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

An overview for wildlife authorities and others working with wildlife

First edition

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Abbreviations and acronyms

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DNA	deoxyribose nucleic acid
ELISA	enzyme-linked immunosorbent assay
FAO	Food and Agriculture Organization of the United Nations
FETP	field epidemiology training programmes
FPIC	free, prior and informed consent
GPS	global positioning system
IACUC	Institutional Animal Care and Use Committees
IUCN	International Union for Conservation of Nature
NbS	Nature-based Solutions
NGO	non-governmental organisation
PCR	polymerase chain reaction
PPE	personal protective equipment
SSC	Species Survival Commission
SMART	Spatial Monitoring and Reporting Tool
UNEP	United Nations Environment Programme
WHO	World Health Organization
WHSG	Wildlife Health Specialist Group
WOAH	World Organisation for Animal Health

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1. Key terms for the purpose of this guidance

These terms are used to promote common understanding in this introductory guidance. *For official definitions, please consult the latest WOAH* Terrestrial *and* Aquatic Animal Health Code *glossary.*

Disease – any disturbance in the health or function of an animal or human. Disease can be linked to an infectious cause (e.g. pathogen) or non-infectious cause (such as toxic agents, chemical poisoning or cancer).

Diagnostic investigation – any procedure used to aid in the characterisation of the cause or nature of a disease, standardised procedures (e.g. post-mortem and subsequent microscopic examination of tissues [histology], often complemented by further screening tests).

Host – a species or population that is affected by disease or in which a pathogen is living (e.g. infected). A host may or may not be involved in onward transmission of a pathogen.

Infection – the presence of a pathogen within an individual which may or may not result in disease. A range of outcomes are possible when an animal becomes infected with a pathogen. Infection can be permanent or temporary. Individuals may:

- carry a pathogen or be infected with a pathogen, without developing disease (see **Reservoir**, below);
- develop a mild or moderate illness from which they recover;
- develop a persistent infection (carry and shed the pathogen but no longer show any signs of disease);
- develop a severe illness resulting in death.

Pathogen – an infectious agent capable of causing disease in a host, e.g. viruses, bacteria, fungi, protozoa, internal parasites such as worms and external parasites such as fleas, lice and mites, as well as other agents, e.g. transmissible tumours, prions.

Reservoir – a species or population that is a natural carrier of a pathogen and can present as the source of a pathogen for another species or maintain it in a population. Reservoir hosts may or may not experience disease.

Screening test – any procedure used (e.g. laboratory analysis) to aid in the identification of pathogens or toxic agents in an individual or sample, such as bacterial culture, molecular methods including polymerase chain reaction (PCR) for certain pathogens, or toxicological tests (see **Diagnostic investigation**, above).

Surveillance – the systematic ongoing collection, collation and analysis of information on animal health and the timely dissemination of information so that action can be taken (WOAH *Terrestrial Animal Health Code*). May be active or passive.

Toxic agent – a naturally occurring toxin (e.g. algal toxic agents) or synthetic compound toxicant (e.g. anticoagulant rodenticides, heavy metals and pesticides) that can have toxic effects. The distinction refers to natural versus human-driven occurrence. For this guidance, the term is used to refer to both toxins and toxicants.

Transmission – the process by which a pathogen passes from a source of infection to a new host. Transmission can occur directly between individuals; indirectly through a vector, such as a mosquito or tick; or from environmental contamination, such as objects contaminated by bodily fluids.

Wildlife – non-domesticated animals and plants. For the purpose of this guidance, wildlife refers to free-ranging wild animals. The definition includes wildlife in areas managed by public agencies as well as private entities (for example, both public parks and private game reserves).

Zoonotic disease ('zoonosis') – an infectious disease caused by any pathogen that can be transmitted between humans and other animal species (adapted from IUCN–EHA 2022).

2. Introduction

2.1. Background

Wildlife plays a vital role in our environment, health, culture and economy. Wildlife contribute to ecosystem services such as pest control, seed dispersal, and pollination; they promote care for and stewardship of the environment; provide a source of food, including for subsistence; serve as an economic engine in sustainable tourism, trade and other wildlife-based livelihood activities; and hold high cultural importance and – in many cultures – spiritual value as well.

Free-ranging wild animals face numerous threats, including pathogens, pollution, other anthropogenic causes, and natural events that can lead to disease and death. Thus, wildlife health is a foundation stone of the Global Biodiversity Framework's outcomes and an essential element for the success of specific targets that address disease, health, species extinctions and ecosystem services (e.g. Targets 4, 5 and 11) (Box 1). Like humans and domestic animals, wildlife can experience disease and may carry or be infected by pathogens or contaminated by toxic agents (Figure 1). Surveillance supports continuing understanding of these risks and impacts to inform effective action. Thus, surveillance is an essential contribution towards protecting wild and domestic animal health, conservation, public health, and economic and broader societal outcomes that can be threatened by disease, pathogens, or toxic agent exposures, and is a vital aspect of the One Health approach (Figure 2, page 10).

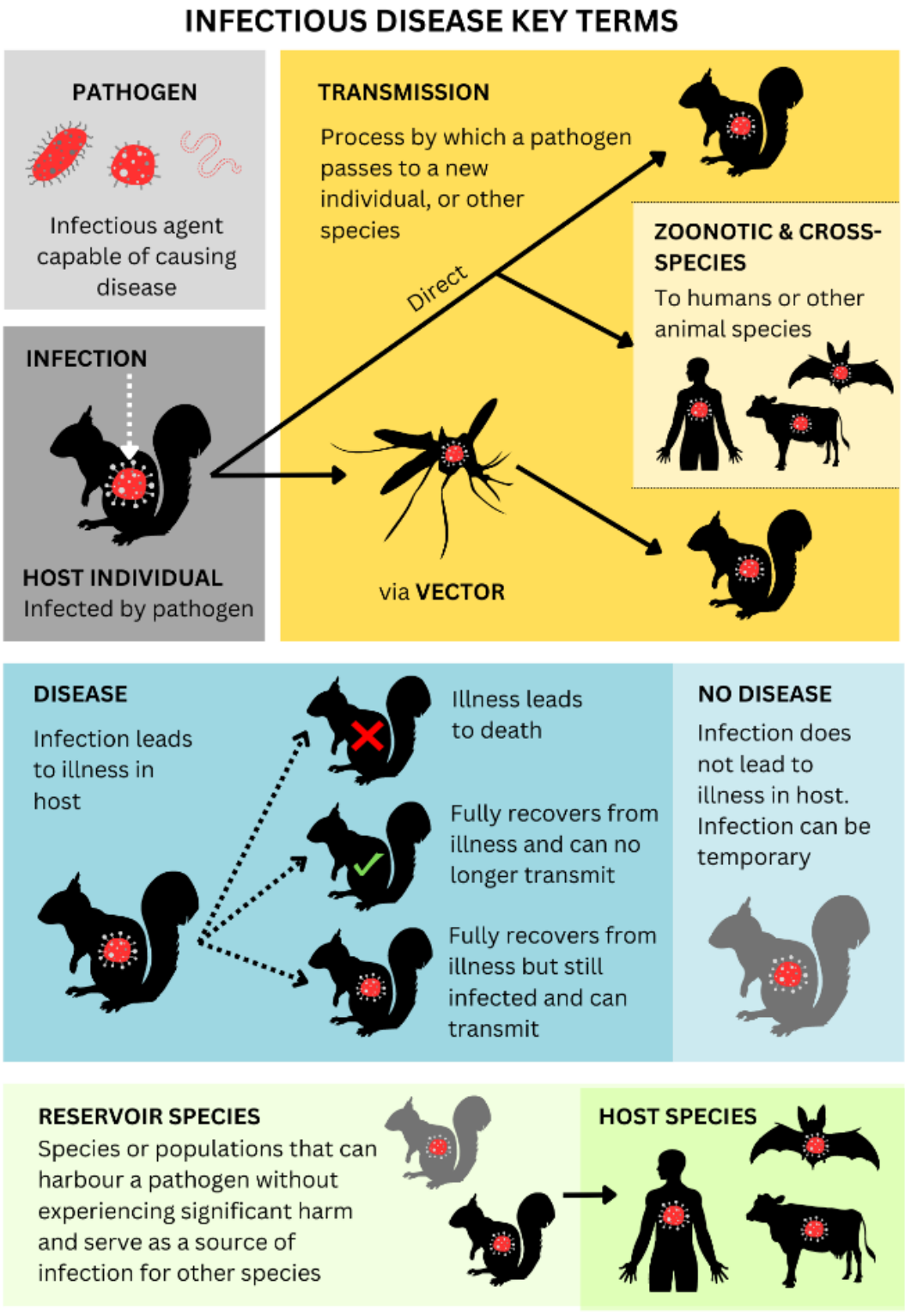


Figure 1. A simplified presentation of key terms related to infectious disease.

There are many features that make wildlife relevant for One Health. There are millions of wild animal species (mammals, birds, fish, reptiles, amphibians and insects) on Earth. Over 60% of human pathogens are zoonotic, and most recently emerging zoonoses have wildlife origins, yet, in contrast to domestic animals, there has been limited surveillance of wildlife. The drivers of biodiversity loss, ecosystem degradation, and emerging infectious diseases overlap, increasing the risks and impacts of wildlife disease and pathogen transmission. Indeed, the IUCN Red List of Threatened Species™ recognises pollution and disease as threats to species survival. Accordingly, the One Health Joint Plan of Action developed by FAO, UNEP, WHO and WOAH includes the following objective, to: 'Protect and restore biodiversity, prevent the degradation of ecosystems and the wider environment to jointly support the health of people, animals, plants and ecosystems, underpinning sustainable development.' Surveillance in wildlife plays an essential role in this understanding of One Health and the ability to take necessary, effective action.

Box 1. The Global Biodiversity Framework

The Kunming-Montreal Global Biodiversity Framework, adopted in 2022 by parties to the United Nations Convention on Biological Diversity, calls for action to halt and reverse biodiversity loss towards the vision of a world where: 'by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people'.

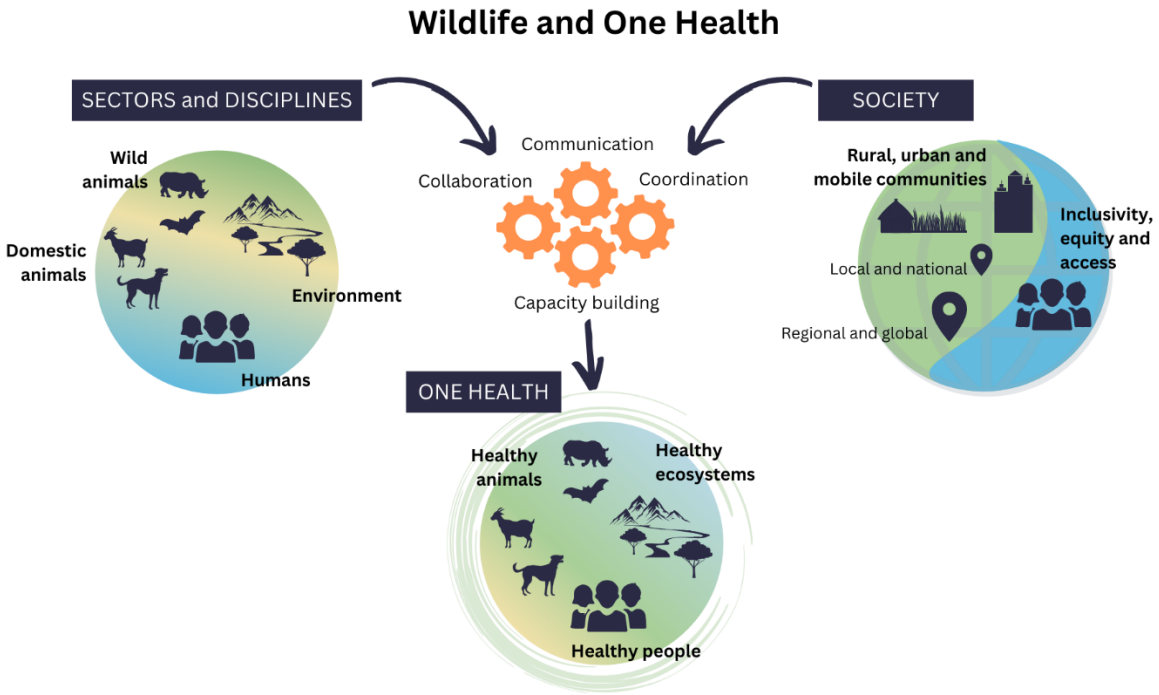


Figure 2. Components of One Health, reinforcing the relevance of wild animals to a One Health approach and target outcomes. Adapted from the One Health Definition Visual published by the One Health High-Level Expert Panel, 2021.

The World Organisation for Animal Health (WOAH) has a mandate to improve animal health worldwide, including the health of wildlife. Under the WOAH Wildlife Health Framework, the improvement of surveillance systems for early detection, notification and management is a core objective in pursuit of the goal to protect global wildlife health and achieve One Health (Annex I). Information gathered by surveillance leads to better understanding which is required to prevent, prepare for, manage and respond to health issues across all sectors. WOAH works with the IUCN and its Species Survival Commission (SSC) Wildlife Health Specialist Group (WHSG), alongside other partners, towards this mandate.

Box 2. Why wildlife surveillance?

Wildlife surveillance can have many practical uses for health and conservation, such as informing the epidemiological investigation of a disease event (e.g. identifying new locations or species affected by the disease) and monitoring the effects of changes in policies and practices (such as the introduction or phasing out of toxic chemicals). Information gained from surveillance can help in monitoring the drivers of species decline and exploring impacts on wild animal populations, including as part of species assessments under the IUCN Red List of Threatened Species™. Surveillance can also yield information about changes resulting from other drivers of biodiversity loss, such as the introduction of invasive species and the pathogens they may carry. The relevant uses will depend on the specific surveillance objectives. Further coverage of the use of surveillance information is provided throughout this document, with specific examples in Annex I.

Surveillance contributes to an ongoing understanding of risks and impacts to inform actions. Thus, surveillance is an essential part of protecting wild and domestic animal health, conservation, public health, and economic and broader societal outcomes that can be threatened by disease, pathogens, or toxic agent exposures, supporting the One Health approach.

Before designing and implementing any wildlife surveillance programme, its objectives must be clearly defined and communicated to all stakeholders. The objectives will determine the design of the programme and approach to implementation.

2.2. What is the purpose of this guidance, and who is it intended for?

This document provides broad guidance on surveillance of infectious and non-infectious wildlife diseases, pathogens and toxic agents to assist in the implementation of a national surveillance programme for free-ranging wildlife. It is intended to promote a common understanding, which can serve as a foundation for training and operational procedures.

While this guidance is geared to surveillance of free-ranging wildlife (whether in spaces managed by the public or private sector), much of the information is also generally applicable to (though not comprehensive for) wild animals in captive settings.

Box 3. Surveillance scenario

Below is a fictional but realistic scenario of a situation many Wildlife Authorities may come across in their work. As you read the following sections, keep this scenario in mind, thinking of the different components that go into a surveillance programme, as well as their practical application. As you will see, surveillance programmes vary widely around the world because of differing objectives and factors such as species, risks, resources and stakeholders. See Box 11 to follow this scenario further.

During a patrol, rangers find a dead antelope in the forest. The body (carcass) does not have any obvious signs of injury from hunting or attack. The rangers recall their One Health training and the surveillance programme recently put into place for situations like this. Being careful not to touch the carcass in case of disease risk, they take a photo from a few feet away while recording the location coordinates in their patrol reporting system. Next, they get the information to the site manager, who informs the relevant authority – in this case, the Veterinary Services. An agreement and budget are already in place for the park and Veterinary Services authorities to work together to exchange information and conduct disease investigations. The Veterinary Services authority uses this information to consider potential causes (checking with other partners to see if there have been reports of ill health in other wild animals, domestic animals or humans), and, if thought necessary, sends a trained sampling team to collect samples. The type of samples collected, and the subsequent laboratory testing methods are based on solid epidemiological and laboratory expertise, as well as practical logistics, cost considerations and biosafety protocols. The Veterinary Services authority shares information from its investigation as it progresses. The rangers are asked to keep their eyes and ears open in case there are any other dead antelopes – or other species – seen or reported in or around the park. Information about the event, including the date, location, species, number of individuals affected, and any diagnosis, is entered into a national wildlife health database and is reported to WOAH if it meets the criteria for international reporting. Based on what wildlife managers learn from this investigation, and the relevance for human, animal and environmental health (also considering previous surveillance findings in humans and domestic animals, as well as environmental samples), the information from this investigation could inform the country's routine wildlife surveillance programme and resulting actions by Wildlife Authorities and other relevant authorities. Depending on the cause and context, examples of actions could include:

- increasing conservation-based solutions for antelope populations
- proactive communication to the local community during increased detection of a pathogen or toxic agent
- changes in policies (e.g. those related to pollution)
- deployment of vaccination strategies
- other measures as relevant and appropriate.

The primary audience is national wildlife health and management authorities ('Wildlife Authorities'), including WOAH National Focal Points for Wildlife, as well as other groups responsible for managing wildlife in protected and conserved areas, Indigenous Peoples, local communities, private landowners,

and park and reserve managers. However, a much wider range of stakeholders play a meaningful role in surveillance, including those working in occupations that bring them into contact with wildlife (see Annex II).

The guidelines complement WOAH's e–learning modules on Wildlife Disease Surveillance, which provide background on key concepts and the importance of surveillance. Together, they provide a general understanding of the 'Why', 'What' and 'How' of surveillance, as well as complementing WOAH's dedicated training manuals on wildlife health, surveillance, communication and disease control, and IUCN's publications on wildlife disease risk analysis and protected area management (please see 'Additional resources and references', below).

2.3. What is the difference between surveillance of pathogens and toxic agents, and surveillance of wildlife diseases?

Surveillance of pathogens and toxic agents refers to surveillance focused on the detection of pathogens, toxic agents or other agents (e.g. prions) that may or may not lead to disease in an animal. Pathogens may be detected in the animal, its secretions and excretions in the local environment, or, in the case of vector-borne diseases, in captured vectors. Toxins may also be detected in the animal or in the environment (including feed and water sources) to which the animal is exposed. Pathogen/toxic agent surveillance is often used when infection with pathogen(s) or the presence of a toxic agent or chemical may not always produce visible signs associated with disease (e.g. illness or death) in a given species or at a given point in time. Surveillance of pathogens may include surveillance to look for exposure to a pathogen (sero-surveillance, which detects antibodies in the animal) as well as the pathogen itself (antigen detection). Sometimes the two types of surveillance are combined.

Species can play various roles in pathogen circulation. These roles are sometimes distinguished by the terms 'reservoir species' and 'host species' (see 'Key terms for the purpose of this guidance' and associated Figure 1, above). Similarly, toxic agents can affect species in different ways based on physical, chemical and ecological factors. For this reason, it is important to consider which species to target for surveillance as well as what screening tests to perform and when for infectious and/or toxic agents. For example, the Natal multimammate rat (*Mastomys natalensis*) is considered the 'reservoir' species of Lassa virus, whereas humans are considered a susceptible 'host' species. Thus, surveillance in the rat population could indicate risk to humans before any detection of human infection. In addition to improving our understanding of pathogens circulating in an animal or species, pathogen or toxic

agent surveillance can detect threats to a broader population or species, as well as to other species of wild or domestic animals or humans.

Disease surveillance refers to surveillance focused on disease detection through the observation of clinical signs (e.g. illness or death). Disease may be linked to infectious (e.g. pathogenic) or non-infectious causes (such as toxic agents, chemical poisoning, radiological causes or cancer). Clinical signs associated with disease in wild animals may appear as morbidity (sickness/illness detected by physical or behavioural signs) or mortality (death, detected via dead animals, carcasses or parts of their remains). Disease surveillance is typically performed by diagnostic investigation of animal carcasses or through the collection of samples from sick or dead animals to determine one or more infectious or non-infectious causes. Investigation may involve screening for pathogens and toxic agents (in response to visible signs of disease), or diagnosis based on visual or physiological indicators. In addition to noticing the effects on individual animal(s), disease surveillance can detect threats to a broader population or species, as well as other species, including wild or domestic animals, or humans.

Readers may wonder about the difference between surveillance and monitoring. While these terms are related, they can be distinguished as follows.

- **Surveillance:** The systematic ongoing collection, collation and analysis of information related to animal health and the timely dissemination of this information so that action can be taken.

- **Monitoring:** The intermittent performance and analysis of routine measurements and observations, aimed at detecting changes in the environment or health status of a population.

While research activities can contribute important information and understanding to inform surveillance and actions, they are not a substitute for surveillance programmes. Surveillance programmes are intended to lead to concrete decisions and action (including communication and management), as needed, on a continuing basis, whereas research activities may have other objectives and timelines.

Box 4. Potential uses of surveillance information

Depending on the scope and objectives, information collected from surveillance may:

- provide a baseline understanding and allow for detection of changes;
- detect immediate or potential threats and impacts, including emerging diseases;
- support species conservation assessments and the development of action plans;
- evaluate the effectiveness of disease management and risk reduction initiatives and guide refinements as needed;
- demonstrate the absence of a disease or pathogen;
- inform risk and impact assessments for human, animal and environmental health.

The objective of a surveillance programme should be clearly defined as to whether it aims to detect one or a combination of diseases, pathogens or toxic agents as well as to the intended use of the information. Different objectives can be linked to various surveillance methods or approaches (see pages 18–23).

3. Operational aspects

3.1. What roles and responsibilities are important for wildlife disease, pathogen and toxic agent surveillance?

In many cases, rangers, hunters, local communities, and Indigenous Peoples play a key role in the detection of disease events in wildlife. They are often the first people at the scene, interact very regularly with wildlife, and have an important understanding of what may be unusual in relation to wildlife health. They often have a presence or authority in settings where other agencies may not, making their role in the surveillance system invaluable. At the same time, agencies responsible for wildlife and the environment may not have all of the elements in place for surveillance (e.g. mandates and the capacity for veterinary expertise, animal sampling and biosafety, and laboratory support).

Samples can help in making a diagnosis. If you see a sick or dead wild animal, do not touch it. Get in contact with a veterinary expert who can carry out the next steps, using appropriate personal protective equipment (PPE) and biosafety measures.

Surveillance requires the combined and coordinated expertise of people and groups who can respond to observations or detections, carry out investigations, and interpret and communicate findings. Thus, it is important to ensure that the relevant legal framework/legislation is in place to provide mandates for wildlife/environment departments or managers to act on wildlife health issues and for Veterinary Services to engage with them. It is also crucial that roles and responsibilities are clearly defined in any surveillance programme for wildlife diseases, pathogens and toxic agents. This includes establishing a process and chain of command for communication to the Veterinary Services; relevant decision-makers; local, regional and national elected officials; and rights-holders; as well as feedback to the stakeholders who first detected the disease, pathogen or toxic agent, in order to maintain trust.

The WOAH National Focal Points for Wildlife are a key resource in WOAH Member Countries and Territories for the development and success of wildlife disease surveillance programmes. When empowered in their role, they support these programmes by coordinating a network of people and institutions to participate in wildlife disease surveillance, promoting effective collaboration and reporting, and identifying needs for national capacity-building. For wildlife specifically, there is a need for interaction and solid collaboration with existing wildlife management and environmental programmes and constant updating of knowledge to ensure that surveillance, management actions and broader risk analysis reflect best practice.

Depending on the purpose and approach of the surveillance programme, information and expertise may be sourced from a variety of stakeholders (see Annex II). For example, indigenous knowledge holders and managers have an in-depth understanding of wildlife behaviour, physiology and health. A range of settings could also be relevant, including wild settings and along wildlife trade chains; for example, where available and appropriate, samples may be provided by hunters or collected from wildlife carcasses. Zoos, animal sanctuaries and other captive settings can be a valuable source of information on wildlife diseases and pathogens (whether from monitoring or surveillance). For example, the detection of disease in wild animals in zoos, facilitated by proximity to humans, informed early risk assessments of COVID-19 in great apes. While surveillance information from captive animals can contribute significantly to surveillance systems, they are not a complete substitute for surveillance in free-ranging populations.

Key messages

- Surveillance requires the combined and coordinated expertise of people and groups who can respond to observations and detections, carry out investigations, and interpret and communicate findings.
- Defining stakeholder roles and responsibilities, including relevant communication channels, is an important part of effective implementation.
- Ongoing stakeholder engagement should be built into surveillance programmes, including information feedback (e.g. guidance, news of results), to encourage continued engagement and reporting, as well as the adoption of any necessary actions resulting from surveillance findings.

3.2. What are the key steps to follow when designing a surveillance programme?

Surveillance programmes ideally operate within a comprehensive national system that incorporates risk mitigation strategies. For wild animals, a national wildlife health surveillance system collects information from multiple programmes across the country, linking up resources to identify and manage risks to humans, animals and the environment.

There are many aspects to consider when designing, developing, implementing and evaluating a surveillance programme. In general, eight steps can help to guide key decisions (Figure 3, page 19).

Throughout these steps, consider factors such as the:

- role and engagement of different stakeholders, partners, collaborators and rights-holders, including Indigenous Peoples;
- location/setting (e.g. protected area, community forest, village, sanctuary, urban area, reserve, market, etc.);
- species or taxonomic group of focus for the surveillance;
- type of information (e.g. visual observation) or sample to be collected;
- screening test(s) to be run, as relevant;
- use of the data (e.g. as part of a risk assessment, to inform or evaluate a disease management initiative, or inform an awareness campaign);
- limitations of the information generated (e.g. representativeness of the study population and potential sources of bias);

- resources available (human, financial, technical, logistical, etc.);
- feasibility, including logistical factors (e.g. road condition, cold chain) and field and laboratory biosafety;
- biological risk management – safety of personnel, animals and the environment during sample collection, handling, shipment, laboratory testing and storage;
- legal and cultural considerations (community protocols, permissions to access sites and/or interact with protected or culturally significant species, transport samples, data ownership, etc.);
- ethics – animal welfare, local customs, consent from local stakeholders, proprietary rights over biological material.

Surveillance programmes should be co-developed and co-managed through the direct participation of Indigenous Peoples in activities that affect their lands and territories and the species they make use of and depend upon. This will provide transparency for the Indigenous Peoples' community that is directly involved, as well as for the surrounding affected Indigenous Peoples' communities.

3.3. What surveillance strategy should be used?

Surveillance programmes should consider what information is important, as well as the sources of the information gathered, to serve the target objectives. In the design or refinement of a surveillance programme, thought should be given as to whether general (passive) or targeted (active) surveillance is more appropriate to achieve the programme's specific aims.

Under those broad categories, surveillance can take many forms, such as using more specific criteria or tailoring the surveillance to particular stakeholders. For example, it is not practical to have targeted surveillance programmes for every pathogen or toxic agent; therefore, hazard identification and risk assessment can be useful tools to inform surveillance priorities. Risk-based approaches focus on populations or settings considered to be at risk or a source of risk where exposures are occurring (sometimes called 'interfaces'). For example, surveillance could be conducted in areas where gorilla trekking tours are taking place, based on the known risk of disease transmission from people to great apes. Information on changes in land use and extreme weather events (flooding/droughts) could be used to inform the prioritisation of sampling in key locations. Typically, programmes will make use of multiple surveillance strategies to maximise resources across the range of priorities, situations and conditions in a country.

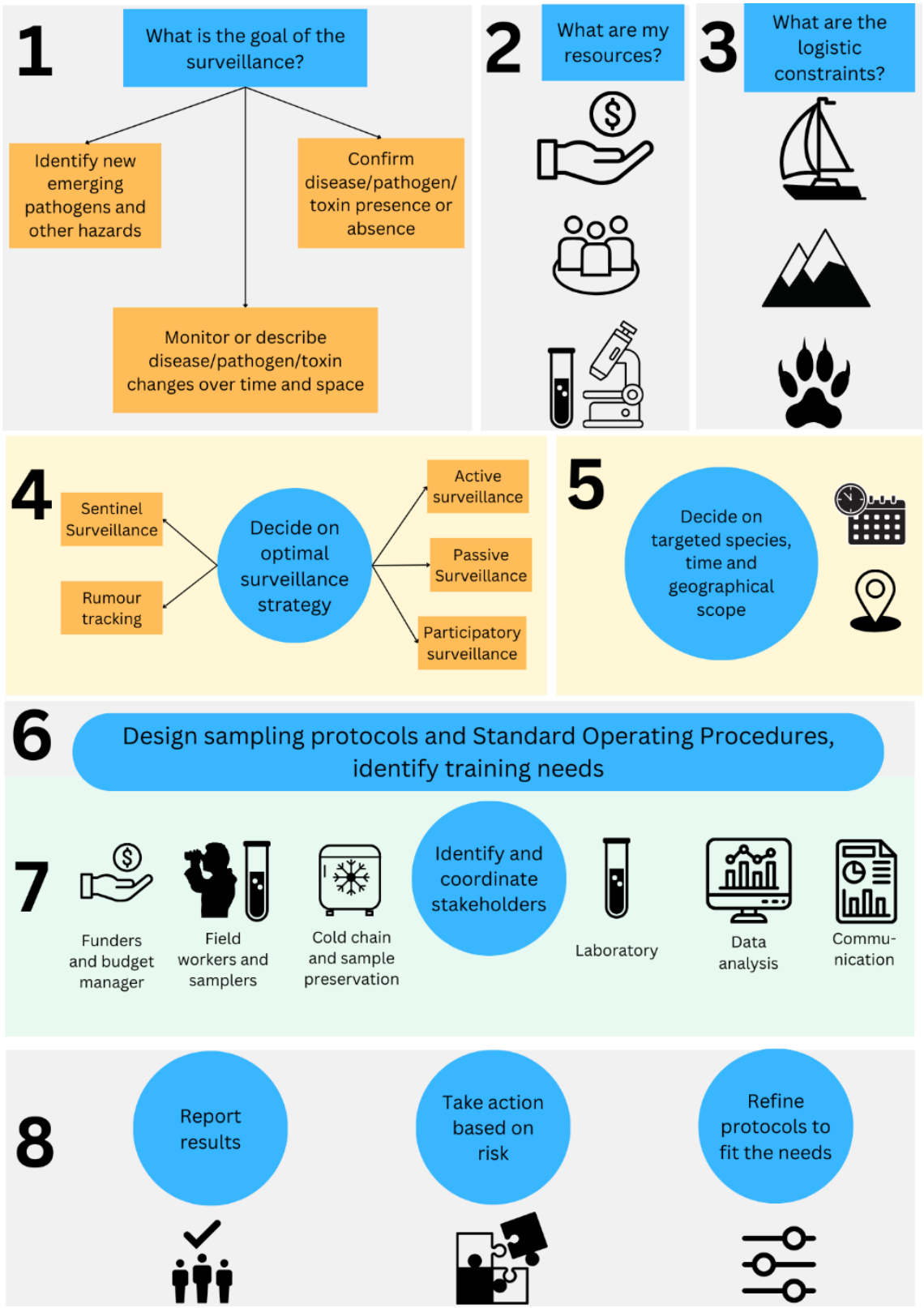


Figure 3. Steps to consider in the design of surveillance programmes.

Table 1. Types of surveillance.

Surveillance type	Active (targeted) surveillance	Passive (general) surveillance
Description	Active surveillance involves the systematic testing of animals, whether sick or healthy, to detect the presence of a specific disease, pathogen or toxic agent. This system involves the collection of information (e.g. visual observations) or samples (e.g. faecal, blood, urine, etc.) from wild animals, followed by analysis Examples: In some countries, avian influenza virus surveillance is conducted via the annual collection of samples from wild birds to determine the circulating virus strains and their effects on wild bird populations. Mange surveillance in wombats involves proactively walking the transects of a geographic area to identify wombats with visual signs of disease	Passive surveillance relies on the reporting of sick or dead animals, followed by investigation to determine the cause Example: park rangers may observe suspected disease events in wild animals and report them (for example, the dead antelope in the example at the start of these guidelines). A member of the public or field ecologist might notice unusual behavioural signs in numerous individuals in a population, such as an inability to move, and report them
Purpose	• Active surveillance is used to determine the level or distribution of a disease, pathogen or toxic agent in a specific host or reservoir species • Active surveillance focuses on one or more diseases, pathogens or toxic agents (for example, organophosphate pesticides) in one or more wild animal species, during specific season(s) or in a specific location(s). It is typically used to obtain statistical data on prevalence, age and sex distribution of infection, or geographic distribution	• Passive surveillance is typically carried out by diagnostic investigation of animal carcasses or collecting samples from sick or dead animals to determine a diagnosis or the infectious and/or non-infectious cause (there may be multiple causes) • Screening tests for specific diseases, pathogens or toxic agents may use animals reported through a passive surveillance strategy. For example, barn owls found dead by members of the public may be used specifically to monitor rodenticide toxic agents that can be harmful to a broad range of predatory birds
Design and scope	• Specific decisions must be made on sample size, sampling times and locations, specific species, and number and type(s) of observations/samples to be collected in targeted surveillance programmes • There are often challenges in getting a representative sample base, but this approach can more precisely estimate prevalence or incidence. Unique field	• A wide range of stakeholders (hunters, wildlife rangers, community liaisons, citizen scientists, conservation organisations, etc.) and rights-holders (e.g. Indigenous Peoples) may be involved in an opportunistic disease detection network for general surveillance • For the detection network to be effective, key stakeholder groups who interact with

Surveillance type	Active (targeted) surveillance	Passive (general) surveillance
	methods (such as radar tracking or mark–recapture) may be necessary to estimate population size and structure	wildlife should be aware of the role they can play, what to look for (e.g. clinical signs), what information to collect, how to report and who to notify. This approach may need capacity building, awareness raising, and possibly the development of a reporting app/platform/other channel
Costs	• In some cases, the costs associated with active surveillance tend to be higher than those of passive surveillance, as active surveillance may require investment in specialised equipment and trained personnel • The process of collecting observations and samples may be time-consuming, and the cost of data/laboratory analysis can also be high	• The costs associated with passive surveillance tend to be relatively low as it generally relies on the public to report any incidents of sick or dead animals • The main costs associated with passive surveillance are related to training staff who analyse and investigate the reports, diagnostic investigation and laboratory analysis of samples, raising the awareness of network members and training them (e.g. community liaisons), and communication and coordination of the surveillance network (e.g. notebooks and pencils, phones, transit costs, etc.). A diagnostic investigation can become expensive if the diagnosis is not clear after initial diagnostic investigation, as specialist screening tests may be required

Active and passive surveillance are complementary. Under either of these broad categories, surveillance strategies can take more distinct forms, e.g.:

- **Event-based surveillance** is the rapid capture of information that might signal an outbreak early. The information gathered can include rumours or *ad hoc* reports via formal or informal channels (e.g. social media) on events related to the occurrence of disease (e.g. reports of sick wildlife) or potential exposures (e.g. a suspect illness in humans handling, consuming or using wildlife products).

- **Sentinel surveillance** often refers to the collection of information from specific, designated sites or species. When used in a One Health context, it typically refers to detection in a species

or population that can signal a potential threat to other animals and the environment, trade or public health. For example, second-generation anticoagulant rodenticide residues in the livers of barn owls found dead from across Britain are monitored annually to determine whether there has been any change in toxic agent exposure in this wildlife sentinel. Any change could help inform the understanding of the effects of contaminants on predatory birds and possible implications for ecological processes relevant to ecosystems and human health (for example, rodent control).

- **Syndromic surveillance** monitors non-specific signs of disease. This type of surveillance is not usually focused on a particular pathogen or toxic agent so can be used to detect a variety of diseases or pathogens, including new (emerging) diseases. A syndrome is a collection of frequently associated clinical signs putatively linked to infection with a given pathogen or pathogen(s) or exposure to a toxic agent. For example, skin lesions in amphibians can be a sign of infection with chytrid fungus.

- **Participatory surveillance** involves bi-directional engagement of communities and supplements traditional surveillance information networks to collect knowledge and information on health events (for instance, through reports of animal sickness and death). For wildlife, a key example is the participation of communities living in and around protected and conserved areas.

- **Integrated surveillance** involves combining multiple approaches for a comprehensive surveillance system.

Box 5. Weighing costs and benefits

Surveillance involves much more than just taking samples or running tests in a laboratory. Careful thought should always be given as to whether the benefits outweigh the costs and to ensure that all steps in the system are properly set up! Otherwise, resources can easily be wasted and potential human, animal and environmental health risks may not justify the costs.

While these multiple types may initially seem complex, they offer flexibility in the design of surveillance programmes to best serve specific objectives and fit within the practical constraints that a country may face. Consultation with wildlife health, One Health and laboratory experts as well as epidemiologists can help Wildlife Authorities to select the best approach(es) (see 'What Roles and responsibilities are Important?'; see also Annex II). Over time, initial surveillance information will allow improved understanding of risk and help to inform future surveillance strategies.

Key messages

- Surveillance programmes take many forms, varying significantly in their breadth and specificity, as well as in the resources required to meet their goals.
- The design of surveillance programmes may be directed to detection in specific sites, seasons or species, as informed by hazard identification or risk assessment.
- Any surveillance strategy should be well defined to serve its intended objective(s), considering the different potential sources of information and stakeholders, and their strengths and limitations.

3.4. What samples may be useful?

Depending on the purpose and design of a surveillance programme, sampling may or may not involve the collection of biological samples from wildlife. The most appropriate samples to collect depend on the type of surveillance and what one is looking for.

A biological sample may include blood, urine, faeces, or tissue samples, such as skin or organ tissue or swabs (see 'Biological samples and tests', below). Sampling may require the collection of biological samples directly from the live animal or carcass (e.g. via post-mortem or buccal, cloacal, anal or other swabs), or indirectly, via non-invasive sampling of hair, feathers, faeces, urine, saliva or even blow/breath collection from marine mammals. For example, urine or faeces (guano) can be collected indirectly by spreading plastic sheets under known bat roosts. A non-biological sample may include collecting visual observations, either directly or via remote sensing (e.g. using camera traps to identify animals with visible hair loss due to sarcoptic mange).

Sample type, storage procedures, and types of tests play an important role in what information can be gleaned from surveillance.

Existing and approved capture, handling, sample collection, sample transport, and testing protocols should be used to determine and prepare for sampling, including appropriate qualifications and the use of PPE (see 'What Roles and Responsibilities are Important?'). Seeking advice from the Competent Authority (Wildlife and Veterinary Services) and other key experts can ensure that sampling is effective, feasible and realistic, and will result in the desired surveillance outcome. The WOAH *Training Manual on Wildlife Health Information Management* and *Manual on Sample Collection and Transport* are key sources of information (while the latter is focused on foot and mouth disease surveillance, it highlights

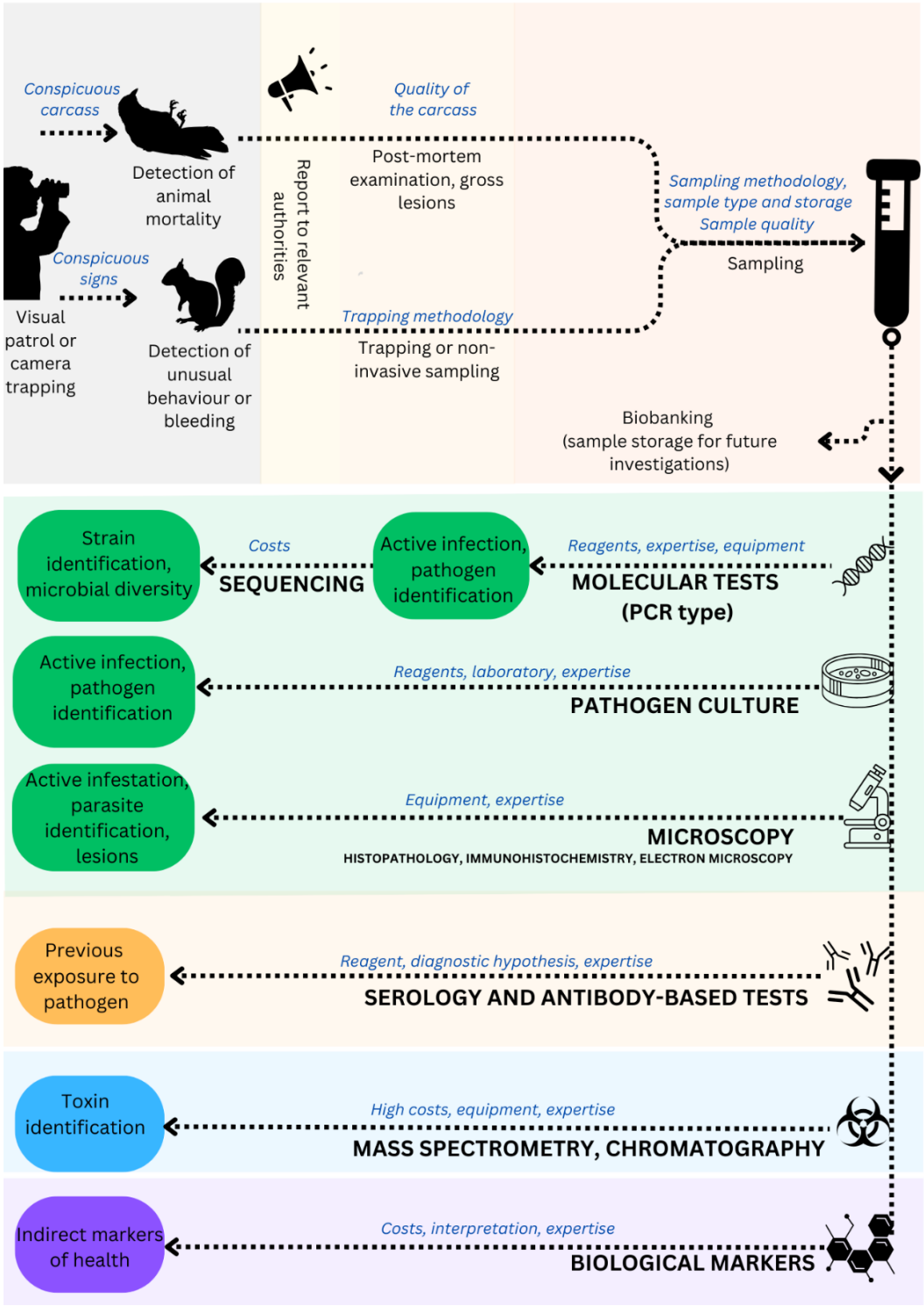
considerations that are broadly relevant). WOAH's dedicated training manuals on wildlife health, surveillance, communication and disease control, specifically the 1st, 2nd and 4th cycle manuals, include additional information on sampling and diagnostic tests. In addition, the WOAH *Manuals of Diagnostic Tests and Vaccines for Terrestrial Animals* and *Aquatic Animals* both provide specific information for laboratories.

Biological samples and tests

A wide variety of possible detection methods can be considered in the design of a surveillance programme (Figure 4). In general, a specific pathogen or toxic agent will have a particular test or group of tests that are recommended for use in diagnosis or investigation of that agent. Each test may require a specific type of biological sample. A number of different biological samples may be used to test for diseases, pathogens and toxic agents (see Annexes III–V). These include:

- serum, plasma or whole blood
- mucosal swabs (from oral/buccal, nasal and/or urogenital cavities, conjunctiva, cloaca, or the rectum/anus)
- faeces or urine
- scrapings or samples of skin, fur, feathers, or scales
- biopsies (small samples of skin or another organ collected surgically from a live animal)
- samples of pus or other discharges
- tissue and organ samples (e.g. collected during post-mortem investigation, from hunter surveillance programmes, etc.)
- environmental genetic evidence (e.g. environmental DNA [eDNA] to detect a pathogen in a body of water in which an animal lives).

Note that some of these sample types may already or readily be routinely collected in wildlife population and biodiversity surveys (and general health assessments, where conducted), with potential resource efficiencies for collection and screening. Additionally, in some cases, archived samples may be available. These may be valuable in helping to understand the historical situation and in comparing current findings. Co-variate data can also provide important information for putting findings into context (Box 6).



PCR: polymerase chain reaction

Figure 4. Individual animal mortality and morbidity investigation. The blue text shows the critical points (requirements or limitations) for each step. Note that not all observations of death or sickness in animals will necessarily lead to sample collection and laboratory screening.

Generally, each specific diagnostic test or detection method requires a specific type of sample. Some tests can be performed on a wide range of samples. The accuracy of tests can also vary. For example, field-based tests (where available) may be useful in remote settings but may not be validated or practical for all settings, conditions, pathogens or toxic agents. In general, laboratory-based tests offer a wider scope of testing and quality control, among other considerations. Please consult with diagnostic, laboratory and technical experts on the most appropriate sample types, techniques, storage, shipment, and biosafety requirements. The network of WOAH Reference Laboratories and Collaborating Centres can be found online to support your needs.

Box 6. Additional information to collect – wildlife populations and threats

In addition to the detection of diseases, pathogens, and toxic agents, samples can be used to collect information on wildlife populations and the source of threats. Such co-variate data can help to provide a complete understanding of ecological and epidemiological dynamics and, in turn, the interpretation of disease, pathogen or toxic agent surveillance data (whether as a baseline or as part of a disease investigation). Relevant information will depend on the context. Illustrative examples include:

- species of animal (e.g. based on visual information);
- event identifiers (e.g. date, location);
- demographic information (e.g. sex, life stage, weight of animal);
- mineral profile (to determine the geospatial origin of a bird);
- stomach content (to identify possible exposures);
- environmental samples (water, soil, sediment, plants, etc.), e.g. for pollutants and toxic agents such as heavy metals;
- abiotic parameters (e.g. temperature, rainfall, salinity);
- a description of the signs of illness/death including the number of animals affected.

Sometimes a combination of different tests may be used in the surveillance programme, depending on its objective. For example, sero-surveillance (via collection of blood samples) may initially be carried out to assess whether a population has been exposed to a pathogen, before more targeted surveillance (to detect the pathogen itself) is conducted.

Proper storage is crucial to maintain sample quality. Maintaining a cold chain often presents a challenge in remote settings, particularly in areas with limited access to consistent electricity. Some alternatives to cold storage have been developed to preserve samples (e.g. the use of stabilisation reagents). At present these options may not be readily available in all settings.

For most Wildlife Authorities, the use of visual detection should be considered the first component of setting up a wildlife disease surveillance programme. Information from physical and behavioural monitoring can help to identify a potential disease event and trigger a disease investigation (see Box 7). Collaborations with veterinary and other professionals can be developed to support wildlife capture,

sampling, transport, and laboratory functions necessary for other surveillance methods. For example, some Wildlife Authorities have in-house veterinarians, whereas others may form links to national or sub-national Veterinary Services to mobilise qualified veterinary staff when needed. Certain capture techniques, such as immobilisation, are highly complex and require specialised training and equipment.

Box 7. When should we be alarmed?

It is difficult to accurately assess the importance of a disease situation based only on visual observations, because some wild animals may carry serious pathogens without showing signs. However, the following situations may be especially concerning and urgent given the potential risks they could present (e.g. zoonotic disease):

- **Something unusual or different:** unusual, unexplained illness or deaths or numbers of deaths, including those in neighbouring jurisdictions;
- **Neurological signs:** unusual behaviour;
- **Unclotted blood coming from any orifice (mouth, nose, rectum, etc)** not linked to normal birth, menstruation or estrus.

3.5. Why and what should be reported to WOAH?

WOAH Member States and Territories are obligated to report on 'Listed diseases' and 'Emerging diseases', defined as a disease, infection or infestation listed in Chapter 1.3. of the WOAH Terrestrial and Aquatic Animal Health Codes, as adopted by the World Assembly of Delegates. Emerging disease means a new occurrence in an animal of a disease, infection or infestation that causes a significant impact on animal or public health, resulting from a change in a known pathogen or its spread to a new geographic area or species; or a previously unrecognised pathogen or disease diagnosed for the first time.

In general, the WOAH Listed Diseases are important for international trade and may be a threat to species conservation and public health. In addition, WOAH recommends that Delegates track certain infections, diseases and unusual events in wildlife on a voluntary basis (referred to as WOAH's 'non-listed pathogens and diseases in wildlife'). This voluntary reporting of non-listed diseases in wildlife does not have negative implications for trade; its value is to improve our understanding of epidemiological and ecological dynamics and inform the conservation of wild species and populations and public and animal health protection. To assist with tracking, it is assumed that countries will

maintain national wildlife health reporting systems informed by wildlife disease, pathogen and toxic agent surveillance programmes.

Any surveillance programme established will need to link to the relevant authorities to report to WOAH on the obligated and voluntary requirements. In general, reporting via WAHIS and WAHIS–Wild is conducted or overseen by the National Delegate, who is based in the Competent Authority, with inputs from the National Focal Point for Wildlife.

Key message

Reporting information collected through a wildlife health surveillance programme to WOAH via the relevant Competent Authority builds knowledge and underpins decision-making and action to protect health across all sectors.

4. Financial considerations

4.1. What should be included in the budget?

The development of a designated budget for wildlife disease surveillance is an essential part of a national programme. While many stakeholders may contribute to surveillance in various financial and technical ways (including through related research activities), national budgets should ensure that national agencies are able to deliver on their wildlife disease surveillance mandates (when they exist). Budgeting for a wildlife disease surveillance programme should include the main cost categories in an animal health surveillance system:

- personnel
- materials and infrastructure
- communication
- training.

However, these may be incorporated into complementary budget-planning frameworks, such as the four main components of a surveillance system:

- detection of diseases, pathogens and toxic agents
- identification of diseases, pathogens and toxic agents
- analysis and communication
- information management.

Budget planning should consider the purpose and key elements of the proposed surveillance programme, such as the intended number of samples per budget period, and the cost of the diagnostic procedures to be used (post-mortem and additional laboratory tests for general surveillance; specific tests for pathogens, toxic agents or biomarkers, e.g. antibodies, in targeted surveillance) since these will determine resource and capacity requirements and associated costs. Remember that designing surveillance programmes offers considerable flexibility to promote both efficiency and effectiveness, ideally making use of the existing capacity of Wildlife Authorities and tailored to the programme's specific context and goals. Budgeting should also take into account the need for quick access to resources and capacity to implement a rapid response, such as in the case of an emergency event requiring urgent investigation (for example, unexpected mortality events), via contingency funds. Some budget items will require upfront (initial set-up) funds or occasional investments, whereas others are continuing operational and administrative costs. Items within the broad cost categories that may typically be expected include:

Personnel: Human resources are an essential component of surveillance programmes, requiring qualified personnel, in-service training, and adequate staffing.

- Specific cost items include salaries, benefits, contractor fees, and insurance, along with workforce development and in-service training costs.

- Under a One Health approach, which is beneficial for wildlife surveillance, a variety of skills and expertise are likely to be necessary in any surveillance programme. Qualifications and experience should be well matched to specific roles and responsibilities and may include expertise in the design and use of surveillance programmes. Such skills and experience may be drawn from multiple health sectors, such as domestic animal, environmental or human health professionals (e.g. the human healthcare workforce, epidemiologists, and environmental professionals) (see Annex II).

- Team members are likely to include rangers (for visual observation of sick or dead animals), veterinarians and veterinary assistants or technicians (for sample collection and diagnostic investigation), animal capture teams, laboratory personnel, administrative personnel, and

information managers, as well as wildlife biologists, ecologists, epidemiologists, and those skilled in data analytics, information management, communication, and outreach.

- In some cases, laboratory work will potentially need to be conducted outside the country if the appropriate personnel and other capacity are not available nationally. Resource requirements for fee-for-service sample screening as well as for interpreting results would then need to be taken into account.

Important note: Only authorised persons who are fully trained and qualified in safe and humane animal sampling and handling, including field biosafety protocols, should be involved in biological sample collection. This is essential to manage pathogen transmission risks as well as animal welfare. This typically includes only veterinary and animal health workers and, in some cases, wildlife biologists.

Materials and infrastructure: Infrastructure provides the ability to safely and reliably (and correctly) collect, transport and test samples.

For collection and transport:

- Sample collection may include cost items such as PPE, the transport of dead animals or samples to the laboratory, or camera devices for visual capture of animal morbidity (illness) or mortality (death) situations.

- Samples from live animals may require vehicles, capture equipment, pharmaceuticals for capture and sedation (as relevant), and sample collection supplies such as cryovials, virus transport media and sampling needles. The use of a helicopter for wildlife capture may be needed in certain situations where on-the-ground capture is impractical or dangerous.

- Sampling and sample storage may include cost items such as vehicle and fuel costs or other modes of transport to and from field sites and laboratories; sampling consumables; cold chain resources such as freezers, dry ice, liquid nitrogen or preserving solutions; special packaging; and shipping.

- The cost of these items may vary greatly depending on local conditions and sites, including the distance and time required for sample movement.

For sample screening tests:

- Laboratory screening may include cost items such as physical laboratory space, equipment, reagents and lab consumables, per-test costs, refrigerators and freezers, PPE, and electricity, as well as any other equipment needed for taking species-specific measurements such as calipers or weighing instruments.
- Data recording and analysis may include cost items such as GPS data collection and site-mapping tools, field notebooks and computers for data recording, Internet services and database costs for longer-term data management, and Artificial Intelligence (AI) platforms and programme fees (see Box 8).
- Laboratory capacity may not be available in some countries, requiring resources for sample shipping, permits, and potential fee-for-service testing costs.

Box 8. Data archiving and accessibility

Good data management requires having a process in place that considers potential interruptions in services and integrates appropriate safeguards. Involving a data manager can help in developing a practical and fit-for-purpose approach to data management.

- Who is inputting data, and what conditions are they working in? Considering connectivity and field conditions can help to identify the best strategy. For example, ranger patrols using the Spatial Monitoring and Reporting Tool (SMART) platform for conservation and observations recorded on applications such as iNaturalist have access to remote storage features that enable data to be saved until they can be uploaded to the Internet.
- Permissions: who needs to see the data, and in what format? Some data (such as location coordinates for endangered species) may be sensitive. Determining who needs access and what level of access they need (e.g. full information or a data subset, viewing versus entry) can inform different permissions to serve different stakeholder needs.
- Where is the data stored? Avoid local storage on one computer – this makes data vulnerable to being lost. Cloud-based secure (i.e. password-protected) services offer a layer of protection in the event of device theft or personnel changes. Keep local copies of all relevant documents for access in case of limited Internet connection.
- Connectivity: considering links to other reporting systems (such as WAHIS–Wild) in the design of a database can allow for streamlined reporting functions.

Communication: Effective communication underpins the timely sharing, access to and use of information in surveillance programmes, including within and across agencies. This is especially

important for linking between field teams (including community stakeholders) and laboratory teams, and notifying other authorities in accordance with a One Health approach, as needed (Box 9).

- Specific cost items include databases, printed materials, teleconference lines, cell phones with data, websites, and hosting or travelling to meetings with stakeholders, including for coordinated planning, data review and interpretation.

- Certain communication channels may already be in place for human and domestic animal health, as well as wildlife monitoring and management, which can be used to support the sharing and use of information.

Box 9. Importance of communication

Wildlife managers have a key role to play in the interpretation and use of findings from wildlife disease surveillance. Unfortunately, in the past, insufficient coordination has resulted in rash actions, including the killing of wildlife or destruction of wildlife habitat as a result of fears about suspected disease or pathogens in wildlife. These killings were not supported by scientific evidence, in some cases were targeted at entirely the wrong species, and presented the risk of longer-term health and ecological consequences, including potentially spreading pathogens further. Thus, coordination with wildlife managers is essential to ensure that management actions are appropriate to species biology and ecology. Similarly, sentinel detection in animals can be important for human health and vice versa (disease in humans signaling a threat to animals), reinforcing the importance of timely bi-directional communication in line with a One Health approach. Proactively and routinely engaging stakeholders, partners and communities about wildlife disease and pathogen surveillance using a One Health approach can help us to be prepared, avoiding wasted resources and detrimental effects to biodiversity and ecosystems.

Training: Training is vital to developing and strengthening the capacity of a wildlife health surveillance workforce.

- Specific training needs will depend on the particular context, roles and responsibilities, but could range from surveillance or study design to event reporting, sample collection methods, sample storage and packaging, data entry, or analysis methods.

- Relevant costs include capacity building and capacity strengthening resources such as information workshops, hands-on training and textbooks, delivered in a variety of formats and settings, such as classroom-based or online, observations in the field, or via simulation-based exercises. Additional costs may include fees for laboratory certification, continuing education, and consultations or exchanges with reference laboratories.

- Training pipelines can in some cases leverage existing programmes in the human and domestic animal health sectors (Box 10).
- Even for experts, routine refresher courses can be important to keep skills and knowledge up to date.

Box 10. In-service field epidemiology training programmes

Many countries have embraced in-service field epidemiology training programmes (FETPs) for public and domestic animal health professionals in recent years. The inclusion of wildlife managers and rangers in FETPs can help to build up epidemiological expertise in government wildlife and forestry services and provide cross-training opportunities to support the implementation of One Health.

Based on these broad categories, budgets can be developed for a general national wildlife disease surveillance plan or for disease-specific targeted surveillance (for example, a specific programme targeted at high pathogenicity avian influenza in wild birds). Example surveillance budget templates can be found in Annex VI.

Key messages

- Budgeting for a wildlife disease surveillance programme should include the four main cost categories in an animal health surveillance system: personnel, materials and infrastructure, communication, and training, although these may be incorporated into complementary budget-planning frameworks.
- Budget planning should consider the purpose and key elements of the surveillance programme.
- Where possible, using frameworks for domestic animal or human health may reduce costs while also providing an opportunity for an integrated One Health approach to the surveillance programme.

4.2. How can resources be mobilised for surveillance?

As with all things, resources for wildlife health and conservation are scarce, and the design of surveillance programmes should consider financial and other factors in context. Advocating for the resources needed is an important part of setting up and sustaining a successful programme. In some

cases, this may involve the allocation or transfer of funds; in others, in-kind resources may be mobilised, such as veterinary or laboratory staff time or equipment through other agencies or research centres.

Countries may wish to pursue several options for mobilising resources for programmes, with attention to both emergency and routine activities, such as:

- integrating surveillance into existing ranger and wildlife manager workflows to leverage existing efforts, such as building visual reports of wildlife morbidity (illness) events into ranger patrols;
- making use of readily available information to develop low-budget baseline surveillance initiatives, supplemented by more resource-intensive priorities where funding allows;
- working with public health authorities and Veterinary Services to identify existing resources that could be leveraged (e.g. personnel time for sample collection, sample transport, laboratory equipment, reagents, results interpretation support, etc.);
- working with public health authorities and Veterinary Services to identify the approaches that are most cost-effective to support epidemiological understanding and action;
- raising and maintaining awareness about the value of wildlife surveillance, including the benefits of the information generated relative to the cost, to promote equitable resource sharing in line with a One Health approach;
- building core surveillance system functions into funding and projects directed at biodiversity conservation, through national funding mechanisms under the Global Environment Facility. (For example, surveillance can play a role in meeting Targets 5 and 11 of the Global Biodiversity Framework);
- requesting resources from the central national budget (via the agency or via the treasury) or, where, relevant, as a government entity (e.g. a parastatal organisation), financed by grants and direct revenue sources such as tourism fees from visitors;
- regularly discussing surveillance priorities with research and conservation entities to encourage work that fills gaps in our knowledge;

- for specific emergency situations affecting species threatened with extinction, accessing species-conservation-focused grants could be beneficial, for example the Save Our Species fund through the IUCN supports disease management efforts, including surveillance.

While external resources may play an important role in implementation, government-led surveillance programmes should be designed with a plan to sustain some level of the programme without external funding.

Key messages

- While it is important to have a dedicated budget in place to sustain efforts in routine and emergency situations, surveillance does not need to be expensive.
- Effective prioritisation, collaboration, coordination, and monitoring (and refinement) of efforts can help maximise the utility of existing and additional resources.
- Advocacy in Wildlife Services and other sectors plays a role in mobilising needed resources.

5. Other considerations and resources

5.1. Importance of safety and biosafety in the collection of samples – what are the minimum considerations?

The management of biological risks (e.g. the risks of exposing humans, other animals or the environment to pathogens or toxins) from sample collection and handling through to sample transport, testing and storage should be a key consideration in programme design. Biological risk management needs to include an assessment of these risks and how to manage them, taking into account all planned activities. If the risks are too high and cannot be adequately managed, then a decision not to carry out surveillance at all may be taken. Depending on the specific situation, risk management options may include the use of PPE, taking samples indirectly from the environment or remotely, or the inactivation of samples.

Working in remote locations with wild animals and infectious materials can put staff at risk, underscoring the importance of thorough work health and safety procedures, including biosafety, training and established protocols in field and laboratory settings.

Humans can also facilitate the spread of disease to animals and thus should avoid field sampling activities when ill and, potentially, during active epidemics (in this event, a risk–benefit assessment should be conducted; for example, see the COVID-19 guidelines for working with free-ranging wildlife). Proper use of PPE should be followed at all times to protect human and animal health.

In addition, surveillance activities should not disturb or stress wild animal populations which could lead to further dissemination of disease.

Gear should be thoroughly disinfected to prevent the introduction of pathogens and invasive species (for example, the chytrid fungus can be spread to additional populations or settings via contaminated boots). The appropriate biosafety level varies according to such factors as species, storage methods, pathogens, and technological features (e.g. negative pressure laboratories).

The failure to apply biological risk management along the chain from sample collection to sample transport through to laboratory analysis and, ultimately, sample destruction or storage carries significant health and reputational risks.

5.2. What ethical and legal considerations are relevant?

The risks, benefits and legal requirements of any surveillance programme should be routinely considered. While specific conditions vary by country, general good practices for permissions, animal welfare, biosafety and communities are briefly discussed below.

Indigenous Peoples: As rights-holders and custodians of large areas of land, Indigenous Peoples support a significant proportion of the world's biodiversity. It is therefore essential that they are involved at the very beginning of planning and implementing a surveillance programme on or adjacent to their land or territories and involving the species they use and depend on. For example, when working with Indigenous Peoples, it is crucial – and often legally required – to follow Free, Prior, and Informed Consent (FPIC) processes. This is especially relevant to engagement in participatory surveillance and the conduct of wildlife surveillance on Indigenous territory. In addition to land rights, wildlife and wildlife habitats may hold sacred values that affect Indigenous Peoples' acceptance of or permission for

surveillance initiatives. The trust and communication that should be created or enhanced during this process can also be integral to the design and success of follow-up actions informed by the surveillance.

Permissions: Wildlife samples require approval (often via a permit) from Wildlife Authorities (which often come under biodiversity conservation departments). Locally or nationally protected species may also have additional requirements for sample collection or international movement. There may also be specific permission required from Indigenous Peoples or local landholders in terms of access to land and interaction with species. In addition, local communities often play an important role in the success of many surveillance programmes and need to be considered as one of the key stakeholder groups to engage with. Agreement from Indigenous Peoples and other potential rights-holders should also be sought before conducting surveillance on or adjacent to their lands (see previous paragraph).

Animal welfare: Invasive wildlife sampling techniques may be stressful for animals and can result in accidental injury or death if proper procedures are not followed. This highlights the importance of well-trained and equipped veterinary or other qualified professionals (e.g. qualified wildlife biologists) to manage field risks and continually monitor the condition of each animal being sampled, adapting methods as needed to ensure the wellbeing and welfare of the animal. In general, surveillance and sampling techniques should use measures with the lowest welfare impacts (e.g. as minimally invasive as possible), without compromising the effectiveness of the surveillance measures, taking into account costs, benefits, feasibility and public perception, and respecting all relevant animal welfare laws as well as requirements under Institutional Animal Care and Use Committee (IACUC). WOAH's National Animal Welfare Focal Points can serve as a resource to assist surveillance programmes in accessing the relevant information.

International movement of samples: Under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the international movement of biological specimens (including samples) from CITES-listed species is regulated. In this case, early coordination with national CITES authorities is crucial to ensure there is awareness about wildlife surveillance initiatives and the situations where international laboratory services may be needed. This can especially help to avoid delays in emergency situations where broad (e.g. pathogen and toxic agent) and rapid screening efforts may be needed. Unfortunately, substantial delays have occurred in the past, even during mass die-off wildlife events, hindering disease investigation. The lack of consistent cold storage ('cold chain') even if only for a few hours can result in some types of samples being useless for disease investigation. International partner laboratories should be registered on the CITES Database to avoid delays when

activating the Simplified Procedures for Emergency Diagnostic Specimens (note that this is only available for CITES Appendix II and III species; Appendix I species must go through the normal permitting process). The CITES Secretariat and national CITES authorities can be called on to provide guidance on this process.

5.3. How does surveillance fit into a country's wildlife health and One Health efforts?

Surveillance is an important part of a country's efforts to monitor and ultimately protect the health of humans, animals, and the environment in accordance with a One Health approach. Surveillance can inform a country **what diseases, pathogens and toxic agents** are present within its wild animal populations and **what effects** these may have, in **which geographic areas** and in **which host species**. Surveillance can detect new or emerging diseases or threats and, depending on the surveillance approach, can measure the proportion of animals affected within a population. All of this information is required to inform risk assessment and broader risk analysis processes, including strategies to respond to disease events and manage disease and health risks. Surveillance also requires an organised system of observation of wild animals in the field, veterinary diagnostics, and information management and communication, all of which are required when a country decides to respond to a disease outbreak and take management actions. Thus, surveillance can build the national capacity that is required to manage urgent health events, as well as to feed into short- and long-term species assessment and conservation planning. The importance of collaboration between Veterinary Services, Wildlife Authorities, the Human Health Ministry, agricultural and environmental authorities, Indigenous Peoples, and local communities, among other sectors and stakeholders, to successfully carry out and use surveillance findings cannot be overstated and reinforces the value and necessity of a One Health approach (see 'Antelope surveillance example' in Box 11, below).

Further information about risk assessment, response and management of disease risks and impacts can be found in 'Additional resources', below.

The thoughtful design, implementation and refinement of disease, pathogen and toxic agent surveillance in wildlife contributes to conservation and health objectives. Best practice protocols for the field, laboratory, risk analysis and information management should be consulted in the design of programmes. Programmes should be tailored to their context to help integrate both wildlife and environmental dimensions into One Health, improving the epidemiological understanding and health protection of humans, animals, and ecosystems.

Box 11. Antelope surveillance example

Think back to the disease investigation in antelope from the beginning of this document. Building on the guidance in the previous sections, we can apply the same principles to this scenario.

The disease investigation found high levels of a toxic substance in the antelope screened. Additional antelope deaths were reported by communities living near the protected area but could not be sampled in time. The Wildlife Authority is concerned the substance could be linked to these deaths. A team, including the WOAH National Focal Point for Wildlife, meets to consider any next steps. They note that currently information is only collected from antelope via general (passive) surveillance. The population of antelope in the country has declined from multiple pressures in recent years. In consultation with the Veterinary Services, the Wildlife Authority determines that targeted (active) surveillance should be conducted to determine the levels of this substance in the antelope population and any link to negative health effects. A sample size calculation is conducted to determine the number of samples to be collected to serve this particular objective.

A sampling plan is developed and a qualified team is trained on the sampling protocol. Blood samples are determined to be the most appropriate sample type for the toxic agent of focus. Biosafety considerations guide the appropriate level of personal protective equipment. With their ecological expertise, hoofprint tracking, and camera trap information, rangers will help the veterinary team to find the antelope herds. In addition, a monthly alert will be issued to community wildlife wardens, animal health workers, and village chiefs for participatory surveillance to report any dead antelope they find. As part of the sampling procedure, the capture and handling team will take co-variate information to understand the overall health status and inform the conservation management of these animals, also examining human activities occurring in the area. Collaboration agreements are made. The team will also work with the Environmental Authority to examine where the substance is being released into the environment and ways that antelope may be exposed. Similarly, they consult with the public health authority in case the toxic agent is harmful to people, considering the risk to food safety if the animal is consumed as well as the potential importance of a 'canary in the coal mine' early warning indication of a potential toxic agent harmful to human populations. The samples will be sent to the national toxic agents laboratory, run by the Ministry of Health, for chemical screening. It is agreed that the Veterinary Services will continue to provide support on the interpretation of findings.

A portion of budgets from the relevant authorities is allocated to support this surveillance. The team veterinarian purchases a reference textbook about antelope physiology and capture methods. The Wildlife Services draw on their field expertise to share their knowledge of antelope behaviour to determine key surveillance sites. Most of the sampling supplies and equipment are already stocked as part of the broader wildlife surveillance programme. The key cost is the sample testing.

As the surveillance progresses, data analysts begin to detect trends. Using geospatial analysis (mapping points from geographic information systems), they see that levels are high in a specific area, and they find that health status is worse in individuals with a higher level of the substance. Working with local teams on the ground to put these findings into context, they look at recent changes in the area to identify the source of contaminants, including commercial activities as well as reports of illegal activities, eventually tracing it to a mining operation. Based on their findings, which are entered into the national surveillance database, they identify the need to work with local communities – including miners – in the affected area to limit dissemination of the substance. The surveillance objective is refined, now focusing efforts on seeing if levels have decreased and the health status of the population improves over time. Note that throughout this targeted active surveillance, general surveillance is still ongoing. This case study has demonstrated the utility and complementarity of different surveillance approaches and unique roles and responsibilities, as well as practical collaboration, budget considerations, and other aspects of wildlife surveillance for disease, pathogens and toxic agents.

5.4. Additional resources

Further guidance and training

IUCN and EcoHealth Alliance. 2022. *Healthy people and wildlife through nature protection: Guidelines for prevention, detection, response, and recovery from disease risks in and around protected and conserved areas*: https://portals.iucn.org/library/node/50682

IUCN and EcoHealth Alliance. 2022. *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*: https://portals.iucn.org/library/node/50683

IUCN–WOAH. 2014. *Guidelines for Wildlife Disease Risk Analysis*: https://portals.iucn.org/library/node/43385

IUCN–WOAH. 2014. *Manual of Procedures for Wildlife Disease Risk Analysis*: https://portals.iucn.org/library/node/43386

Wildlife Health Australia Wildlife Biosecurity Guidelines: https://wildlifehealthaustralia.com.au/Portals/0/ResourceCentre/BiosecurityMgmt/National_Wildlife_Biosecurity_Guidelines.pdf

WOAH E–learning Modules on Wildlife Disease Surveillance: https://training.woah.org/

WOAH *Manual on Sample Collection and Transport* https://rr-asia.woah.org/wp-content/uploads/2020/02/seacfmd-manual-7.pdf

WOAH *Training Manuals* https://www.woah.org/en/what-we-do/animal-health-and-welfare/wildlife-health/#ui-id-5

Background materials and standards

WHO Risk Assessment Tool for Biosafety and Laboratory Biosecurity: https://www.who.int/news/item/07-03-2024-who-launches-a-mobile-app-for-biosafety-risk-assessment (accessed on 19 April 2024).

WOAH *Terrestrial Manual*, Chapter 1.1.2. Collection, submission and storage of diagnostic specimens: https://www.woah.org/fileadmin/Home/eng/Health_standards/tahm/1.01.02_COLLECTION_DIAG_SPECIMENS.pdf

WOAH *Terrestrial Manual*, Chapter 1.1.3. Transport of biological materials: https://www.woah.org/fileadmin/Home/eng/Health_standards/tahm/1.01.03_TRANSPORT.pdf

WOAH *Terrestrial Code*, Chapter 2.2.7. Principles and methods for the validation of diagnostic tests for infectious diseases applicable to wildlife: https://www.woah.org/fileadmin/Home/eng/Health_standards/tahm/2.02.07_WILDLIFE.pdf

WOAH Wildlife Health Framework: https://www.woah.org/fileadmin/Home/eng/Internationa_Standard_Setting/docs/pdf/WGWildlife/A_Wildlifehealth_conceptnote.pdf

Case studies and examples

PANORAMA Solutions case studies on species conservation and One Health: https://panorama.solutions

Sources of disease reports and information and species threat assessments

IUCN Red List of Threatened Species™: https://www.iucnredlist.org

State of the World's Amphibians, 2023

Wildlife Situation Reports: https://www.woah.org/app/uploads/2023/03/wildlife-situation-report-1.pdf

WOAH Wildlife Health Information: https://www.woah.org/en/what-we-do/animal-health-and-welfare/wildlife-health/

WOAH Animal Disease Portal: https://www.woah.org/en/what-we-do/animal-health-and-welfare/animal-diseases/

World Animal Health Information System (WAHIS) – Reported by Member and non-Member Countries and Territories on terrestrial and aquatic WOAH-listed diseases: https://www.woah.org/en/what-we-do/animal-health-and-welfare/disease-data-collection/world-animal-health-information-system/

Awareness and simulation materials (available from WOAH on request)

ALERT Game pedagogical tools to provide practical visuals on communication and chains of command within surveillance systems (using a One Health approach): https://rr-africa.woah.org/wp-content/uploads/2022/12/14-the-ebo-sursy-serious-game-alert-yacinthe-guigma.pdf

WOAH posters on community-based surveillance: https://rr-africa.woah.org/en/projects/ebo-sursy-en/capacity-building-tools-and-resources/

Specific topics relevant for disease surveillance in wildlife (not a comprehensive list)

CITES scientific exchange exception and simplified procedures: https://cites.org/sites/default/files/eng/prog/exemptions/E_SimplifiedProcedures_endorsed_SC73.pdf

Migratory species and disease considerations: Convention on the Conservation of Migratory Species of Wild Animals. Migratory Species and Health: a review of migration and wildlife disease dynamics, and the health of migratory species, within the context of One Health. UNEP/CMS/COP14/Inf.30.4.3: https://www.cms.int/en/document/migratory-species-and-health-review-migration-and-wildlife-disease-dynamics-and-health

6. Annexes

Annex I. Benefits

What are the benefits of wildlife disease, pathogen and toxic agent surveillance?

When designed and conducted thoughtfully, there are many potential benefits of wildlife disease, pathogen and toxic agent surveillance. As with human and domestic animal health, surveillance can provide essential information to assess risks and design disease and threat management strategies. Among these are the improved prevention of spillover events between wildlife, humans, and domestic animals, representing an under-used but most cost-effective risk management approach. Parallel approaches have been used to address invasive alien species (IAS) threats and impacts by focusing efforts on prevention of introduction and early detection and rapid response which is far more cost effective than managing impacts from IAS once they become established.

WOAH's Wildlife Health Framework clearly articulates the importance of wildlife:

'The survival of humans, animals, and plants depends on the health of their ecosystems. Bats and bees are essential pollinators, small mammals maintain soil health, coral reefs produce oxygen and capture carbon, fruit-eaters disperse seeds, and predators help control the populations of other species. Ecosystems are only as healthy as the wildlife that lives within them and require rich biodiversity to thrive. Wildlife is a valuable asset for many communities across the world, supporting livelihoods through the provision of income, whether it be through tourism or as a source of food. Importantly, wildlife has a positive effect on human well-being, contributing to education, physical and mental health, social values, culture and spirituality.

'During recent years, the increasing number of emerging disease events has been linked, or even blamed, on wildlife. However, human activity, along with factors such as climate change, wildlife trade, deforestation, and certain farming practices are also major forces behind disease emergence. Animals and biodiversity can often be the forgotten victims of disease outbreaks.'

In addition, IUCN in its Nature 2030 Programme highlights the critical role that a healthy environment plays in addressing other challenges such as poverty, inequality, climate change, human health, and food and water security. It states that the underlying causes of pandemics are related to the environmental changes that drive biodiversity loss and climate change, including unsustainable exploitation of the environment due to land-use change, agricultural expansion and intensification, and wildlife trade and consumption. IUCN also stresses that nature-based solutions (NbS), which are actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges, can provide an important contribution to reducing the risk of future spillover events of zoonotic diseases and pandemics. Under the IUCN Red List of Threatened Species™, disease and mortality from pathogens, poisoning, and other causes inform the assessment of species endangerment status and associated conservation planning.

Baseline information can help to refine surveillance objectives over time. Surveillance targeted to interfaces where human–wildlife or wildlife–livestock contact is occurring or anticipated to occur can also inform on cross-species transmission risk, both to and from wildlife. Surveillance on toxic agents in wildlife can help in understanding aspects such as the bioaccumulation of toxic substances and the effects of toxic agents on the health of wildlife which in turn could be indicators of toxic threats to humans. This can guide risk prevention and mitigation strategies, as part of environmental, social, and health impact assessment processes (see Box 12).

Wildlife health surveillance systems, like all surveillance systems, also benefit from flexibility. This is especially important as more information is generated that can improve understanding of disease, pathogen or toxic agent risks and help refine relevant wildlife health surveillance strategies. Flexibility is also important given that priorities may change; for example, an influenza outbreak in poultry originating from a wild bird strain may demand enhanced wild bird surveillance which may require scaling up or expanding to different sites or species. Having surveillance capacity in place that can be scaled up rapidly as needed can help achieve early detection and inform response and control measures.

Box 12. Case studies on disease, pathogen and chemical surveillance in wildlife: demonstrating practical value

Conservation: surveillance in amphibians detected the international spread and impact of chytrid fungus. This highly detrimental group of pathogens (*Batrachochytrium dendrobatidis* and *Batrachochytrium salamandrivorans*) currently threatens over 600 amphibian species and has been responsible for the extinction of nine amphibian species to date – and the loss of genetic diversity and ecosystem services along with them*. Both pathogens were initially detected via general surveillance and diagnostic investigation of sick and dying amphibians. Based on ongoing general (passive) and targeted (active) surveillance information, countries have been taking action to avoid the introduction and limit geographic movement of the pathogen, including via import bans, and minimise population impacts, such as by using experimental therapies aimed at promoting survival.

Food security and pest control: White-nose syndrome in bats was detected when Wildlife Authorities noted a major die-off in hibernating bat colonies in caves adjoining a commercial tourist cave in New York state in 2007. The causative pathogen was later described as *Pseudogymnoascus destructans*, which was likely introduced by human activity, possibly by a visitor to the cave in New York. Insectivorous bats play a key role in the North American food production system by consuming agricultural insect pests. The value of the ecosystem services of insectivorous bats to United States agriculture is estimated at billions annually. Surveillance continues to play a key role in informing and evaluating management strategies to try to stem the spread and impact of the pathogen on bat species in North America.

Domestic animal health and livestock production: infection with rabies virus is fatal in mammals. While domestic dogs are the main reservoir for rabies virus globally and an important source of introduction into wild animal populations, the virus is maintained in wildlife hosts in some regions and can contribute to infection of livestock. Surveillance in wildlife has been important for understanding and clarifying transmission dynamics to inform risk management strategies.

Public health and tourism: The development of Marburg virus disease in visitors to the 'python' cave in Uganda's Queen Elizabeth National Park resulted in a surveillance study that determined that the pathogen was circulating in bat populations in the cave. This finding informed a risk reduction strategy: the construction of a glass enclosure to allow safe viewing. This has the triple win of keeping visitors safe while allowing the continuation of tourist activities and protecting the cave and its wildlife from degradation.

Ecosystem function: The use of diclofenac as a non-steroidal anti-inflammatory (NSAID) for pain relief in livestock resulted in the poisoning of vultures that feed on dead carcasses. Vultures have specialised digestive systems that allow them to be 'nature's scavengers', helping to keep ecosystems healthy. Declines of over 90% of *Gyps* vulture populations were observed in parts of southern India in recent decades. Surveillance has been vital in understanding the impact on vultures and linking it to diclofenac, enabling changes in veterinary substance licensing and supporting an ongoing recovery of the region's vulture population.

*See State of the World's Amphibians, *2023* for more information.

Annex II. Stakeholders

Depending on the role and context, these groups may be part of government agencies, regional or international entities, academia/research, NGOs, professional associations, communities and the private sector.

Table 2. Examples of relevant stakeholder groups for wildlife disease, pathogen and toxic agent surveillance.

Group	Description
Veterinary and animal health professionals	Animal capture, sampling, and handling
Wildlife veterinarians, pathogen and disease specialists	Surveillance study design and interpretation specific to wildlife (this group's expertise may overlap with other group expertise)
Epidemiologists	Surveillance study design and interpretation (epidemiological aspects)
Diagnostic and anatomical pathologists and laboratory experts	Design of sample collection and storage protocols; diagnostic testing and microbial screening (e.g. for pathogen detection and identification); toxic agent screening
Rangers	Observation of wildlife sickness or death (e.g. event detection) and reporting
Biosafety experts	Field and laboratory biosafety practices, including personal protective equipment, transport, and facility requirements
Wildlife biologists/ ecologists	Surveillance study design and interpretation (ecological aspects); knowledge of wildlife behaviour, physiology, and health
Information managers	Data management (data-reporting structures and formats; data archiving)
Statisticians and/or data analysts	Analysis of data; modelling studies
Communication and outreach managers	Communication to public or other stakeholders to encourage reporting (and communicate risk mitigation measures as needed, based on findings)
Public health and medical professionals	Interpretation of findings for public health relevance; involvement in the design of programmes (including detection in humans for animal health or in animals for human health)

Group	Description
Indigenous Peoples	Rights-holders and participatory surveillance; knowledge of wildlife behaviour, physiology and health, and permissions
Local communities	Community-based participatory surveillance (including community representatives serving as eco-guards, community health workers, private landowners/managers, etc.) and permissions
Occupational groups in contact with wildlife	Worker-based participatory surveillance, e.g. hunters, traders, wildlife farmers, extractive industries and infrastructure project staff, ecotourism guides, etc.
Social scientists	To support the design of community-based participatory surveillance
Zoological parks and associations, and wildlife sanctuaries	May be a source of veterinary and animal health professionals, laboratory experts or other key personnel to support surveillance programmes
CITES authorities	Export and import permits for CITES-listed species and their specimens (including samples)
Environmental and Land Use Authorities	Can provide information on ecosystem loss or degradation to inform surveillance priorities

Annex III. Common sample types to detect disease-causing agents

Table 3. Common sample types used to detect the presence of or exposure to disease-causing agents in wildlife[1].

Sample type	Uses	Examples	Comments
Intact carcasses	Cause of sickness/death determination	Various pathogens (viral, bacterial, parasitic) or toxic agents	Carcasses allow testing of multiple tissues for multiple pathogens and examination for gross and microscopic lesions
Blood	Evidence of exposure or previous exposure to various pathogens (i.e. antibodies) and contaminants and the presence of blood-borne parasites	Morbillivirus, elephant endotheliotropic herpesvirus, equine influenza Lead, insecticide poisoning, mercury, polychlorinated biphenyls Malaria, babesiosis, leucocytozoonosis	Whether antibodies indicate current infection or previous exposure is disease-dependent and sometimes species-dependent. Paired testing of individuals (e.g. sampling the same individual at separate points in time) can sometimes be used to establish infection status
Swabs	Pathogen presence, shedding	Avian influenza (cloacal, oropharyngeal swabs) *Batrachochytrium dendrobatidis* (skin swab)	Useful for sampling large numbers of specimens for a single pathogen (targeted surveillance)

[1] Adapted from the Training Manual on Wildlife Health Information Management, Workshop for WOAH National Focal Points for Wildlife, 6th Cycle.

Sample type	Uses	Examples	Comments
			Does not indicate whether the pathogen is causing disease
Faeces, urine	Pathogen shedding, presence of parasites	*Salmonella*, *Escherichia coli*, Paratuberculosis, *Cryptosporidium* spp. *Toxoplasmosis gondii*, *Sarcocystis neurona*	Useful for determining the presence of a pathogen or parasite in a population or area when animal capture is not feasible. Difficult to pair results with individual animals. Does not indicate whether the pathogen is causing disease in the population
Environmental samples (e.g. water samples, soil samples)	Pathogen presence (e.g. via eDNA) or the presence of a toxic agent	*Batrachochytrium dendrobatidis*, algal blooms and other biotic and abiotic changes (water sample) *Pseudogymnoascus destructans* (causative pathogen of white-nose syndrome in bats) (soil sample)	Useful for determining the potential presence of a pathogen or parasite in a population or area when animal capture is not feasible. Difficult to pair results with individual animals. Does not indicate whether the pathogen is causing disease in the population

Disease Technical Cards for non-WOAH-listed diseases provide additional information on the types of samples and testing needed for important wildlife diseases.

Annex IV. Detection aims and methods

Table 4. Main detection aims and methods for wildlife disease, pathogen and toxic agent disease surveillance. *Note that these objectives could be applied in a variety of settings, such as a national park or wildlife market.*

Detection aim	Typical method(s)	Considerations and common challenges	Learn more
Detection of animal mortality (death)	Visual patrol or camera trapping	Physical condition may or may not indicate disease or the carcass may not be usable for sampling	
Detection of animal morbidity (sick animal)	Visual patrol or camera trapping; post-mortem examination	Physical or behavioural condition may or may not indicate disease Post-mortem evaluation may be visual or include sample collection	
To identify the disease or cause of morbidity or mortality	Diagnostic investigation and pathology studies via examination of the whole carcass (post mortem) or samples collected from animals (live or dead) (e.g. swabs, biopsies, etc.)	Gross and microscopic pathology examination of samples may be used to identify disease visually, which may indicate the cause(s) of morbidity or mortality Can be complemented by additional screening testing described below. Microscopic identification requires trained staff and equipment	How to interpret diagnostic tests in wildlife (Wildlife Health Australia Fact Sheet)
Direct evidence of the pathogen/ infectious agent (e.g.	Pathogen screening tests include: • molecular techniques to	Pathogen-specific (or pathogen group-specific) screening tests look for direct evidence of pathogens in a biological sample collected from the animal. These tests can only reflect the infection	WOAH Training Manuals (1st, 2nd, 4th and 6th cycle manuals)

Detection aim	Typical method(s)	Considerations and common challenges	Learn more
active infection)	detect the DNA or RNA of pathogens • culture for the growth of bacteria or fungi • direct observation of pathogens, such as bacteria via microscope, or macroparasites by gross observation	status of an individual animal at a given point in time (when the sample was collected), as infections are often detectable for only a short time. When the portion of infected animals in a population being sampled is predicted to be low, sample pooling could be considered to save on resources Specific laboratory settings, reagents and trained personal are required to apply these methods	WOAH Animal Disease Portal WOAH *Terrestrial* and *Aquatic Manuals*
Evidence of previous exposure to a pathogen or infectious agent	Indirect screening tests looking for an immune response to the pathogen (e.g. antibodies) Serology (serological evidence of antibodies, e.g. through ELISA, virus neutralisation) or other immune reactions (e.g. skin tests for mycobacterium) Detection of biological markers of disease/infection/ toxic agents /health status	Pathogen-specific; does not allow temporal association (when the exposure occurred and whether it caused illness in an animal) Specific laboratory settings and reagents, optimisation of the method to a given species and trained personal are required to apply these methods	

Detection aim	Typical method(s)	Considerations and common challenges	Learn more
Broad-spectrum screening for pathogens	Genetic sequencing of a biological sample to detect microbial diversity Environmental DNA/RNA (eDNA, eRNA)	Useful for determining the potential presence of a pathogen in a biological or environmental sample Additional testing and analysis may be required to confirm the pathogen detected and whether it is causing disease High cost; the equipment is not widely available; it requires reagents and bioinformatics expertise to identify a segment of a pathogen sequence indicating its presence	WOAH *Terrestrial* and *Aquatic Animal Health Manuals* WOAH discussion paper on the use of eDNA methods for detection of WOAH-listed aquatic animal diseases
Toxic agents: both biological (e.g. harmful algae, aflatoxins) and chemical (e.g. heavy metals, drug residues)	Clinical signs, diagnostic investigation (see above), detection of a toxic agent in blood, tissue, hair, feathers, skin, scales or other biological samples, mass spectrometry, chromatography	Toxic-agent-specific. A high cost per sample, provides a quantified level of detection. Where a toxic agent has caused disease, the signs of disease (visual, microscopic, physiological) may be indicators of the specific toxic agent but may require further tests to confirm Note that chemicals bioaccumulate and metabolise differently based on type as well as species	WOAH Animal Disease Portal (e.g. chemical poisoning, algal toxicosis, botulism)
Parasites	Gross visual identification and microscopy	Also some of the above techniques	WOAH Animal Disease Portal (e.g. sacroptes, toxoplasmosis, etc.)

Annex V. Interpretation of test results – infectious agents

Table 5. Common interpretations of test results for infectious disease pathogens (Source: *Wildlife Health Australia.* For more on how to interpret diagnostic tests in wildlife, click here)

Test	Comments	Positive means that...	Negative means that...
Direct tests			
Pathogen culture or isolation	Infected individuals may only excrete the pathogen intermittently, in low amounts, or only in specific tissues/ secretions. Must know which samples to collect, and how to handle and store them appropriately, for the pathogen in question	The animal is currently infected	The animal might be uninfected or infected but it is not shedding or there is insufficient pathogen in the sample for detection (false negative)
Direct observation	As above	The animal is currently infected	As above
PCR and other molecular techniques	As above. PCR detects the pathogen genome OR a genome fragment DNA/RNA extraction from tissue or biological samples can be problematic	The individual is currently infected (may also have recently cleared the infection but it is lingering in tissues or secretions).	As above. No genome/ fragment was detected in that particular sample at that particular time.
Indirect (immunological) tests			
Serology	A single serology result gives limited information about current infection status. Immune responses in wildlife are incompletely	The individual could be: currently infected and infectious (shedding pathogen)	The individual could be: Uninfected OR

Test	Comments	Positive means that...	Negative means that...
	understood and may differ between host species. Antibodies may take time to be produced in response to infection.	OR previously infected, immune, and not infectious	currently infected and shedding pathogen without having seroconverted (in the period of time before antibodies are produced by the immune system and detectable in the blood stream).
Other immunological tests (cell-mediated immunity) e.g. the gamma interferon test	Only useful for some pathogens, where this immune response is significant in the host. Gamma interferon blood tests require careful handling of samples and highly specialised laboratory techniques.	The individual is currently infected or has previously been exposed to infection.	The animal's immune response is not showing a reaction. The animal could be infected but not reacting; not infected; or there could be errors in the way the test was administered).

Annex VI. Budget-planning examples

The following hypothetical budget templates are provided as examples of specific aspects that might be considered when completing a budget plan. Expense categories may vary based on local practices, workforce, surveillance design, relevant species and disease concerns, etc.

a) Wildlife Disease Surveillance: budget template (illustrative)

Budget period: January 2024 to December 2024
Purpose: e.g. foot and mouth disease surveillance in buffalos

Item	Cost per unit	Number of units	Total (cost per unit × number of units)
Detection of diseases, pathogens and toxic agents			
In-house field personnel	X	Number of employees × dedicated months	X
External personnel	X	Number of employees × days/months contracted	X
Per diem for employee(s)	X	Number of employees × days in field (may vary for local versus overnight travel)	X
Sampling supplies	X	Number of sampling days	X
Vehicle rental and average fuel per sampling trip	X	Number of sampling days	X
Helicopter use (pilot, fuel, etc.)	X	Number of sampling days	X
Dry ice	X	Number of sampling days	X
Sample shipping (local and/or international)	X	Number of shipments	X
Identification of diseases, pathogens and toxic agents			
Laboratory personnel	X	Number of employees × dedicated months	X
Testing equipment	X	Number of PCR machine(s)	X
Testing supplies	X	Number of samples	X
Fixed/fee-for-service testing rate	X	Number of samples	X
Training (e.g. on new diagnostic method)	X	Number of personnel travelling to training site and/or training fees	
Analysis and communication			
Personnel	X	Number of employees × dedicated months	X
Teleconference and/or virtual meeting system	X	Number of cross-Ministry calls	X
Data-recording material	X	Number of sampling trips	X
Annual report	X	Number of reports produced	X
Information management			
Personnel	X	Number of employees × dedicated months	X
Equipment	X	Number of equipment items	X
Software	X	Number of software items	X
Total			**X**

b) Wildlife Disease Surveillance: budget template (illustrative)

Budget period: January 2024 to December 2024

Purpose: e.g. general surveillance for sickness and death (morbidity and mortality) in wildlife in and around protected areas

Cost item (examples)	Cost considerations (examples)
Personnel	
Rangers	X (for example, 1 per ranger patrol) × X% staff time
Veterinarians	X (for example, serving different regions of the country) × X% staff time
Laboratory experts	X (serving laboratories) × X% staff time
Data analyst (e.g. epidemiologist)	X × X% staff time
Information manager	X × X% staff time
Materials and infrastructure	
Camera traps and data-recording devices	Number of traps, number of phones or tablets for ranger patrols (e.g. SMART)
Sample collection, personal protective equipment, storage, equipment and consumables	Number of sampling kits, number of personal protective equipment kits, cold storage (e.g. a portable freezer, dry ice)
Vehicles and other transport	Purchase or maintenance of on-site transport (e.g. truck, canoe) and transport to/from field to laboratory; fuel
Laboratory equipment, facility costs, consumables (government laboratory)	Disease, pathogen, and toxic agent screening protocols (machines, reagents, etc.); personal protective equipment kits; electricity
Computer hardware and software for data entry and analysis	Number of computers × cost per computer
Shipping (local and/or international)	Number of samples, speed and distance, storage needs
Fee-for-service testing (external laboratories, e.g. private facility or international reference laboratories)	Number of tests × cost per test (some samples may be pooled depending on objectives)
Communication	
Databases, printed materials, teleconference lines, cell phones and computers with Internet data, websites	Number of users and devices; back-up systems (e.g. Cloud-based data storage)
Outreach to stakeholders	Community awareness campaigns on reporting protocols and findings; hosting of or travel to meetings (including other agencies)
Training	
Simulation exercises, workshops, exchanges	Training fees, venue, food, materials, lodging, etc.
Materials	Books, folders, stationery
Workforce pipeline	Number of students or in-service trainees supported by agency × cost per student
Total	