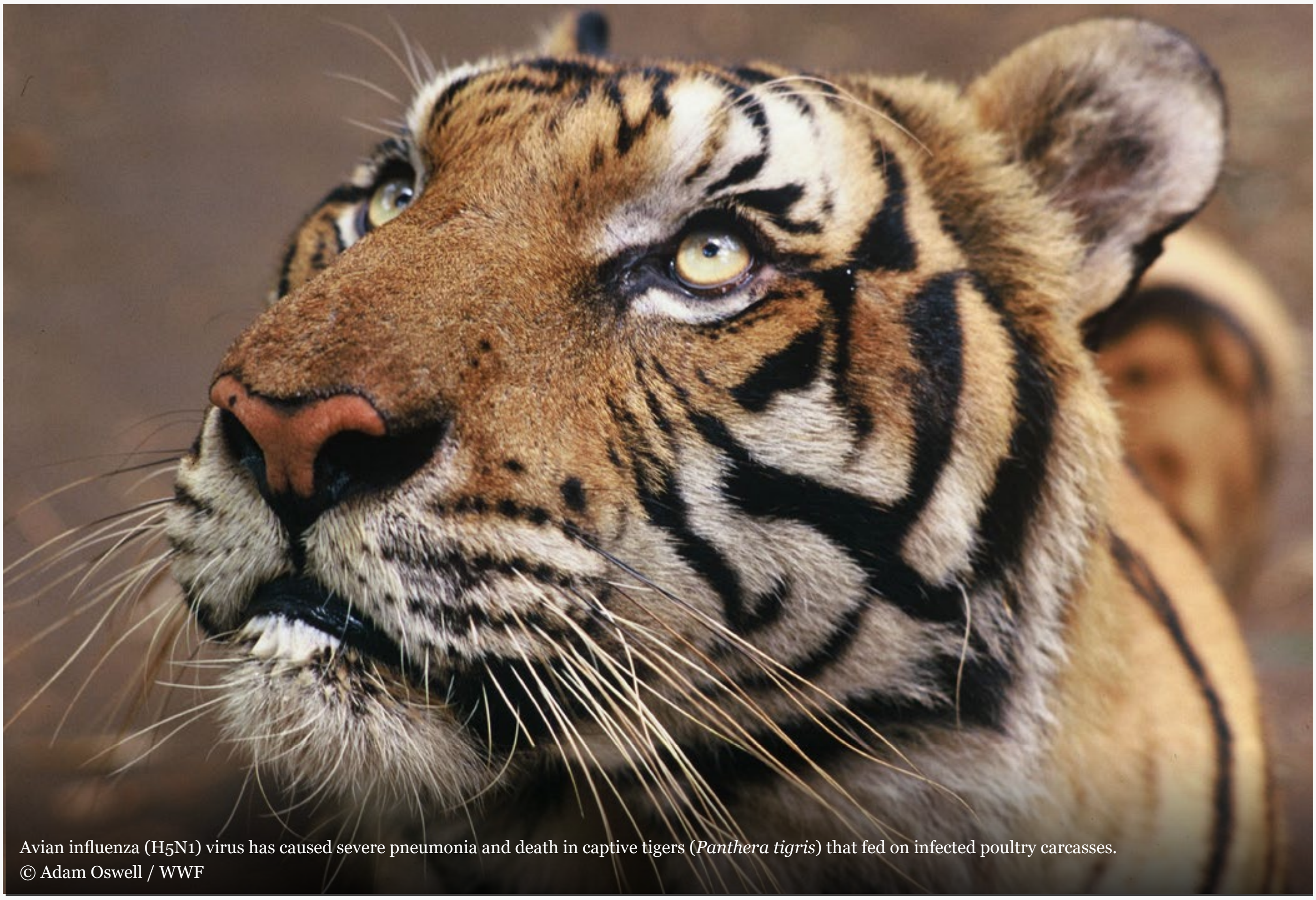
The Quadripartite (FAO, UNEP, WOAH and WHO) One Health Joint Plan of Action - Implementation guide: Pathways to operationalize the 2022 One Health Joint Plan of Action

Convention on Biological Diversity Global Action Plan on Biodiversity and Health: A draft global action plan to mainstream biodiversity and health linkages into national policies, strategies, programmes and accounts

9. MONITORING

World Bank – One Health (Annex 7 – indicators): Operational framework for strengthening human, animal, and environmental public health systems at their interface

World Bank Investing in Sustainable Livestock Guide: Animal Health Indicators



Avian influenza (H5N1) virus has caused severe pneumonia and death in captive tigers (*Panthera tigris*) that fed on infected poultry carcasses.
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