Guidelines for Addressing Disease Risks in Wildlife Trade

World Organisation for Animal Health

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2024

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Foreword

I am delighted to present WOAH's Guidelines for Addressing Disease Risks in Wildlife Trade.

The Guidelines respond to a need to better manage risks from emerging diseases at the human–animal–environment interface, while protecting wildlife, through a One Health approach.

The Guidelines support WOAH's core mission of improving animal health, and contribute to the WOAH Wildlife Health Framework.

Over 2021 to 2023, with financial support from the Australian Government, a multidisciplinary WOAH *Ad Hoc* Group developed the Guidelines. The WOAH Collaborating Centre on Risk Analysis and Modelling (co-hosted by the Royal Veterinary College and the Animal and Plant Health Agency) further contributed on the subject of risk analysis. The result is an overarching framework to assess disease risk and identify risk-management strategies in a variety of wildlife trade scenarios.

WOAH will collaborate closely with key stakeholders, including international partners and WOAH Members, to support implementation of the Guidelines.

We invite you to use these Guidelines. Our intention is that they be a living, practical document that is regularly reviewed and revised as new knowledge on this subject is generated and shared.

Monique Éloit
WOAH Director General

Main Recommendations

The Guidelines make the following recommendations for developing strategies to reduce disease transmission risks at wildlife markets and along the wildlife supply chain:

- **Use a One Health approach**, working together across the human, animal and environmental health sectors to ensure all aspects are considered, including biodiversity conservation, animal welfare, national and international regulations on threatened and endangered species, and the reduction of risks to human and animal health.
- **Establish transparent, replicable and science-based decision-making processes** to identify agreed-upon approaches that are risk-based and informed by the best available evidence and expert advice.
- **Conduct risk analyses** that consider animal welfare, health risks, conservation risks and risks to socio-economic values and then identify proportionate risk-management or risk-reduction measures.
- **Use multi-hazard risk-management strategies** that balance the different risks.
- **Tailor risk-management strategies** to the specific socio-ecological conditions and local context.
- Prior to and during implementation, **identify, document and measure potential unintended consequences** of the risk-management strategy.
- Develop metrics for each risk-management strategy to **monitor, evaluate and assess its feasibility and effectiveness**; subsequently, use these metrics to inform improvements in an iterative process.
- **Engage with all relevant stakeholders** throughout the risk-analysis process to build awareness, understanding, support and stewardship in a continuous, iterative and transparent process.

Introduction


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Introduction

For thousands of years, humans have been using wildlife for commercial and subsistence purposes. Wildlife trade takes place at local, national and international levels, with different forms of wildlife, such as live animals, partly processed products and finished products. Wildlife is a vital source of safe and nutritious food, clothing, medicine, and other products, in addition to having religious and cultural value. Wildlife trade also contributes to livelihoods, income generation and overall economic development.

However, wildlife trade can have detrimental effects on species conservation, depleting natural resources, impoverishing biodiversity and degrading ecosystems (Morton *et al.*, 2021). Wildlife trade, whether legal or illegal, regulated or unregulated, can pose threats to animal health and welfare. It also presents opportunities for zoonotic pathogens to spill over between wildlife and domestic animals, and for diseases to emerge with serious consequences for public or animal health and profound economic impacts (IPBES, 2020; Swift *et al.*, 2007; Smith *et al.*, 2009; Gortazar *et al.*, 2014; Stephen, 2021; Stephen *et al.*, 2022; FAO, 2020). The risk of pathogen spillover and disease emergence is amplified with increased interaction between humans, wildlife and domestic animals. The risk of pathogen spillover has also been exacerbated by climate change, intensified agriculture and livestock production, deforestation, and other land-use changes. Wildlife trade is also a risk to ecosystem biodiversity via the introduction of invasive species (Wikramanayake *et al.*, 2021). Therefore, increased effort must be put into understanding the potential consequences of the wildlife trade, mapping and analysing the adjacent risks, and implementing strategies to manage those risks. Reducing wildlife-trade risks not only helps to limit disease but also minimises the negative effects of invasive species. Between 1960 and 2021, invasive alien species caused estimated cumulative damage of around 116 billion euros across 39 countries in the European Union alone, despite strict import regulations (Haubrock *et al.*, 2021). The effect of invasive species is extremely apparent.

Factors contributing to disease emergence and pathogen transmission vary depending on which forms of wildlife are traded. For example, live animals present higher risks than processed products. And while all animals can host infectious agents, some species carry pathogens with a higher zoonotic spillover potential. Disease risks also vary depending on the setting, for example, whether farm or market.

Wildlife-trade-related welfare impacts also vary across activities, including, but not limited to:

- capture
- transport
- holding
- killing and slaughter.

Impaired animal welfare can lead to stress and immunosuppression, potentially increasing an animal's susceptibility to pathogens in the environment and the severity of infection, thereby increasing the number of subsequent onward pathogen

transmission events. For example, keeping animals in poorly managed holding facilities or transporting live animals in cramped conditions leads to high levels of stress and provides greater opportunity for pathogen transmission. Hygiene and biosecurity are therefore critical to minimising risk in situations which cause stress.

Disease risks may be further exacerbated by mixing wildlife from various geographic locations or by mixing wildlife with domestic and peri-domestic animal species, as this provides opportunities for pathogen transmission between animals that would not normally be in contact. The relative level of interactions between species varies with the complexity of wildlife supply chains, which are often informal and less regulated than domestic animal supply chains. Intensification of existing uses and emergence of new uses for wild species may also lead to new interfaces that modify pathogen spillover risks.

While pathogens do not discriminate between legal and illegal forms of trade, interventions to prevent disease emergence or reduce pathogen transmission are likely to be more effective in legal supply chains and markets, where regulations are more likely to be enforced. Illegal wildlife trade, by comparison, intrinsically involves illicit or non-standard practices and brings higher risk. Hence, reducing pathogen spillover from illegal wildlife trade relies on efforts to combat wildlife trafficking and limit illicit activities and high-risk practices.

Animal trade practices create multiple interfaces between humans, wildlife and domestic animals. They interact multiple times along the supply chain, such as during capture, farming, handling, storage, slaughter, processing, sale, transportation, relocation and translocation. Additional points of contact are created when animals are used for display at zoos and exhibitions, in traditional rites, for medical research or as companion animals. An assessment of the wildlife trade system in which these interfaces occur identifies the main stakeholders and the trade-offs between different interests (e.g. economic, health and conservation) inherent in this complex system. Risk assessment then identifies key hotspots and weaknesses where risks are greatest (Keller *et al.,* 2011). The results can then inform the development of risk-management strategies targeted at key stakeholders and the hazards assessed to be greatest.

Decisions related to disease risk management within wildlife trade are complicated not only by the sector's diversity but also by competing interests, such as sustaining economic development, conserving biodiversity and protecting the health of the public and of domestic animals. It is important to take a holistic approach when assessing wildlife trade systems, since focusing on singular hazards ignores these trade-offs. A One Health approach should be applied to wildlife trade. In other words, consideration should be given to biodiversity conservation, animal welfare, national and international regulations on threatened and endangered species, and reduction and management of risks to human and animal health.

Although domestic-animal risk analysis approaches can be adapted to wildlife trade, they can be insufficient because the latter is a highly complex system with a wide range of stakeholders and activities. These activities include local hunting, transboundary movement of wildlife as companion animals, farming and distribution of wildlife along large and complex supply chains, and marketing and

consumption of wildlife specimens and products. The types of markets and points of sale involved may not come under the same level of scrutiny as domestic livestock markets dealing in animals destined for the food chain. Therefore, specialised approaches to risk analysis are needed for wildlife trade.

Purpose

The Guidelines for Addressing Disease Risks in Wildlife Trade present a high-level framework to assess risk and identify risk-management strategies for wildlife trade.

These Guidelines are intended to help users to determine appropriate measures to reduce risk. They provide insights into how this can be done and how to overcome some of the likely challenges. The Guidelines highlight that significant positive change can be made in a cost-effective way.

These Guidelines provide support in applying risk analysis to the wildlife trade system. For the purposes of these Guidelines, risk analysis is a process that includes hazard identification, risk assessment, risk management and risk communication. The Guidelines also highlight some of the challenges that result from the complexity of the landscape and significant knowledge gaps.

In summary, these Guidelines enable key actors in wildlife trade to identify and select pragmatic, flexible, practical, adaptable and relevant risk-management strategies based on identified disease risks and available capacity, and to ensure their effective and sustainable implementation.

Creating and supporting communities of practice to share lessons learned will encourage continual improvement. The Guidelines will be reviewed and revised as new knowledge is generated, documented and shared.

Scope

The Guidelines are intended for authorities with a mandate related to animal health and welfare, public health, or wildlife management and trade. The Guidelines are also intended for a wide range of stakeholders in wildlife trade at local, sub-national, national, regional and international levels, including community-based groups, individuals, governmental organisations and non-governmental bodies. For the purposes of this document, wildlife is defined by WOAH (2022) as feral animals (domestic animals living without human supervision or control), captive wild animals (with a phenotype unchanged by human intervention and living under human supervision or control) or wild animals (with a phenotype unchanged by human intervention and living without requiring human supervision or control).

The Guidelines can be applied across the spectrum of interfaces for wildlife, domestic animals and humans at wildlife markets, traditional food markets selling wildlife or their products, or another point of sale if not in a market, and at all points along supply chains in a wildlife trade system. **Figure 2**, p. 22 shows a generic wildlife supply chain; each component of the chain represents a critical control point or interface where the Guidelines can be applied (e.g. harvest, capture, processing, slaughter, transportation, farming, sale and use by the end-user). Risk-management strategies need to be sensitive to and adapted to differing socio-ecological, socio-political and cultural settings and contexts (Stephen, 2021; Stephen *et al.*, 2022). They should not create unjustified barriers to trade and should be feasible in terms of cost, available capacity and technical requirements.

As information for disease risk management in wildlife trade may be limited or biased towards a particular location, scenario or time period, decision-makers may sometimes need to consider a precautionary approach. That is, if the emergence of a particular pathogen would have serious consequences, precautionary measures may be implemented on the basis of a risk assessment.

The Guidelines present a framework to assess risk and identify risk-management strategies for wildlife trade. They also provide some examples of cost-effective and sustainable approaches to reducing disease risk in wildlife trade. They do not, however, provide specific guidance on disease prevention, biosecurity, surveillance, wildlife health intelligence or wildlife health resilience. Neither are they intended to address drivers of disease emergence or social and behavioural change.

How to Use the Guidelines

These Guidelines are a framework for analysing risks within a wildlife trade system. The Guidelines are not prescriptive, so they can be adapted as needed.

Because all sections of the Guidelines should be considered when applying them to a particular wildlife trade system, it is recommended that the user reviews the entire document and becomes familiar with its general principles, before applying them for the first time.

The guidance portion of this document is split into four main sections.

1. Engagement with stakeholders and system mapping
2. Risk analysis
3. Monitoring and evaluation
4. Tools and guidance.

Section 1 describes important preparation that should be done before starting the risk analysis. This includes describing the wildlife trade system, identifying and mapping stakeholders, engaging with the stakeholders, and, where necessary, carrying out an initial risk prioritisation.

For the purposes of the Guidelines, a **wildlife trade system** is the network of interfaces between wildlife, humans and domestic animals, spanning the original source of the wild animal to the point at which the animal (or its derived products) is consumed or used.

Examples of wildlife trade systems include:

- a wildlife supply chain for a single species within a country
- urban wildlife markets at which live, terrestrial and aquatic wildlife species are sold
- wildlife used for human consumption in traditional food markets
- farmed wildlife or captive wild animals used for skins and furs
- transcontinental trade of wildlife used as companion animals, for research or as captive animals in zoos and exhibitions.

A description of the wildlife trade system should help the user to answer the questions of 'who' is managing the risk and 'where'. Such a description is important for the risk analysis and will support stakeholder engagement.

Once the user has carried out the preparatory work, they can move onto risk analysis, covered in Section 2, which includes the steps of hazard identification, risk assessment and then risk management.

Risk communication is an iterative process and should be included at multiple stages of the risk analysis. It is recommended that a risk communication plan be developed at the start of the risk analysis and redeveloped at each step, providing formal communication on goals or outcomes. In addition to risk communication, continual informal multidirectional communication should be maintained between stakeholders and users undertaking this process.

Section 3 ('Monitoring and Evaluation') describes the process of assessing the effectiveness of the risk management strategy. It explains why monitoring and evaluation is important and provides guidance on designing and implementing a monitoring and evaluation framework.

Section 4 ('Tools and Guidance') and the annexes point to complementary resources, including well-established standards and other resources that can support implementation. These complement existing WOAH standards and resources, which are used by national Veterinary Services and governments to protect the health and welfare of their animals and facilitate safe trade for sustainable development. It is recognised that these resources are continually being updated and revised and that the links provided may go out of date.

Some of the considerations and approaches outlined in the various sections of the Guidelines are interdependent. For example, engagement with stakeholders and experts should be considered when undertaking risk assessments, exploring risk-management strategies and developing a monitoring and evaluation framework. New information gathered as part of the risk assessment may point to a stakeholder group that has not previously been considered but should now be included in risk-management strategies.

The wildlife trade system to be addressed, and any work already undertaken, may influence the way and sequence in which each section is used.

Section 1
Engaging with Stakeholders and System Mapping

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Engaging with Stakeholders and System Mapping

Stakeholders are individuals, groups or organisations with an interest, influence or involvement in a wildlife trade system or on whom decisions and operations have a direct impact. In wildlife trade, stakeholders include regulators, such as competent national and international authorities and personnel responsible for animal health and welfare, public health, wildlife management and trade, compliance, and law enforcement. Stakeholders include people involved in wildlife trade itself, such as traders, transporters, animal handlers and consumers. Stakeholders also include the indigenous peoples and local communities around the world for whom wildlife is an important component in their livelihoods, culture and tradition; their knowledge and effectiveness in conserving wildlife provides a clear rationale for involving them in decisions about use and management (FAO, 2020).

Stakeholders oversee parts or the entirety of a given supply chain and the wildlife movements within it. They are a useful resource, as a source of opinion and knowledge that can inform efforts to optimise system design or change.

Stakeholder analysis or mapping identifies individuals and groups that should be involved in risk analysis. In addition to regulators, it should identify those involved in or impacted by risk-management strategies and those who benefit from wildlife trade, either directly or indirectly, including traders, market employees, farmers, consumers, transporters and feed providers.

Data are important for informing risk analysis, but centralised knowledge and data may be incomplete, undocumented or limited. Therefore, involving local stakeholders with knowledge, expertise and experience, as well as diverse perspectives, will maximise outcomes.

Stakeholder analysis, engagement and communication will ensure:

- the views and considerations of stakeholders with diverse and potentially conflicting perspectives and interests, as well as of those responsible for implementation and associated budgets, are considered
- potential unintended consequences of risk-management strategies are identified and addressed early
- the context, knowledge gaps and systems currently in place are understood by all stakeholders
- the identified context-specific risks and needs are appropriate and relevant.
- all communities concerned commit to collective, sustainable, long-term action and stewardship in reducing disease risk.

Establishing cross-sectoral relationships, inter-agency communication and participatory approaches early in the process will help to break down barriers and foster the trust necessary for effective collaboration, thus minimising conflict. Two-way

communication generates insight and the deep knowledge required to inform good decision-making and enable wildlife disease risk-management goals to be achieved (Stephen, 2021; Alders *et al.*, 2020; Jeleff *et al.*, 2022; Johnson *et al.*, 2020; Merkle *et al.*, 2019).

Building on and complementing existing governance bodies, coordination mechanisms and initiatives (such as the Wildlife Enforcement Networks [ICCWC, 2020] and IHR–PVS National Bridging Workshops [Belot *et al.*, 2021]) will provide opportunities to involve wildlife trade management, the regulatory sector (competent authority) and law enforcement in the design and implementation of interventions to reduce disease risk.

Communication and stakeholder engagement increase buy-in, augment the information available for risk analysis and ensure that decisions take account of ethical and cultural considerations. Communication and stakeholder engagement also raise awareness, ensure uptake of existing regulations, help frontline workers implement strategies, and promote development and enforcement of the legal reforms necessary for successful and sustainable outcomes.

Social and behavioural change and participatory epidemiology approaches also offer important insights into what is influential and impactful.

In a comprehensive situation analysis of social and behavioural change communications related to wildlife disease risks, Campbell *et al.* (2021) identify factors that consistently contributed to successful strategic communications and stakeholder engagement. Their analysis identifies the following five success factors:

- basing messaging and communications on the target audiences' pre-existing values
- using positive social messages, not just negative environmental (or health) messages
- ensuring messengers are credible, relevant and can speak with authority on the issue
- focusing on what is relevant to, and resonates with, specific audiences
- clarifying and simplifying guidance on change, and enabling, rather than instructing.

Identifying Stakeholders

An essential part of risk analysis is knowing who the various stakeholders are within a system.

A list of stakeholders should be developed based on the available information surrounding the wildlife trade system. Various ways of identifying potential stakeholders should be explored, ensuring inclusivity (OIE, 2010). The list could be compiled from internal institutional knowledge, literature reviews and information gathered from professional networks, for example.

It is important to represent all stakeholder groups equitably, as far as practicable. To produce a complete picture of who these groups are, analysts should ask, 'Who has an interest in and who has knowledge of value to the topic?' and 'Who may have influence to support or block recommendations resulting from the analysis?' (Jakob-Off *et al.*, 2014).

All wildlife scenarios attract interest from a range of people. Groups or individuals to consider as a starting point are importers and exporters; traders; producers; farmers; consumers; indigenous people and local communities; academic and scientific institutions; competent authorities responsible for wildlife, animal health and public health; veterinary epidemiological institutions; interest groups and activists; and the media. Wherever communication can be facilitated between relevant experts and stakeholders, there are opportunities to share information and gain insights that might not otherwise arise. This recommendation applies whether the risk analysis is conducted by an individual or a group.

Once a list of stakeholders is established, a strategy for engagement and communication should be devised. It is important to learn whether contact has already been established with any of the proposed stakeholders. Those with existing links may be able to help contact other stakeholders. For institutions, groups and organisations, it is important to ensure that the correct person is contacted, namely someone who is empowered to be a representative.

Next, the most appropriate and cost-effective means of providing stakeholders with the necessary information should be explored. Options include mailings, publications, web pages and online or face-to-face meetings (OIE, 2010).

Each stakeholder successfully contacted can be a source for further information. A structured interview, using a pre-planned series of questions, is recommended.

Stakeholder Mapping

Once the stakeholders are identified, it is useful to understand their level of engagement in and influence on the wildlife trade system. This can be done by mapping, using Mendelow's matrix (**Figure 1**) or similar methodologies. Stakeholder mapping identifies the most influential stakeholders in the system or those who hold the largest stake.

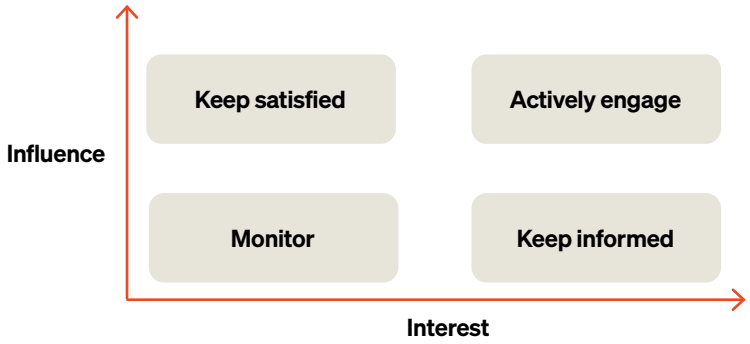

Figure 1. Modified Mendelow's matrix for mapping stakeholders (APGAW, n.d.)

Structured interviews, questionnaires or workshops can be used to determine the stakeholder's level of influence and interest in the system. Direct, descriptive questions are a good starting point: for example, 'What is your perceived level of influence on the system?' (Horigan *et al.*, 2022). It may be useful to follow up with more questions.

Where it is not possible to engage directly with a stakeholder, a proxy can be used to estimate the influence and interest the stakeholder has (Horigan *et al.*, 2022).

The completed map or matrix of stakeholders should then be verified by the stakeholders themselves. The stakeholders can see the results and evaluate whether their position in the system is appropriate (Horigan *et al.*, 2022). Later, the analyst should periodically evaluate whether the stakeholders' positions on the matrix should change, considering their current influence in the system (Horigan *et al.*, 2022).

Mapping the Wildlife Trade System

A description and map of the wildlife trade system is important for both risk analysis and stakeholder engagement. The description and map should answer the questions of 'who' is managing the risk and 'where'.

When describing and mapping the wildlife trade system, the following characteristics should be considered:

- Geographic scale: Is it local, national, regional or international?
- Wildlife supply chain or market type: Where might humans, wildlife and domestic animals come into contact along the supply chain, from source to end use? What human–animal–environment interfaces exist within the market? What is traded or used? For example, is it live animals or animal products? Does this change along the supply chain?
- Type of wildlife: Which taxa or species are involved?
- Volume of trade: How many animals are being traded, or what is the weight of the product?
- Existing strategies and policies: What are the current risk-management measures (e.g. biosecurity, surveillance, movement controls, hygiene)? What are the local, national and international policies, regulations and standards that apply along the supply chain or at the interface? Are they applied effectively?
- Relevant wildlife species considerations: What considerations specific to the species or scenario need to be acknowledged (e.g. source, husbandry requirements, welfare)?
- Knowledge gaps or limitations: What are the limitations or gaps in knowledge (e.g. regarding the disease, stakeholders involved in the trade, locations of markets or farms, numbers of animals or volume of trade, and compliance with regulations)?

The wildlife trade system description and map should be revised at each stage in the risk analysis, integrating new knowledge and lessons learned.

Figure 2 illustrates a generic wildlife supply chain. Wildlife supply chains can, of course, be far more complex than shown.

When considering the generic wildlife supply chain, the following points should be considered:

- All human–animal–environment interfaces, whether commercial or non-commercial, legal (both regulated or unregulated) or illegal, may carry disease risks.
- Not all interfaces present equal disease risks.
- The current evidence base around wildlife trade and disease emergence is limited because studies focus on particular zoonoses, certain geographical regions and specific activities (Gortazar *et al.*, 2014).
- A lack of systematic evaluations and impact assessments of risk-management options makes it difficult to pinpoint feasible, effective, efficient, acceptable or sustainable policies or practices (Stephen, 2021).

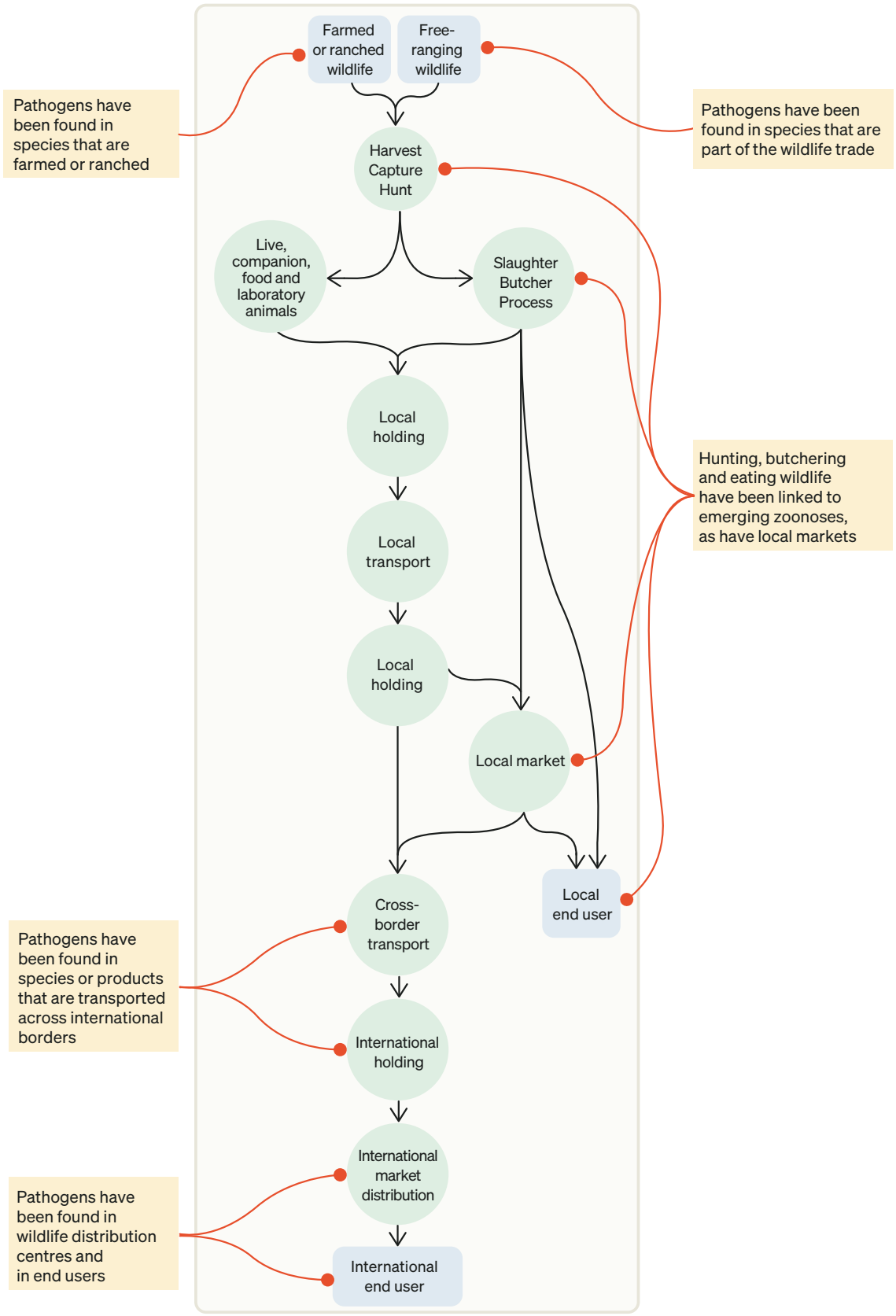

Figure 2. The generic wildlife supply chain (credit: John Berezowski, adapted from Stephen, 2021)

Risk Prioritisation

As a next step in securing a specific wildlife trade system against disease, the risks associated with the system – including risks to health, animal welfare, conservation and socio-economics – should be identified and prioritised. In this step, the most severe risks are identified so they can be addressed first. Broadly, this step involves identifying risks, measuring their probability, assessing their impact, calculating the total risk and, based on the outcomes, determining which risk to act upon first. By identifying the most pertinent risks, risk prioritisation will support both decision-making and resource allocation.

It should be noted that risks should be prioritised before the risk analysis is performed. It should also be noted that risks differ from hazards. During risk analysis, one of the steps is hazard identification, which also entails prioritisation. Users may choose to combine hazard prioritisation and risk prioritisation. But where a system is particularly complex or new, it is recommended to undertake risk prioritisation as a separate, preliminary step to inform the hazard identification. If needed, a more detailed risk prioritisation process can be performed during hazard identification.

The initial risk prioritisation can be broken down into five main steps:

1. Use available information (often historical) to identify risks associated with the system being assessed.
2. For each identified risk, estimate its associated perceived risk and impact levels.
3. Rank each risk based on the outcomes of step 2.
4. Identify the highest priority risk(s) based on this ranking.
5. Review the results of each step with system owners and stakeholders and revise as needed.

The tools available in section 4 can be used to facilitate risk prioritisation, along with expert opinion, literature reviews and other appropriate methods.

The priority assigned to each risk will depend on multiple factors including the laws and import and export policies of the countries involved; stakeholders' views; knowledge of the habitat types, species and climates; and the industry practices of the importing and exporting countries. For example, in some settings, the need to prevent illegal trade in CITES species and disease spillover to humans and other animals will be prioritised over protecting the traditional use of wildlife in religious rites and the use of animal products for medicines or consumption.

Risk prioritisation will be performed, reviewed and revised at multiple stages, as many sources will feed into it, such as feedback from stakeholders and literature reviews. Like with stakeholder mapping, risk prioritisation involves a cyclical process of review, whereby risks identified in a prior exercise should be reassessed periodically to determine whether their ranking remains the same. It is possible that the situation has changed in terms of risks present, probability of a risk occurring, or risk appetite, for example.

Additional information may shift risk priorities. For example, an initial risk prioritisation may determine that pet trade in a certain non-native live species carries a low risk of introducing an exotic disease. This opinion should be revised if, in the hazard identification, the literature review and expert opinion determine the risk to be almost negligible. However, risk level should be raised if it is later learned that import of this species has damaged ecosystem stability in countries with similar climates, habitats and species composition.

After the initial risk prioritisation, stakeholders are informed of the outcomes. This step of communicating preliminary risk occurs before the risk analysis.

Section 2 – Risk Analysis

Risk Analysis

Risk analysis involves identifying hazards; identifying, prioritising and assessing risks; identifying, selecting and implementing measures that can reduce the risk to an appropriate level; and communicating the risks and control measures (FAO and WHO, 2011).

Figure 3 provides an overview of the interactions and processes within risk analysis.

Figure 3. The structure of a risk analysis (OIE, 2010)

Hazard Identification

Hazard identification results in a list of pathogens or pests associated with the wildlife commodity of interest. Hazards may also include potentially invasive species or physical or chemical hazards. Literature reviews, along with information drawn from experts and horizon scanning, are used to create a list of the possible pests, pathogens and other hazards. Gaps in knowledge can also be identified and recorded.

Once identified, each hazard can be assessed through the next steps (of risk assessment) to define the level of risk it presents for each of the prioritised areas – human health, animal health, environmental health, biodiversity – throughout the entire wildlife trade system. The hazards can also be classed by whether they are listed pathogens (according to the WOAH Terrestrial and Aquatic Codes, Chapter 1.2) or whether they have potential to be emerging diseases.

Identification of high-risk wildlife species, according to the risk prioritisation, will assist this hazard identification step (**Table 1**). It should be noted that what constitutes a high-risk species and the absolute risk it presents will vary based on the risk prioritisation. For example, if the prioritised risk is the impact to biodiversity, then a high-risk species could be a CITES vulnerable species, whereas if spillover to domestic species is prioritised, the high-risk species may be captive wild animals (Simpson *et al.*, 2020).

Table 1. Examples of high-risk species

Examples of high-risk species according to a risk prioritisation approach that considers risks to human health, animal welfare, conservation and socio-economics
Those that risk disease spillover into domestic animals either through consumption or proximity E.g. small feral ruminants, game birds and feral pigs
Those with high risk of disease spillover at the human–animal interface not through consumption E.g. peri-domestic rodents, bats, exotic animals (including birds) as pets, non-human primates, animals used for traditional medicines or religious rites
Those with high risk of disease spillover at the human–animal interface through consumption E.g. any animal or product of animal origin being sold as food or for slaughter (includes bushmeat)
Those that risk biodiversity impact through export E.g. an animal on the CITES list (except those of 'least concern') removed from its habitat for trade (e.g. pangolins, wild donkeys, sharks)
Those that risk biodiversity impact through import E.g. any live non-native animal introduced to an import destination through wildlife trade
Live animals with high risk of causing economic impact to commodities though import to non-native habitats E.g. rodent species, European rabbits, lionfish and certain other species in fisheries, agriculture and forestry

Compile Potential Hazards

The first step in conducting a hazard identification is to list all the initial hazards that may be associated with the system being examined. Examples may be pathogens that can cause epizootic, exotic and endemic diseases; physical and chemical hazards; and the introduction of non-endemic animals (potentially invasive species). A thorough investigation of these hazards is necessary, and their presence should be confirmed from multiple, up-to-date sources.

Information sources for a hazard identification may include the following (Jakob-Hoff *et al.*, 2014):

- literature searches, PubMed, Web of Science
- online incidence reporting databases, such as the World Animal Health Information System (WAHIS) for disease and the Global Register of Introduced and Invasive Species (GRIIS) for introduced and invasive species
- requests to governmental departments involved in the trade system (through border control, imports/exports, policy)
- expert opinion, including stakeholders
- previous risk assessments.

Define Decision Criteria

Decision criteria are questions used to categorise potential hazards. They can be, for example, configured into a flow chart of relevant questions in the form of a decision tree. The purpose is to filter out potential hazards and categorise them as negligible, non-negligible, etc. The questions used will vary depending on the system or interface.

Figure 4 provides an example pathway for assessing potential hazards, although some systems or interfaces may require much more complex decision trees. **Table 2** provides a list of sample questions. Further examples of decision trees are included in Annex 2.

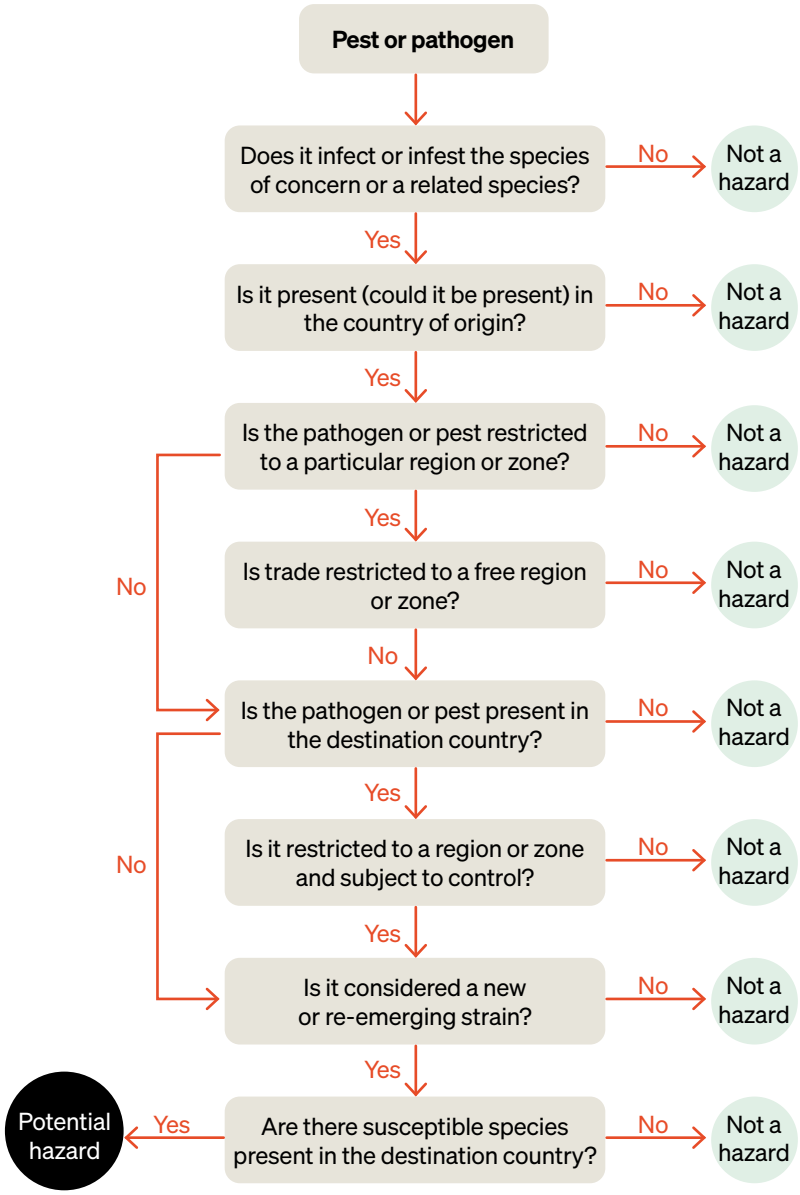

Figure 4. Example of a simple decision tree for conducting a hazard identification

Table 2. Sample questions for creating a decision tree. Those chosen will depend on hazard type.

Is the hazard present in the source country?
Is the hazard able to affect or infect a relevant species?
Is it present across the whole country or only in restricted zones?
If horizon scanning is included, what is the geographic radius to be included?
Are affected species present at wildlife markets or other trade sources?
Is the hazard present at the destination?
Is it endemic, exotic or epizootic?
Are the strains or species that are present at the destination different from those in the exporting country?
Is its presence at the import destination country-wide or restricted to a few areas?
Would import of farmed wildlife risk a higher level of contact with humans or livestock than currently exists?
Is the hazard notifiable or under a veterinary surveillance or control programme in the target destination?
If the hazard is a live animal, is the species present? If not, could it establish and negatively affect local biodiversity?
Could the hazard affect biodiversity in the source or destination country?
Is the hazard a listed disease, according to the World Organisation for Animal Health?
Could the hazard be a vector for diseases, and are these diseases of concern to human health, agriculture and/or local wildlife?

The selected risk questions can be answered by conducting a literature review for each hazard. The answers to risk questions inform decision making.

Ideally, once the list of hazards has been compiled and the risk questions answered, the relevant stakeholders and subject experts should be consulted once again to review the list and offer feedback. This step helps to ensure that the criteria sufficiently cover the required scope.

The hazard identification steps will lead to a list of non-negligible and/or negligible hazards. Those of concern can then be reliably put forward for further risk assessment (OIE, 2010).

Risk Assessment

A risk assessment estimates the likelihood of introduction, spread or establishment of the identified pathogens and hazards of concern (including the emergence of a novel pathogen), as well as the likelihood of biological, environmental and socio-economic consequences. With wildlife risk assessments, it is also necessary to consider biodiversity risk.

Risk assessments can be qualitative, quantitative or semi-quantitative, depending on the type and amount of data available. Given that there will be knowledge gaps and certain assumptions made, it is important to estimate the uncertainty level for likelihoods and consequences associated with the risks. Incomplete data will likely

limit the practicality of quantitative approaches; therefore, qualitative approaches (i.e. those that describe risk levels in categorical terms such as 'negligible', 'low', 'moderate', 'high') may be employed.

In the context of zoonoses, any physical or contextual variable becomes a risk factor if it contributes to the likelihood or impact of an outcome of interest, such as a disease occurring in an individual or population, or cross-species transmission (adapted from WHO, FAO and OIE, 2020).

Steps in Risk Assessment

Before any assessment is undertaken, it is important to first determine and state the purpose of the risk assessment. Doing so will give all stakeholders, including those undertaking the risk assessment and the affected and interested individuals or groups, a clear understanding of its overall objectives and the nature of the risk being estimated. This is a critical step and one that involves interactive discussion with those requesting the assessment. If the purpose is vague or ill-defined, problems will inevitably arise (OIE, 2010).

Next, a risk question should be determined. The risk question should include reference to the commodity, the hazard, and spatial (space) and temporal (time) bounds. The question should be agreed upon with the risk managers (in other words, those people responsible for licensing or certifying the trade or for managing the impacts on wildlife; e.g. the trade team, wildlife managers, public health risk managers). It may also include input from other stakeholders.

The wildlife trade system or interface to be assessed will determine which of the following steps will be undertaken, but the complete process of risk assessment includes the following:

1. Entry assessment. This step estimates the likelihood that the importing commodity will introduce the hazard.
    a. Consider the prevalence of the pathogen or pest (e.g. prevalence or presence/absence in the country of origin and the region) and its biology; animal species being imported and harvest or production method of the wildlife or product; any existing import controls; and the means of transport (including the gathering of animals and mixing of species, the route, etc.).
    b. Assess the likelihood of the commodity carrying the hazard. For example, consider the likelihood of the commodity still being infectious or contaminated during transport and whether any trade rules have been applied that could mitigate the risk, such as pre-movement testing or quarantine.

2. Exposure assessment. This step estimates the likelihood that susceptible animals, humans or environment will be exposed to the hazard in the traded commodity in the trade system.
    a. Again, consider the means of transport and the handling of the animals.
    b. Consider the likelihood of contact with local susceptible animals (or humans, if there is a zoonotic disease risk).
    c. Learn whether vector transmission or direct contact or indirect contact are necessary to allow transmission.
3. Consequence assessment. This step estimates the likely magnitude of potential biological, environmental and economic consequences associated with the entry, establishment or spread of the hazard.
    a. List the possible direct and indirect consequences (e.g. on health, welfare, trade, the economy, the environment, biodiversity or society) if transmission to a susceptible species were to occur. An economic analysis may be undertaken, but health, conservation and welfare consequences are equally valid.

For each of these types of assessment, the steps are similar. The commodity (i.e. the wildlife or product) under consideration, which may act as a vehicle for a hazard, must be evaluated in the form in which it is intended to be traded, used, processed or sold. The assessment should consider all the pathways in which a hazard could present a risk. With each identified hazard, available information is used to assess the likelihood of the risk occurring.

For greater detail, the *WOAH Import Risk Analysis Handbook* should be referred to for trade in animals and animal products. Where food safety is an issue, alternative methodology can be used (e.g. from the Codex Alimentarius Commission). The International Union for Conservation of Nature/WOAH Guidelines for Wildlife Disease Risk Analysis and the Manual of Procedures for Wildlife Disease Risk Analysis can also be used, in particular where a risk to conservation is being considered.

It can be helpful to draw a risk pathway flow chart for each hazard under consideration. **Figure 5** provides an example set of risk pathways. Risk pathway flow charts are a graphic depiction of the biological pathways by which a hazard might present a risk (e.g. through introduction into an importing country or from introduction to a market setting following wild harvest). A risk pathway flow chart also conveys in a simple, transparent and meaningful fashion the range and type of pathways considered. It provides a useful conceptual framework to facilitate the identification of biological pathways leading to the commodity harbouring the hazard; the exposure of susceptible animals and humans; and potential outbreak scenarios (including the environmental, ecological, biodiversity-related and socio-economic impacts). It also helps to identify risk-management strategies.

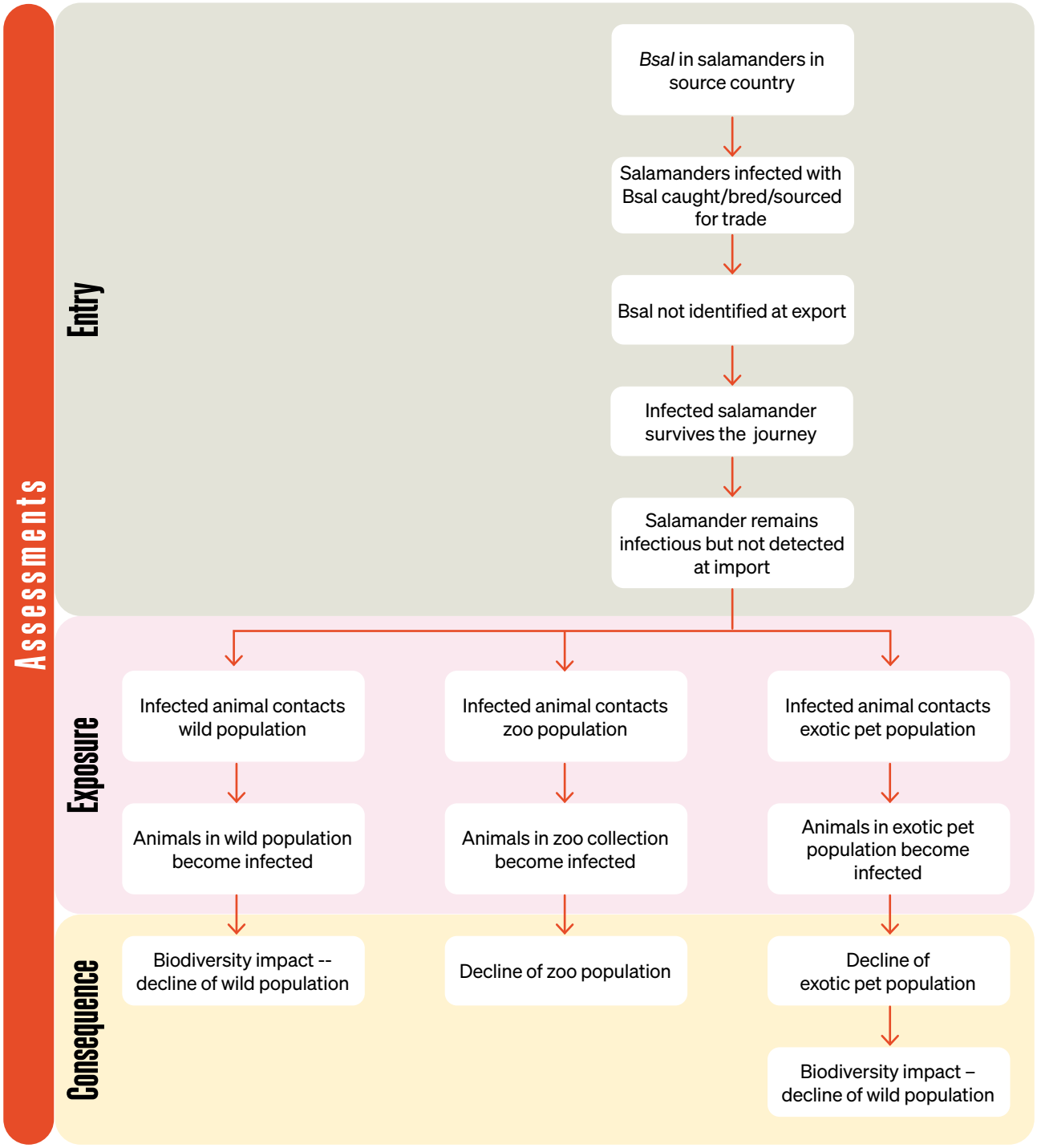

Figure 5. Example risk pathway for entry, exposure and consequence assessment using *Batrachochytrium salamandrivorans* (Bsal)

Risk Scores

Risk scores are a value assigned to a risk factor to reflect its estimated level of risk. To estimate a risk score, a conditional likelihood method can be used. In this method, each prior step in a pathway is assumed to have occurred. For example, if the likelihood for an animal contaminating other animals in a holding pen is being considered, it is assumed that the animal is infected.

Examples of risk levels and definitions are shown in **Table 3**. After assigning overall risk scores for each pathway step, these may be kept separate or aggregated into a single estimate for the whole pathway. **Table 4** details an example methodology for creating an overall estimate for the whole pathway, through the multiplication of two qualitative likelihoods.

Table 3. Definitions for qualitative risk terms
(Spiegelhalter and Riesch, 2011; OIE, 2010)

Risk level	Definition
Negligible	Event is so rare, it does not merit consideration
Very low	Event is very rare, but cannot be excluded
Low	Event is rare, but does occur
Medium	Event occurs regularly
High	Event occurs very often
Very high	Event occurs almost certainly

Table 4. Matrix for the multiplication of two qualitative likelihoods
(Mendelow, 1981)

Results of likelihood 2	Results of likelihood 1					
	Negligible	Very low	Low	Medium	High	Very high
Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible
Very low	Negligible	Very low*	Very low*	Very low	Very low	Very low
Low	Negligible	Very low*	Low	Low	Low	Low
Medium	Negligible	Very low	Low	Medium	Medium	Medium
High	Negligible	Very low	Low	Medium	High	High
Very high	Negligible	Very low	Low	Medium	High	Very high

*If multiplying successive likelihoods together, particularly low likelihoods, a modified matrix may be used as given in Kelly *et al.*, (2018), which allows for an improved estimation of risk accounting for basic mathematical principles. Those likelihoods marked with an * are reduced to negligible.

Uncertainty

As with many complex situations, certain data may be unavailable when dealing with wildlife disease. Data for a particular species or group of species may be limited, and studies will certainly focus solely on specific periods, scenarios or geographic locations. Each risk level should therefore be accompanied by an uncertainty score reflecting the perceived completeness of the data and confidence in the estimated risk level, including whether further information is likely to change the estimate. Uncertainty can be thought of as a measure of incompleteness in the information about a particular topic.

Because data relating to wildlife disease are often limited, qualitative analysis is the most common approach in wildlife disease risk assessments. Recording all assumptions and limitations will ensure the best use of available information; it will also help identify significant data gaps for further research and the level of uncertainty that decision-makers should take into consideration.

When uncertainty is medium or high, the analyst should also note how the overall risk estimate would change if the uncertainty were reduced for the different steps in a risk pathway.

Table 5 defines these terms.

Table 5. Qualitative categories for expressing uncertainty given the available evidence
(Spiegelhalter and Riesch, 2011; Kelly *et al.*, 2018)

Uncertainty category and definition	Type of information or evidence on hand to support uncertainty category
Low **Further information is unlikely to change our confidence in the probability estimate**	• Extensive data from peer-reviewed studies on this pathogen or strain of pathogen giving similar results, e.g. survival time of pathogen in the environment • Expert opinion with a consensus among experts • Authorised documentation, such as transport records or animal movement records, that verifies timelines • Meteorological information from recognised source • Documentation of veterinary checks of animals on/off premises • Laboratory study information from this outbreak verifies timeline • Epidemiological information from this outbreak
Medium **Further information is likely to have an important impact on our confidence in the probability estimate**	• Some data from peer reviewed studies on this pathogen or strain of pathogen but the results may be highly variable • Evidence from previous observational studies/surveillance reports/outbreak reports • Individual expert opinion • Some documentation but it may not be accurate or comprehensive • Evidence from observations and/or personal communications recorded from this outbreak
High **Further information is very likely to have an important impact on our confidence in the probability estimate**	• Scarce or no data from peer-reviewed studies on this pathogen or strain of pathogen • Evidence from unpublished reports, observations, personal communications • Individual non-expert opinion • No documentation available

Risk Management

Risk management is a process of identifying, selecting and implementing measures to reduce risk, informed by and specific to the scope of the risk assessment (i.e. hazard of concern, population targeted, geographic area and time period considered). Risk management can also include measures to reduce knowledge gaps (e.g. conducting disease surveillance or carrying out research), which will decrease uncertainty in the risk assessment.

When measured risk derived from the analysis exceeds the risk tolerance (decided by stakeholders), the next step in improving the safety of a wildlife trade system is to introduce risk-management measures and reduce the risk to an acceptable level.

The subsequent selection of risk-management strategies should rely on information gathered in the hazard identification and risk assessment, as well as account for knowledge gaps. The strategy or strategies selected must balance multiple objectives, such as prevention of disease emergence, preservation of socio-economic value and protection of biodiversity (**Table 7**).

The Bsal example in **Figure 6** highlights why risk should be carefully considered. After identifying that the main cause of Bsal spread was live companion animal trade, authorities needed to take the various risks into account to create a management strategy. As a result, authorities implemented multiple risk-management strategies, covering all the relevant considerations to the wildlife supply chain as described in **Table 6**.

Generally, when the risk assessment determines that the risk is greater than is acceptable (i.e. the risk score is greater than the risk tolerance of the stakeholders in that country) for a chosen wildlife trade system, risk-management measures are applied. The chosen risk-management measures should:

- be proportionate, feasible, economically viable and technically operational;
- not create unjustified barriers to trade. That is, measures should have a scientific justification (refer to the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures) and not be disguised trade restrictions that create preferences or biases;
- be based on risk analysis and not be chosen arbitrarily;
- be agreed upon with relevant stakeholders in the system, while keeping others informed;
- consider other sources of knowledge and uncertainty;
- be applied consistently across multiple commodities where hazards are the same, to prevent situations of different protection levels; and
- be scientifically peer reviewed, to ensure technical robustness and that measures are appropriate to the circumstances and international standards (Jakob-Hoff *et al.*, 2014).

Risk-management strategies should be applied only to the extent that is necessary to reasonably and effectively manage the overall described level of risk.

Case Example of Trade in Salamanders

Batrachochytrium salamandrivorans (Bsal) is an emerging pathogen capable of causing significant morbidity and mortality in salamanders and is a WOAH-listed aquatic animal disease. The United States has the largest diversity of salamanders in the world, and the introduction of Bsal to North America could have severe impacts on biodiversity and amphibian conservation. In 2013, unexpected mortalities of wild and captive fire salamanders (*Salamandra salamandra*), ultimately attributed to Bsal, were first observed in Belgium and the Netherlands, leading to significant salamander population declines. Since then, Bsal was also detected in captive salamanders in the United Kingdom and Germany. Studies suggested that Bsal was likely endemic to Asia and may have been introduced into Europe through the global companion animal trade.

Subsequent spillover from captive to wild populations was strongly suspected. From 2010 to 2014, over 750,000 salamanders were imported into the United States for companion animal trade, creating a high probability that Bsal could be introduced.

The United States Geological Survey developed a risk assessment to predict the potential distribution of Bsal invasion using spatial data on salamander imports and companion animal trade establishments. They used it to analyse the potential consequences of an introduction (Richgels *et al*., 2016). The risk assessment identified a likely risk of Bsal introduction with no mitigation measures and identified high-risk areas. The results of the risk assessment informed the government's risk-based and precautionary approach to preventive management actions, including interim regulations on importation of captive salamanders and a large-scale surveillance effort targeting geographic areas at highest risk of exposure to the pathogen.

Subsequent evaluation of the regulatory action and surveillance by Grear *et al*. (2021) found that the regulatory actions put in place in 2016 by the Fish and Wildlife Service under the Lacey Act had the intended effect of reducing salamander imports and subsequently reducing the risk of introduction. A widespread surveillance effort conducted by the Geological Society Amphibian Research and Monitoring Initiative contributed to reducing consequence risk by increasing confidence of Bsal absence in high-risk areas (Waddle *et al*., 2020). However, the evaluation noted that the list of regulated imported species was incomplete, as new research confirmed species capable of carrying Bsal infection included those common in the captive amphibian global trade network. This development illustrated the need for ongoing risk assessment and surveillance to inform adaptive regulatory action.

Chapter 8.2. of the *Aquatic Animal Health Code* (WOAH, 2022a) provides international standards on importation or transit of aquatic animal products in relation to the exporting country's Bsal infection status.

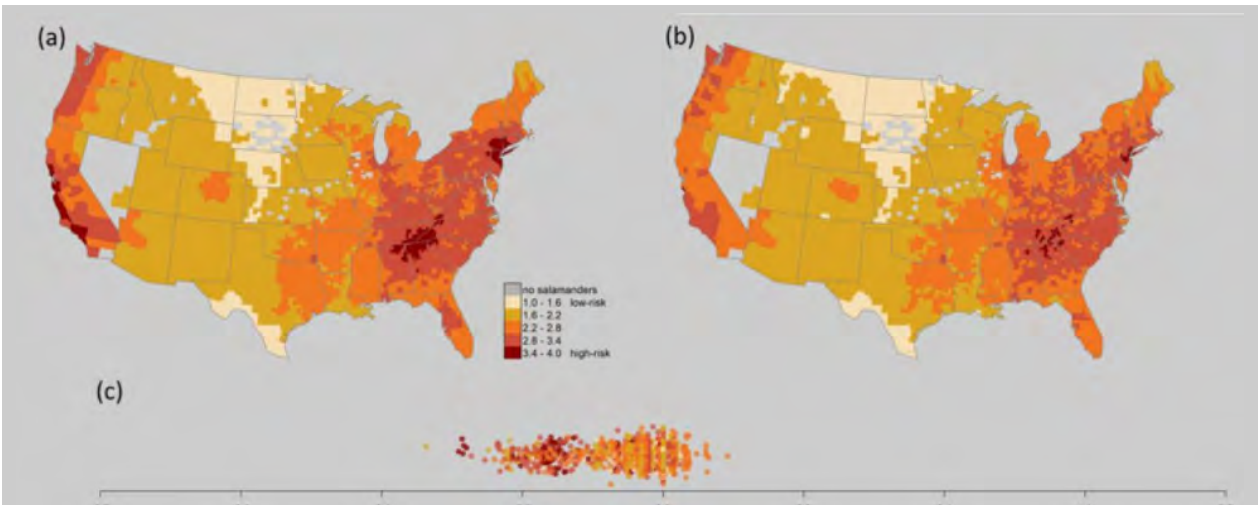

Figure 6. Relative risk maps of combined Bsal risk

Each point is a county, coloured by its risk score in

(a) pre-action risk (2010–2015);
(b) risk after importation restrictions placed on over 200 salamander species (relative risk scores were scaled to 2010–2015); and
(c) change in relative risk score per county as a proportion of pre-action risk, i.e. the change in relative risk after putting import restrictions in place

Table 6. Considerations when assessing the disease risks associated with wildlife markets and supply chains (Booth *et al.*, 2021a; Wikramanayake *et al.*, 2021; Dietrich *et al.*, 2020; Lin *et al.*, 2021)

Practices
Hunting or capture practices
Farming practices
Captive wild animal husbandry practices (e.g. at markets, on farms or for companion animals in homes)
Product-sourcing practices (e.g. hair, wool, velvet)
Transportation practices
Hygiene and biosecurity practices (at each wildlife trade interface, see Wildlife supply chain considerations, below)
Butchering and meat processing practices
Species considerations
Species' evolutionary relationships, socio-ecology and life history patterns
Conservation status and role in ecosystem
Source population and ecosystem management status
Source: wild-caught, captive-bred, farmed, research facility, on exhibition, companion animal, ranched
Distance travelled along supply chain: local, regional, domestic, international
Live or dead, fresh, dried, frozen, smoked
Disease knowns and unknowns
Socio-cultural and religious status
Contribution to economy and livelihoods
Positive/negative contributions (benefits/cost) to the Sustainable Development Goals
Interspecies contact, types of contact, densities and interfaces
People
Domestic species
Other wildlife species
Types of contact and interfaces, including: • setting: in the field, at markets, on farms, in homes (companion animals) • product type: live or dead, fresh, dried, frozen, smoked, etc.
Wildlife supply chain considerations
Hygiene and biosecurity conditions
Location of farms, ranches or animal providers
Length and type of trade supply chains (consider opportunities for pathogen transmission or amplification)
Number and turnover of people
Distance people (buyers, sellers, farmers, etc.) travel to locations along the supply chain/to market
Distance wildlife travel along the supply chain/to market
Domestic or international trade
Number, variety, density and types of wild animal present (see Species considerations, above)
Number and types of domesticated animals present
Point of sale: for consumption or non-consumption, perishable or non-perishable (e.g. live/dead animals, food and medicines)
Regulatory and non-regulatory measures
Current government capacity to regulate, enforce and implement trade regulations
Regulations and policy frameworks in place
Current non-regulatory measures (e.g. industry and voluntary standards, certifications and frameworks)

Decision-makers may need to consider a precautionary approach when scientific evidence about the hazard is uncertain or absent, yet the consequences could be serious. In situations where there are knowledge gaps, another approach that can be applied is the hierarchy of controls, discussed in the next section. Whichever approach is applied, it should be reviewed regularly as new information becomes available from multiple sources (e.g. stakeholders, surveillance, research, monitoring and evaluation of risk-management strategies).

Given the variety of species involved in wildlife trade, as well as the differing harvest, transport, marketing and consumption practices, multiple approaches to risk management may be required. Ideally, they will be based on the outcomes of a risk assessment. They should be solution-focused while being attentive and adaptable to different socio-ecological, socio-political and/or cultural settings and contexts.

To develop feasible and effective measures to reduce the risk of disease spillover throughout the wildlife trade system, each control point in the supply chain must be considered a potential transmission interface that may contain known, novel, unknown or undescribed pathogens or hazards dangerous to humans, domestic animals and wildlife (He *et al.*, 2022). Critical control points are points at which risk-management steps must be applied to prevent or reduce hazards to an acceptable level (**Figure 2**). The development, design and application of standard risk-based disease management will depend on the availability of adequate information. Species-specific information to inform risk management may be limited, or biased towards certain species, locations or scenarios; therefore, application of the precautionary principle should be considered if the pathogen of concern would be likely to have significant consequences.

It is important that interventions are monitored and assessed for their feasibility (especially regarding cost and technical and operational requirements), effectiveness, and intended and unanticipated consequences. Ongoing assessment allows the interventions to be adjusted as necessary. Unfortunately, in general, the use of impact assessments is rare and there is a lack of systematic evaluation of risk-management options (Gortazar, 2014).

Hierarchy of Controls (Control Points)

The hierarchy of controls provides a framework for developing and designing risk-management strategies. It has been used for many years to address occupational health and safety in the workplace. The hierarchy of controls describes various approaches (called ‘controls’) that can be applied to a system to minimise exposure to hazards and ranks these controls from the most effective level of protection to the least effective (CDC, 2022).

The hierarchy of controls has five levels of controls to reduce or remove hazards (see **Figure 7**, which has been adapted for these Guidelines). These levels are 1. risk avoidance (minimise or remove the hazard), 2. substitution (replace the hazard), 3. engineering controls (isolate the hazard), 4. administrative controls (change management or behaviour), 5. biosecurity measures (protect people or animals).

Appropriate controls to reduce exposure to hazards can be identified by working through the various levels of the hierarchy, starting with the most effective level (risk avoidance). The feasibility, effectiveness and context of the controls aimed at risk avoidance are assessed before moving on to the next step (substitution): that is, if it is not acceptable or feasible to apply controls aimed at risk avoidance, then controls aimed at substitution are considered, then engineering controls, and so on. An assessment is repeated at each level in the hierarchy, resulting in the identification of a number of measures to be considered.

Sometimes views differ on where a particular disease management strategy fits into the hierarchy. For example, some might consider a given measure to be a risk-avoidance measure, while others might view it as a substitution. But that should not stop the framework from being used. Sometimes it is necessary to combine different levels of controls. For example, the implementation of biosecurity may require training, which is an administrative control.

These Guidelines use a modified version of the hierarchy of controls (**Figure 7**) to provide a framework to identify potential risk-reduction techniques and interventions to control exposures to occupational hazards and, in turn, minimise or avoid transmission of potential pathogens from wildlife along wildlife supply chains. (See Annex 3 for examples of risk-reduction interventions.)

This approach can be applied to:

- a specific wildlife trade system or interface,
- trade and use of a specific species or higher taxa group, and/or
- trade in a specific geographic, social, political or ecological context.

The control methods at the top of the hierarchy (risk avoidance), which focus on minimising or avoiding disease risks when there is contact between wildlife and humans or domestic animals, are considered the most effective. The method at the bottom, the use of personal protective equipment (PPE), is generally the least protective, especially over time. Although PPE may reduce risk and provide protection at the individual level, it contributes only minimally to building an inherently safer system over all. Interventions targeted at avoiding the disease risk altogether (i.e. via legislative change and full compliance with the introduced laws) generally have a lasting impact on the entire system. Although they may require more financial, social and political resources to achieve, they are considered a long-term investment in disease prevention.

In food health and safety systems, PPE would again be the lowest level in the hierarchy of controls. However, as PPE cannot be directly used on the animals themselves, other biosecurity measures would be implemented, such as transporting species separately or restricting handling of animals. Further examples can be found in the World Health Organization (WHO) Guidance for Reducing Public Health Risks Associated with the Sale of Live Wild Animals of Mammalian Species in Traditional Food Markets (WHO, OIE and UNEP, 2021).

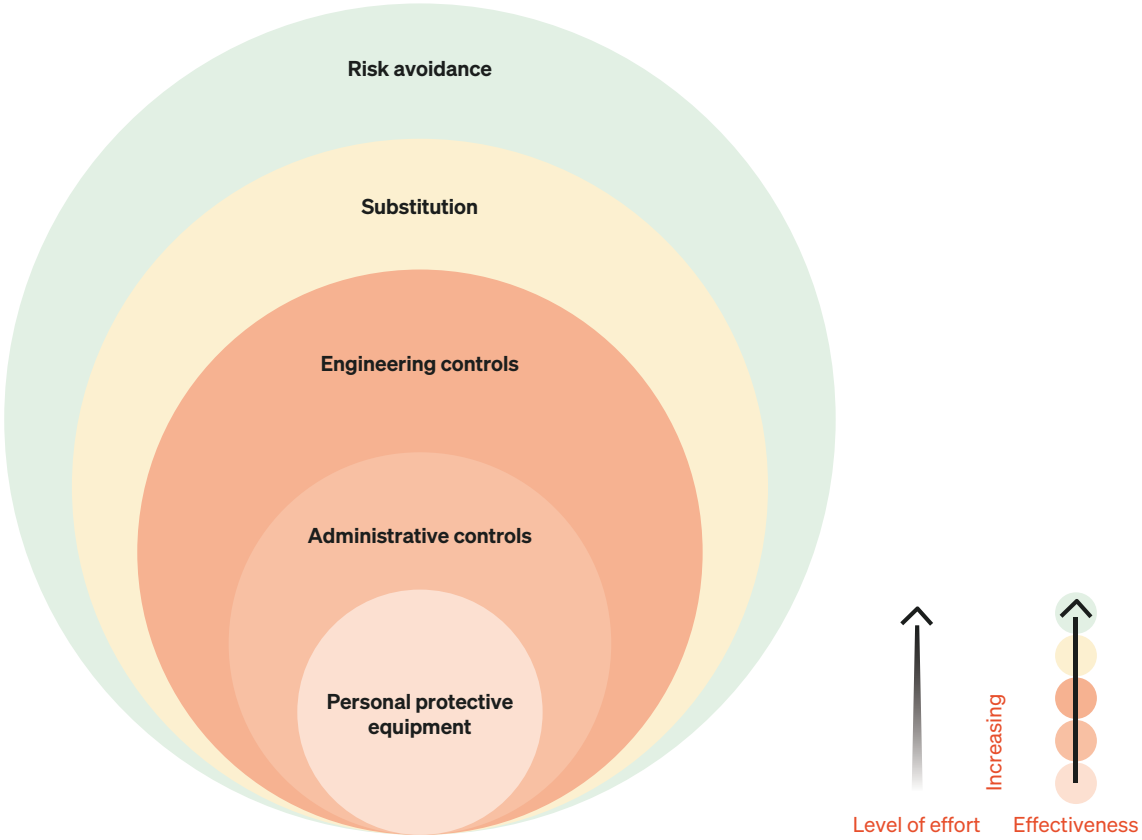

Figure 7. The hierarchy of controls

Hierarchy of Controls Applied to Generic Wildlife Supply Chains

Each step in the hierarchy is described below, along with examples applicable to wildlife trade. Some examples of potential unintended consequences are provided, but it is worth noting that consequences will be context specific. At the time of publishing these Guidelines, there are few studies exploring the unintended consequences of wildlife trade risk-reduction strategies.

Risk Avoidance ('Minimise or Avoid')

In wildlife trade, risk avoidance often focuses on the point of contact that facilitates pathogen transmission (i.e. the interface between traded wildlife, other wildlife, humans and/or domestic animals). It aims to minimise the hazard or remove it from the workplace or setting.

Markets or settings where live animals are held, slaughtered and dressed pose a particular risk for pathogen transmission to workers and customers (WHO, OIE and UNEP, 2021). One possible risk-avoidance control to 'minimise or avoid' could

involve introducing and implementing regulations to limit or prohibit the sale of live wildlife at markets. Another would be to prohibit or limit the presence of free-ranging animals on captive wildlife farms, thereby minimising or avoiding the interface where pathogen transmission could occur. A third example of risk-avoidance intervention is to implement existing laws, regulations or practices that limit contact between humans and wildlife by, for example, prohibiting the hunting, use or trade of specific species. Such an intervention also incorporates the fourth level, administrative controls, because the policy needs to be enforced and managed.

Conservation measures, such as protecting wildlife species from overharvest, are also a type of risk-avoidance control, as they remove or reduce the risk of pathogen transmission from wildlife to humans, domestic animals or other wildlife through human activities.

Risk-based national trade regulations restricting the import or export of wildlife may also be risk-avoidance controls because they prevent high-risk species from being introduced to a national wildlife trade system.

In each case, consideration must be given to potential unintended negative consequences of specific interventions, especially those that could be challenging to track. For example, introducing restrictions might shift wildlife trade into informal or unregulated supply chains and markets.

In sum, risk-avoidance controls can be incorporated at multiple points in the wildlife trade system, through restrictions that reduce or eliminate either the trade itself or contact with wildlife species during harvest, farming or movement along the supply chain.

Substitution to Lower Risk

As an approach to manage disease risk in wildlife trade systems, substitution can take a number of forms. It is aimed at replacing the hazard. For wildlife trade, it could entail substituting trade in high-risk animals with trade in lower-risk animals (informed by a risk assessment). Or it could consist of providing alternative income sources to discourage wildlife hunting and use.

When choosing such a control, it must be noted that if the demand for wildlife is satisfied by a shift to another type of wildlife that has a lower disease risk, the conservation of the substituted animals may be compromised.

In addition, for many species, pathogen information may be limited or biased towards particular locations and scenarios, so substituting one species for another may have an unintended effect of increasing disease risk. This possibility highlights the need to document assumptions and limitations during risk assessments.

Engineering Controls to Lower Risk

Engineering controls involve modifying physical infrastructure and equipment or revising a process to reduce exposure to the hazard. Such controls might include:

- changing the built environment to reduce contact between wildlife, domestic animals and humans
- keeping wildlife species separate from other animals to prevent or reduce pathogen transmission between species that would not normally be in contact (e.g. through fencing or biosecurity)
- using wildlife transport cages or holding facilities with specifications designed to minimise the contact between wildlife and bodily fluids, such as urine and faeces
- limiting situations where people, domestic animals and other wildlife share airspace.

Other engineering controls that can minimise contact between animals and between animals and people, as well as maximise welfare, include:

- using filtration systems and automated feeding or transport systems
- implementing biosecurity measures (e.g. disinfection)
- using wildlife-specific handling equipment.

Implementing engineering controls for wildlife supply chains for which pathogen transmission pathways and risk-control effectiveness are less well understood could lead to investment in structural solutions that are not fit for purpose and that conflict with or discourage 'minimise or avoid' risk controls. Structural measures may give people working with wildlife an unfounded sense of security regarding disease risk if the measures are not accompanied by training in why such structures are needed and must be respected. Engineering controls are usually combined with administrative controls since personnel require training.

Administrative Controls to Lower Risk

Administrative controls to reduce contact between wildlife, humans and domestic animals in the wildlife trade system include interventions designed to change the way people work with wildlife. Examples include:

- working with a team member present to assist and stay vigilant for hazards
- vaccinating workers against the identified pathogen risks in wildlife trade settings
- monitoring illness in workers.

Administrative controls also include:

- integrated strategies for improving hygiene and sanitation at all stages of the wildlife supply chain (from harvest through to processing and marketing)
- regulations relating to movement of species
- regulations requiring inspection of wild animal farms and the places where such animals are processed for food, distributed, and marketed, to ensure compliance
- regulations relating to animal health and welfare, including ante- and post-mortem inspections
- traceability requirements.

In addition, strategies to improve conditions in any of the five domains of animal welfare (nutrition, physical environment, health, behavioural interactions and mental state) also have the potential to serve as administrative controls to lower disease risks (Mellor *et al.*, 2020).

If implementation of administrative controls is attempted without effective stakeholder engagement and buy-in, there may be undesired outcomes, including ineffective results, non-compliance or driving of wildlife trade into unregulated supply chains (Bonwitt *et al.*, 2018; Hueston *et al.*, 2011).

Use of Personal Protective Equipment to Lower Risk

At all interfaces along the wildlife supply chain, personnel working with wildlife must follow guidance from national and public health authorities on the use of dedicated clothing and personal protective equipment (PPE) such as gloves, face shields and respirators.

Although PPE is important, it may also give people working with wildlife a false sense of security regarding disease risk, unless they have been adequately trained in why and how to maintain and use PPE correctly.

Hazard Analysis and Critical Control Points System

Another framework that can guide the development of risk-reduction strategies is the hazard analysis and critical control points system, which has been used to develop risk-based food safety systems (Campbell *et al.*, 2022, present a number of examples). However, this system is not explored in these Guidelines.

Managing Trade-Offs

Decision-making to address wildlife-trade risks is complicated because of the diversity of the trade and the potentially competing objectives of sustaining economic development, conserving biodiversity, and protecting public health and the health of domestic animals and other wild animals. Consequently, the outcomes of risk assessments relating to disease emergence and pathogen transmission cannot be considered in isolation.

The socio-economic benefits of wildlife trade for stakeholders should be balanced against its detrimental impacts on wildlife, biodiversity, humans, domestic animals and ecosystems.

Managing wildlife trade disease risks is a challenge with multiple objectives. These objectives may sometimes conflict, in that a gain for one objective may be at the expense of others (Figure 8). However, there may also be situations in which the objectives are synergistic or mutually beneficial. Where a system has multiple objectives, the trade-offs should be systematically evaluated. Decision tools and frameworks are helpful in this complex environment.

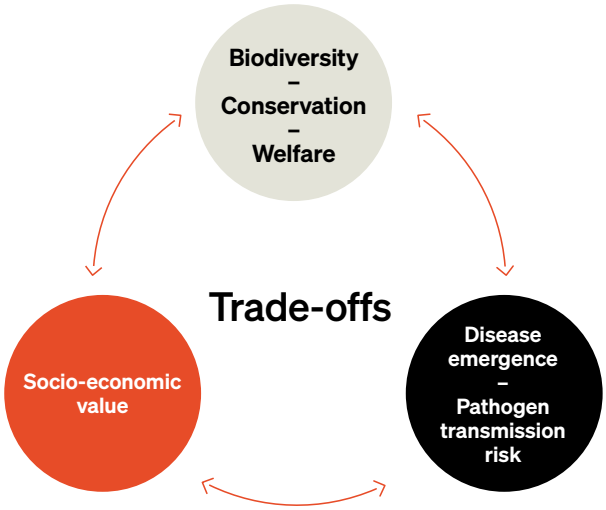

Figure 8. Trade-offs in multi-objective decision-making in the management of wildlife trade

Decision-Making Frameworks

Decision-making frameworks help determine appropriate and proportionate actions when various objectives need to be considered and when trade-offs among the objectives and proposed interventions must be examined. A decision framework should account for complexity and uncertainty and must consider different and sometimes competing interests. It should, therefore, be informed through an inclusive, equitable and transparent process involving stakeholders. The following text provides some high-level ideas on how to approach decisions which may impact differently on various sectors.

After a wildlife trade system has been described, indicators that relate to each domain of interest can be developed in consultation with the stakeholders. For example, indicators can be drawn from the three main domains relating to wildlife trade (Figure 8):

- risks to biodiversity, conservation or welfare (e.g. extinction of a species, damage to environmental resiliency, harm to animal welfare)
- risks to social, cultural or economic value (e.g. economic value of the trade, cultural value to the community)
- risks of disease in humans or animals (e.g. pathogen spillover).

The indicators provide insight into performance or progress of the risk management strategy, or impact on the identified domains. Each indicator requires metrics: specific values that can be used to measure outcomes for different decisions against an agreed-upon set of criteria. In this case, the metrics are used to categorise factors as high or low value, high or low risk, or high or low threat. The indicators can then be incorporated into the decision framework.

The health and welfare benefits of decisions made, and economic, social, biological, environmental, and cultural outcomes should all be considered in the framework.

Trade-offs are also influenced by societal values. These will vary in different settings, but internationally recognised values such as the Sustainable Development Goals can be used as a guide.

Potential actions resulting from decision-making frameworks are:

- prohibiting wildlife trade that has low economic and/or socio-cultural value and high risks for both disease emergence and negative impacts on biodiversity;
- allowing wildlife trade that is of high economic and/or socio-cultural value, has a low risk for disease emergence and poses little threat to biodiversity;
- enhancing or strengthening conservation measures for wildlife trade that poses a low risk for disease emergence but negatively impacts biodiversity; and
- enhancing or strengthening sanitary measures or trade standards for wildlife trade that has a high risk of disease emergence but poses little threat to biodiversity.

The most difficult wildlife trade to manage is trade that has high economic and/or socio-cultural value, represents a high risk for disease emergence, and poses a significant threat to biodiversity conservation; in such cases, it is more difficult to achieve an acceptable trade-off. Management of risk for this category of trade may require coordinated action by many stakeholders in a whole-of-society approach, involving public education, improved governance, economic incentives, new policies and further research to develop benefit-cost models, assess the value of biodiversity and improve selection of interventions.

Table 7 provides an example of a multi-objective decision framework to manage emerging diseases related to wildlife trade.

In summary, taking an inclusive, holistic approach to decision-making and basing decisions on objectives, such as One Health or the Sustainable Development Goals, will ensure that risks to public health and biodiversity are reduced, while maintaining the socio-economic benefits of wildlife trade.

Table 7. A multi-objective decision-making framework to manage emerging diseases related to wildlife trade

	Low disease emergence risk/ pathogen spillover risk	High disease risk emergence/ pathogen spillover risk
Wildlife trade that has low economic and/or socio-cultural value		
Low biodiversity threat	Allow	Restrict, with enhanced sanitary measures and trade standards
High biodiversity threat	Restrict, with enhanced conservation measures	Prohibit
Wildlife trade that has high economic and/or socio-cultural value		
Low biodiversity threat	Allow	Manage, with enhanced sanitary measures and trade standards
High biodiversity threat	Manage, with enhanced conservation measures	Restrict or prohibit, pending further evaluation and additional policy measures

Risk Communication

Risk communication is an open, inclusive, interactive and transparent process of informing stakeholders of the risks associated with the hazards of concern. It involves stakeholders in discussions and decisions throughout the risk-analysis process and during the implementation of mitigation measures.

With any risk issue, the best outcome is one that reduces the risk to an acceptable level using measures that are technically feasible and socially, culturally and economically viable, while minimising disputes, disagreements and conflict between stakeholders. Risk communication may not resolve all disagreements, but it will ensure that stakeholders have a better understanding of the rationale behind the risk-management measures. Stakeholders are less likely to challenge an outcome if they have been fully involved in the risk analysis and decision-making process from the beginning and if their concerns have been adequately addressed.

For any disease of concern, risk communication should be relevant to the local context. An important aspect of risk communication is to provide stakeholders with access to trusted information sources. Stakeholder analysis and mapping can help to identify suppliers and users of information and to determine the best ways to target communications.

Various means can be used to inform the design of social and behavioural change (SBC) messaging, including focus groups, observational studies, and attitudes and practice surveys (see examples in Campbell *et al.*, 2021; Li *et al.*, 2021; Monagin *et al.*, 2018; Saylors *et al.*, 2021). Because perceptions and preferences can vary across demographics (e.g. by age, gender, occupation, income level, education level, culture, religion or population type [urban or rural]), targeted and segmented campaigns may be needed. Furthermore, messaging should be built around the target audience's perceptions and beliefs; it should consider both the benefits derived from changing their behaviour and the potential barriers to behaviour change. For example, rural hunters reliant on wildlife trade for income or subsistence will probably require different channels and forms of outreach than urban end users (Coad *et al.*, 2019).

Barriers to effective risk communication can include lack of credibility (i.e. information from the source is not taken seriously), lack of engagement in the risk-analysis process, and the use of risk comparisons, which can be helpful but are sometimes difficult to understand. It is important to remember that different stakeholders have their own perceptions of risk, and once an attitude is formed, it is difficult to change.

Often, there are significant challenges in communicating the results of a risk analysis. Stakeholders may find the results difficult to understand or follow. The results and information must be provided in a way that stakeholders can follow and understand, e.g. by using plain language.

There has been mixed success with the awareness and SBC campaigns that have been rolled out during epidemics to reduce trade and consumption of certain wild species associated with disease. In some cases, they appear to be successful but with short-lasting effects: populations prefer to revert to wild meat consumption after the epidemic ends (Bonwitt *et al.*, 2018). This reversion may be based on factors such as affordability, cultural values or taste preference. It could also indicate limited understanding of disease transmission and of response efficacy (i.e. individuals may not understand or have confidence in their individual role in preventing disease spillover and spread). To help change perceptions and, most importantly, practices in the long term the long term, it may be necessary to maintain clear SBC messaging between epidemics as well as during them. Lasting change can also be promoted by educating stakeholders and involving them in the design of risk mitigation strategies, as this increases their understanding of the risks and acceptance of alternatives.

Social and behavioural change campaigns should be sensitive to their potential effects on perceptions about wild animals. For example, on one hand, SBC campaigns may empower individuals and communities to reduce their disease risks by observing safe practices; but on the other hand, they may also create fear and misperceptions around disease risk, as well as stigmatise and vilify wildlife. Negative perceptions created by such communication can lead to inappropriate killing of wildlife and the degradation or destruction of their habitats. These inappropriate measures are typically ineffective at reducing risk and are thus a waste of resources. They may even increase disease risk by dispersing animals, threaten biodiversity or destabilise the ecosystem.

The design, roll-out and evaluation of risk communication and SBC messaging should thus strive to balance these considerations to promote safe living with wildlife. For example, messaging that emphasises practical actions to minimise risks can help reduce feelings of helplessness, fear and anxiety in recipients. Information about wildlife as a source of disease should also be paired with information about their wider benefits, to avoid creating overly negative perceptions (Campbell *et al.*, 2021; Leong and Decker, 2020). One Health coordination is important to help ensure that potential adverse outcomes are adequately considered, averted and mitigated.

Insight into the potential impact of information campaigns focused on communicating disease risks is available from two pieces of recent research. In the first, 1,000 people each in Brazil, China, Vietnam and the United States of America were invited by Oxford University researchers to rate their desire to own an exotic companion animal both before and after being shown information on the potential negative impacts (Moorhouse *et al.*, 2021). The impacts were divided into four categories: 1. disease risks, 2. animal welfare concerns, 3. legal implications and 4. the consequences for the animal's conservation status. Each participant was shown either a neutral control statement (about the animal's diet) or a statement from one of the four negative impact categories. All respondents demonstrated decreased desire to own a given exotic companion animal when shown potential negative impacts. Disease information provoked the greatest decrease in desire relative to the control group (a mean decrease of 26.9%). For comparison, information on legal considerations, welfare concerns and conservation issues led to mean decreases of 16.2%, 17.9% and 18.9%, respectively. In the second piece of research, consumer surveys in Japan revealed that more than half (57%) of those intending to buy an exotic companion animal were discouraged from doing so by the risk of catching a zoonotic disease (Bergin *et al.*, 2021).

Section 3–Monitoring and Evaluation

Monitoring and Evaluation

It is important to measure the effectiveness of a risk management strategy to ensure that it is in fact reducing risk and not creating problems. It is also important to identify areas for improvement.

The monitoring and evaluation (M&E) process must be appropriate for the local context and supported by appropriate metrics.

Six questions can guide the M&E process:

Why invest in monitoring and evaluation?

It is important to know whether a risk-management strategy is effective and efficient and that it does not have unintended negative consequences. Monitoring and evaluation (M&E) helps to measure these aspects of a strategy. It also ensures transparency and encourages participation. It helps to better organise the implementation of a strategy and identify areas for improvement.

Despite their importance, impact assessments and systematic evaluations are rarely carried out in the context of wildlife trade risk management (Stephen, 2021).

Development of an M&E system ensures that risk management can be reviewed regularly. It provides an opportunity to set common objectives, accompanied by indicators of success (e.g. benchmarks or targets), on which future actions can be based. The M&E system can be structured in a framework such as a theory of change.

By defining metrics and indicators and setting corresponding benchmarks or targets, users can observe and document change over time through regular review. To guide corrective actions, the metrics developed for each intervention should also be monitored and assessed for effectiveness as well as for potential unintended adverse effects. Monitoring and evaluation informs design and implementation of the strategy. It is a cyclical process (**Figure 9**).

The resulting documentation can also serve as a measure of accountability to stakeholders. It is an important element in adaptive governance, which is responsive to changes in the social, economic and ecological environment. It also enables assessment of available trade data when analysing wildlife trade systems (Green *et al.*, 2023).

Theory of Change

A theory of change is an illustration of how and why a desired change is expected to happen in a particular context. Other common terms for this concept are 'logic model', 'logical framework' and 'causal chain'. For example, in a case where a disease risk assessment identifies live wildlife species 'X' as high risk in terms of pathogen spillover:

- If animal health inspections occur more frequently at markets, then market health standards prohibiting the sale of live wildlife species 'X' will be enforced.
- If standards are enforced, fewer people will sell live wildlife species 'X' in markets.
- If fewer people sell species 'X', fewer people will come into contact with that species, and thus the probability will reduce that a virus or pathogen will spill over to humans.

An M&E system strengthens ongoing review and adaptation of risk-management interventions and enables new knowledge and information to be considered as it becomes available. Sharing evaluated, successful approaches and lessons learned will inform intervention approaches where evidence is currently lacking and support adaptation and upscaling of approaches that work.

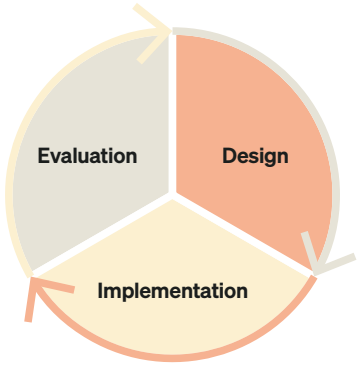

Figure 9. Phases of the project or policy life cycle

What can monitoring and evaluation accomplish?

Monitoring and evaluation will reveal how specific actions are associated with goals and long-term outcomes. It will help to measure progress towards those outcomes. If the risk-management approach under evaluation is effective, change will be linked to a reduction in risk in a wildlife trade system.

Any strategy to reduce risk in wildlife trade systems (interfaces or supply chains) will benefit from a theory of change. The theory of change will describe how the actions intended to reduce risks will result in the desired outcomes. The theory of change is always specific to the local context and setting.

The intended change will vary depending on the point of intervention in the wildlife trade system. For example, if the intervention is aimed at reducing deforestation deforestation, the resulting change from that intervention may be measured at that point in the system, e.g. the rate of forest loss, or it could be measured further downstream, e.g. a change in the volume of wildlife trade.

The absence of disease emergence or transmission is often difficult or even impossible to measure; indicators will inevitably only provide indirect evidence that a strategy has been successful in reducing the risk. When interpreting such M&E data, possible confounding factors and biases must be assessed to be sure that the observed changes do indeed indicate a reduced risk of disease emergence or pathogen transmission and not a systemic change that occurred due to other factors.

It is also important to appreciate the socio-ecological dynamics of the wildlife supply chain. New trade or consumption practices may emerge as a result of the interactions between the different elements of the supply chain or as a result of risk-management solutions. The origins of such change may not always lie within the wildlife supply chain itself. For example, lowered supply of protein from agricultural plant or animal production may raise the demand for wild meat. In a possible scenario, a large outbreak of a livestock disease may reduce the number of livestock available for consumption as risk-management strategies are put in place to curb the outbreak. The cost of protein from that livestock species rises, due to reduced availability to the reduced availability. These factors can lead to an increased demand for protein from wild animals. For the governance of the wildlife supply chain, it is thus of utmost importance to establish mechanisms that capture such unexpected changes and unintended consequences as early as possible. This allows the system to respond constructively to such change. For example, M&E that incorporates indicators of changes within the wildlife supply chain itself, such as changes in trade volumes or in the types of animals and products being traded, could provide additional feedback and early warning of change.

Who is involved in, and responsible for, monitoring and evaluation?

The M&E framework supports stakeholder engagement. All relevant stakeholders should be involved to some extent in the development of the framework and be represented in the framework. However, each stakeholder's level of responsibility for the framework may vary.

Developing the M&E framework through an inclusive and consultative approach will ensure that its indicators and benchmarks are pragmatic, realistic and measurable.

The indicators and benchmarks set may vary and suit different groups of stakeholders. For example, M&E mandates set by funders or investors may focus on costs and benefits, while those set by implementers may focus on process and practice. It is important to investigate whether the indicators and benchmarks address the interests of other key stakeholders. For example, are there any indicators in the framework to measure the engagement of women and girls (i.e. gender equality), which may also be linked to the overall outcome?

Funding, action and compliance are all key to meeting the goal of reducing the risks associated with wildlife trade. An inclusive and positive approach to M&E will provide an opportunity to demonstrate added value (and/or cost benefit) for all stakeholders.

Monitoring and evaluation may be conducted by external evaluators or through internal mechanisms. External evaluators may be impartial but will rely on the commitment of participants to access the relevant information. Internal evaluators usually have a good understanding of the initiative but may be subject to bias

through their involvement. The best outcomes are produced through a balance of both. Similarly, the best results are achieved when there is a commitment to inclusivity and transparency (open data) and when those leading the M&E process understand the issues and desire to provide constructive criticism rather than simply find fault.

How should monitoring and evaluation be implemented?

Key steps include developing a plan for the M&E framework that identifies its purpose (e.g. what should it measure and why); identifying stakeholders; agreeing upon and describing the desired change, goals, and actions or interventions; identifying measurable and relevant indicators; and developing methods for data collection, analysis and organisation.

For meaningful M&E, it may be necessary to establish new data collections, at least in areas of the wildlife supply chain that have not been evaluated previously. However, some aspects of the system may already be monitored for national systems or international agreements.

To gain a comprehensive view of the change occurring in the wildlife supply chain, it is important to compile these data and relate them to the theory of change. The results can be represented as a flow chart or system map. A colour code, such as the traffic light system, can be applied to the indicators: green for those that are moving in the intended direction, red for those that are moving in the opposite direction and amber for those that remain unchanged.

The indicators themselves can be quantitative or qualitative. Where quantitative data are available, the quality and timeliness of the data need to be considered.

Unintended consequences along the wildlife supply chain are rarely captured in quantitative observations. Although the theory of change may consider a broad range of eventualities, unintended consequences always remain surprising. If unexpected outcomes are not identified, evaluation will fail to inform adaptive management. One way of capturing unexpected outcomes is through methods that use complexity-enabled monitoring, evaluation and learning. These methods are used in the fields of development and peacebuilding (Befani *et al.*, 2015; Chigas *et al.*, 2014; Britt and Patsalides, 2013), and many of them can be contextually adapted for the M&E of wildlife supply chains. Importantly, the intention of this M&E practice is not to gain representative information, but to receive early warning signals that can trigger further investigation into potential changes. Big data analysis, such as internet searches, can also provide early warning signs, but these should be considered supplementary since the wildlife supply chain is not well represented in the digital realm.

Table 8 provides potential indicators; however, indicators must be adapted to the M&E framework, which is context specific. Key indicators and metrics need to be tied to testable outcomes.

Table 8. Relevant indicators for monitoring and evaluating risk reduction in wildlife supply chains

Outcome indicators
• Prevalence of the relevant zoonotic pathogens detected through laboratory diagnostics • Number of human cases of the zoonotic pathogens • Number of disease events caused by the zoonotic pathogens • Changes in resource allocation (e.g. financial, human) • Rates of improved knowledge, attitudes and practices in priority communities and populations (e.g. CITES [2022a] provides a set of benchmark criteria relevant to behaviour change in demand-reduction campaigns specific to illegal trade in CITES-listed species)
Process indicators
• Number of samples tested • Number of actions taken to reduce risk (including policies enacted and enforced) • Number of risk-assessment procedures established • Number of risk assessments conducted • Number of risk-communication campaigns conducted • Surveillance and risk-reduction strategies integrated into relevant national and subnational plans (e.g. National Action Plan for Health Security, National Biodiversity Strategy and Action Plan)
Proxy indicators at critical points in the wildlife supply chain
• Free-ranging wildlife » Population counts/remote sensing counts » Portion of habitat integrity/encroachment » Land-use change indicators • Harvest, capture, hunting » Hunting statistics » Number of licences, certificates, etc. » Number of people receiving relevant training (e.g. biosecurity training) • Slaughter, butchering, processing » Number of registered premises • Local holdings/farmed wildlife » Number of registered holdings » Number of animals • Local market » Market volumes » Tax revenues • Local end user » Informal consumption estimates (household surveys) » Number of human infections with zoonotic diseases (incidence) and targeted surveillance » Studies of knowledge, attitudes and practices around consumption and risk perception (Meeks *et al.*, 2022; Triezenberg *et al.*, 2014) • Legal cross-border transport » Border control statistics • Illegal cross-border transport » Border control statistics » INTERPOL statistics

CITES: Convention on International Trade of Endangered Species of Wild Fauna and Flora
INTERPOL: International Criminal Police Organization

When should monitoring and evaluation be implemented?

Evaluation may be carried out prospectively, during use and retrospectively.

Monitoring and evaluation should be implemented through an adaptive and inclusive governance process. It is intended to provide a continuous flow of data towards decision-making. The frequency of meaningful data collection will depend on the specific indicator, e.g. trade volumes may change on a daily or weekly basis, while forest coverage will show slower changes. The cost of collection will also determine frequency. Over all, collection frequency should allow real-time identification of change (or as close to real time as possible) at a reasonable cost.

Incorporating feedback loops

Sharing successful approaches and lessons learned can help wildlife trade professionals inform solutions in other wildlife trade systems. Data monitoring platforms, literature reviews and direct communication with evaluators and stakeholders in other trade systems provide potential sources for collecting this information.

Additionally, the telling of success stories about introduced measures, backed by data obtained through M&E, can help sway public opinion, generating a push for project funding and potential change in policies and legislation. Ultimately, the data provided by M&E can facilitate government action to improve the wildlife trade, as well as incentivise more community-based projects to that end (EFSA, 2006).

Section 4–Tools and Guidance

Tools and Guidance

The previous sections outline several components that are crucial for risk management in wildlife trade. In some cases, countries can leverage capacities already in place or prioritised for investment through Veterinary Services, other competent authorities and other agencies at national and subnational levels. However, baseline capacities related to wildlife pathogen monitoring and disease management are typically weaker in wildlife or environmental agencies relative to other animal services, so system-building or enhanced multisectoral coordination with animal and public health sectors is needed to address gaps. Like all disease management initiatives, successfully implementing and sustaining pathogen monitoring and risk-reduction measures related to wildlife trade ultimately requires sufficient political will, financial and human resources, institutional capacity, and technical knowledge and operations. Aspects unique to the wildlife trade interface are discussed below. Existing tools provide a starting point for capacity assessment and prioritisation.

Existing Tools

Tools exist to evaluate national systems for animal and public health against globally defined benchmarks. Among them are WOAH's Performance of Veterinary Services (PVS) evaluation tool (WOAH, 2023), aligned with the WOAH Codes and Manuals, and WHO's Joint External Evaluation (JEE) tool, aligned with the WHO International Health Regulations (WHO, 2022). These tools are aligned and mainly examine issues related to domestic animals and human health. The findings of these tools are increasingly used to inform multisectoral National Action Plans for Health Security (five-year plans that include a focus on zoonotic disease risks).

Another tool is the IUCN Guidelines for Reintroductions and Other Conservation Translocations (2013).

One Health Zoonotic Disease Prioritisation exercises have also been used by several countries to identify disease-specific priorities, including diseases relevant to wildlife trade (CDC, 2022; 2023a).

The FAO Surveillance Evaluation Tool is an Excel tool that allows for the comprehensive and comparative assessment of a country's surveillance system for animal diseases, including zoonoses, with 90 indicators divided into 7 areas and 19 categories specific to animal disease surveillance. It was developed to support focused evaluation for disease surveillance and laboratory systems, but it could be applied to wildlife trade with sufficient prioritisation, expertise and awareness when conducting evaluations (FAO, n.d.).

Existing tools can support some aspects of monitoring disease and reducing risk at any interface of interest. However, they do not currently offer a coherent way of assessing capabilities and prioritising needs to tackle disease risk in wildlife trade.

The lack of a coherent approach is due to several limitations:

- Specific interfaces are not usually covered in detail in these tools.
- The focus is typically on domestic animals, whether free-ranging or farmed.
- Relevant aspects (e.g. points of entry, zoonotic disease, surveillance, laboratory aspects, and diagnostics) are split across chapters rather than presented together in a dedicated section that provides a clear picture of the specific needs relevant to wildlife trade.

In recognition of these gaps, a needs assessment for national wildlife health programmes has been piloted. It is aimed at identifying infrastructure and capabilities needed to reach a target state, based on the published attributes of national programmes (Stephen *et al.*, 2018). A country assessment for environmental health services has also been developed and piloted as an extension of the World Bank One Health operational framework (Berthe *et al.*, 2018).

Gaps, Needs and Capacity Requirements

Globally, existing capacity assessment and planning processes have not systematically addressed wildlife. For example, an analysis of the PVS and JEE reports published between 2007 and 2020 found that the majority either report gaps in wildlife disease surveillance or make no mention of wildlife considerations (Machalaba *et al.*, 2021). This presents a significant challenge, as no parallel capacity assessment tool exists at the global level that defines capacity benchmarks and standards specifically for environmental and wildlife health systems.

At the time of writing, there are no internationally agreed-upon standards for wildlife trade, and the ones most relevant to wildlife are fragmented among standards for other purposes, such as conservation. Thus, when engaging with other authorities relevant to wildlife management, veterinary authorities should be cognisant of the fact that they may not be familiar with the idea of progressive system strengthening or be aware of the PVS Pathway or the support it provides for capacity strengthening.

While efforts should be made to develop and adopt such international standards, the lack of standards should not be an impediment to current progress. Countries can, and should, set goals for improvement and see progress, even in the absence of international standards. Whatever tools used should be chosen based on their suitability for supporting countries in managing disease risks related to wildlife trade. If they are not suited to wildlife trade in their current form, countries should adapt them as necessary, developing capacity assessment criteria and capacity investment pathways at national and international levels.

Governance Structures and Mandates

Mandates related to wildlife conservation, wildlife health and welfare, and disease transmission from wildlife exposures are often fragmented across several agencies, leaving room for gaps, duplication and contradiction. Even if an agency has jurisdiction over a species or site, it may not have the resources necessary for disease surveillance or enforcement of regulations. These gaps can result in vulnerabilities. Conducting stakeholder mapping provides a practical way to assess who the responsible entities are in wildlife trade, determine the scope of their mandate, and identify key connections or dependencies. It also provides a way to assess where refinements or enhanced coordination may be needed. Stakeholder mapping can also identify the need for new partnerships between agencies (e.g. between authorities responsible for Veterinary Services, wildlife trade, wildlife conservation, public health, commerce, food safety and food security).

While CITES provides an international framework for wildlife trade legislation, CITES listing is based on the threat that trade poses to species conservation and not on disease risk. Therefore, supplemental legislation may be needed to regulate species trade based on disease risk.

There is a clear need for strengthened One Health coordination, with better communication and collaboration between international agencies. For example, there is scope to improve collaborations at the national level to connect wild animal trade authorities with animal health, wildlife health and public health authorities (e.g. between CITES and WOAH points of contact).

Depending on their design and purpose, programmes may relate to a combination of human and animal health and conservation objectives. Multi-objective programmes lead to more robust outcomes and are more easily justified.

Financial Incentives and Justification

Financing mechanisms for addressing disease risk in the wildlife trade need to come from a variety of sources. These include both health and environment entities, at national and international scales. One option is the World Bank's financial intermediary fund for pandemic prevention, preparedness and response, i.e. the Pandemic Fund.

Thus far, funding for investigating the risk of pathogen spillover at high-risk interfaces has largely been targeted at *ad hoc* research or training activities, which have provided an initial basis for identifying pathogens circulating in the wildlife trade. Systems-level investments should ensure that the components included in other

aspects of animal health surveillance (e.g. sampling, laboratory systems, risk analysis, information management, communication) are extended to the wildlife trade. Existing investments should consider whether there is scope for the addition of wildlife trade pathogen surveillance activities at marginal cost (e.g. specimen collection as part of existing wildlife trade confiscations, or pathogen detection as part of food safety screenings).

Investments should also support implementation and maintenance of cross-sectoral collaboration and communication. For example, funding could be provided to enable Customs and police authorities to develop cross-sectoral responses to illegal wildlife trade in conjunction with social and behavioural change experts and wildlife management or wildlife health agencies. This could support a cost-effective effort to manage disease transmission risks, encourage information sharing between jurisdictions and ensure robust risk-reduction outcomes.

As in other systems, ongoing monitoring requires sustained financing to ensure continuous, systematic collection and timely analysis of information; finances are also required for any follow-up actions prompted by the information. Ongoing financial support is also critical for systematic monitoring and evaluation and for carrying out impact assessments of risk-management options. These are essential to identify the most effective, efficient, acceptable and sustainable policies or practices for reducing disease risks from the wildlife trade in a specific socio-economic setting. Given the diversity of wildlife supply chains, examining resource implementation in one socio-economic context or region is not an effective way of identifying management solutions for other contexts.

The successful prevention of epidemics is a public good and should be considered when calculating returns on the investments made into strengthening and sustaining systems for the prevention, detection and response to pathogen spillover in the wildlife trade (Bernstein *et al.*, 2022; Dobson *et al.*, 2020). Institutionalising management of the wildlife trade will require change involving a diverse group of stakeholders, some with competing objectives and others with shared goals (Machalaba and Sleeman, 2022). The main steps towards change are:

- envisioning a future state
- engaging partners for buy-in and coalition building
- identifying barriers and breaking down resistance to change
- institutionalising change for sustainability.

Having available funding may be an incentive to begin to tackle the health risks associated with the wildlife trade, but effective leadership should also be in place to ensure there is strong political will to navigate potential barriers and resistance and ensure sustained efforts. It is crucial that, in addition to supporting good leadership, funding supports the implementation of cross-sectoral and transdisciplinary collaboration.

Knowledge Gaps

Gaps in knowledge along the wildlife supply chain must be expected given the low surveillance in certain taxonomic groups (wildlife species, pathogens or pathogen families) and varying harvest, holding, transport and consumption practices. Countries will have varying levels of resources to address these knowledge gaps and provide more precise understanding of disease dynamics and the effectiveness of interventions. Indeed, to date, few studies have formally tested the effectiveness of wildlife trade risk-reduction interventions (Stephen, 2021). However, basic epidemiological understanding from other settings applies to the wildlife trade, allowing for action to be taken even in the absence of resources for additional research. For example, universal precautions such as avoiding contact with bodily fluids (by wearing masks and gloves) are proven to work, and there is thus no need for specific research to determine their effectiveness in wildlife trade settings. However, there may be factors that hinder the uptake and correct use of these precautions, so there may be a need for additional research to determine effective behavioural change strategies (Change Wildlife Consumers, 2019). Such hindrances are often shaped by socio-economic and cultural factors and thus are likely to require collaboration with experts in other disciplines (e.g. anthropologists) to ensure that uptake strategies are designed effectively.

Coordination

The relevance of wildlife trade to several sustainable development outcomes, including biodiversity conservation, improved health status, food security and livelihoods, makes it important to have coordination across agencies and equitable and appropriate allocation of resources. The inclusion of Veterinary Services in cross-agency efforts is vital, as they are involved in multiple activities along the wildlife supply chain. For example, the results of the 2020 Wildlife Health Survey of WOAH delegates (OIE, 2020) indicated that Veterinary Services were involved to a varying degree in import and export activities related to the wildlife trade (including the issuance of health certificates) (30% of responses), inspection of wildlife products and by-products (10%) and transportation of wildlife (5%).

Priorities and policies driven by one sector alone could inadvertently affect disease risk, whether to consumers, confiscating officers or wildlife populations. Alignment between the Veterinary Services and other relevant agencies (e.g. CITES, Customs, public health, and environment and forestry) can help to ensure disease risk is considered when designing, implementing and evaluating initiatives related to wildlife trade. These coordination platforms could be ideal for mainstreaming disease considerations into decisions on wildlife trade and making the best use of resources to generate co-benefits. Similarly, disease surveillance in wildlife species can also record important information for biodiversity monitoring through, for example, visual identification or the use of genomic analyses for species identification.

Training

To manage the disease risks associated with the wildlife trade, a wide range of skills are necessary. These skills include the safe identification and handling of wild animals and their by-products; ante- and post-mortem inspections; sampling and pathogen-screening methods; information management and reporting; hands-on testing; and fluency in protocols, best practices and plans (e.g. biosafety and biosecurity plans). Stakeholder mapping may identify individuals and authorities other than Veterinary Services who may also require skills training, such as Customs authorities, police, sanctuary staff, wildlife researchers and managers, and wildlife harvesters, transporters and sellers.

Simulation exercises are widely used for the control of highly pathogenic avian influenza and other WOAH-listed diseases (OIE, 2020a). These are a practical way to test systems and assess preparedness for routine and emergency situations. These types of exercises could be useful for preventing or minimising disease risks at wildlife trade interfaces at national and subnational levels. They help build or practise skills, as well as identify additional needs for system strengthening and follow-up training exercises. For topics like wildlife trade that typically involve multiple sectors and stakeholders along the supply chain, taking a One Health approach to simulation and other training exercises could be particularly useful, as it could help to validate or clarify assumptions about each agency's role and identify important gaps. Organisations using these Guidelines may also seek relevant training opportunities from WOAH Collaborating Centres (WOAH, n.d.[a]; n.d.[b]).

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Glossary

Term	Definition
Animal welfare	The physical and mental state of an animal in relation to the conditions in which it lives and dies (WOAH, 2022)
Biosecurity	A set of management and physical measures designed to reduce the risk of introduction, establishment and spread of animal diseases, infections or infestations to, from and within an animal population (WOAH, 2022)
Biosecurity plan	A plan that identifies potential pathways for the introduction and spread of disease in a zone or compartment and describes the measures that are being or will be applied to mitigate the disease risks, if applicable, in accordance with the recommendations in the Terrestrial Code (WOAH, 2022)
Bushmeat	Meat from wildlife species. Bushmeat may sometimes refer to meat obtained from regulated or unregulated practices of harvesting wildlife species for food (International Alliance Against Health Risks in Wildlife Trade, 2022). See also Wild meat and Game meat
Captive wild animal	An animal (terrestrial or aquatic) that has a phenotype not significantly affected by human selection but that is captive or otherwise lives under direct human supervision or control (WOAH, 2022)
Cross-species [pathogen] transmission/spillover	Also called 'interspecies transmission' or 'host jump'. It refers to the transmission of an infectious pathogen, such as a virus, bacterium or fungus, between hosts belonging to different species. Once introduced into an individual of a new host species, the pathogen may cause disease in the new host and/or acquire the ability to infect other individuals of the same species, allowing it to spread through the new host population (adapted from Childs *et al.*, 2007; Parrish *et al.*, 2008)
Disease	Any disturbance in the health or function of an animal or human
Disinfection	After thorough cleansing, the application of procedures intended to destroy the infectious or parasitic agents of animal diseases, including zoonoses; this applies to premises, vehicles and objects that may have been directly or indirectly contaminated (WOAH, 2022)
Domestic wildlife trade	Any commercial activity, including, but not limited to, sale and purchase, within the territory under the jurisdiction of a national government (CITES, 2022)
Emerging infectious disease/Emerging disease	In an animal, a new occurrence of a disease, infection or infestation, causing a significant impact on animal or public health resulting from: a) a change of a known pathogenic agent or its spread to a new geographic area or species, or b) a previously unrecognised pathogenic agent or disease diagnosed for the first time (WOAH, 2022)
Farmed, captive-bred and cultivated	Management and production modes that are distinct from 'wild-sourcing', with breeding and raising taking place in controlled conditions (adapted from Broad, 2020)
Feral animal	An animal of a domesticated species that now lives without direct human supervision or control (WOAH, 2022)
Game meat	Meat from any wild animal that is hunted for food – its hunting is culturally acceptable for sport or recreation; and its harvest is regulated under existing national hunting and food hygiene legislations (International Alliance Against Health Risks in Wildlife Trade, 2022). See also Bushmeat and Wild meat
Hazard	Any infectious pathogen at any interface where direct, indirect or vector-borne transmission may lead to a risk of disease transmission to humans, domestic animals or wildlife (adapted from WOAH, 2022)
Human–animal–environment interface	A continuum of contacts and interactions among people, animals, animal products and their environment(s); in some cases, these interactions facilitate transmission/spillover of pathogens or shared health threats (adapted from WHO, OIE and UNEP, 2021). See also Transmission and Cross-species [pathogen] transmission/spillover
Illegal wildlife trade	Trade in wildlife whereby collection, production, possession, transport, processing and wholesale or retail commerce is (or was at some point in the trade chain) in contravention of one or more applicable international, national or subnational laws or associated regulations (Kock and Caceres-Escobar, 2022)

Term	Definition
Infection	The entry and development or multiplication of a pathogenic agent in the body of a human or animal (WOAH, 2022)
Infectious disease	A disease caused by an organism (or pathogen) such as a virus, bacterium, fungus or parasite
Infestation	The external invasion or colonisation of animals or their immediate surroundings by arthropods, which may cause clinical signs or are potential vectors of pathogenic agents (WOAH, 2022)
Legal wildlife trade	Wildlife trade that is not in contravention of applicable laws and/or regulations at any point in the trade chain (CITES, 2022)
Monitoring and evaluation	A process that helps measure, track and improve performance and assess the results of an ongoing or complete activity, programme or policy. It does so by providing indications of how much progress has been made, how much of the allocated funding has been used, and the extent to which objectives have been met. Its purpose is to improve performance, ensure accountability and/or demonstrate value. Monitoring is the continuous and systematic collection of information on specified indicators related to the project or process, while evaluation is the systematic and objective assessment of the relevance, efficiency, effectiveness or impact of a project or process. Evaluation is based on the information collected on the indicators during monitoring (WHO, FAO and OIE, 2019)
One Health	An integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals and ecosystems. It recognises that the health of humans, domestic animals, wild animals, plants and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilises multiple sectors, disciplines and communities at varying levels of society to work together. The different actors collaborate to foster well-being and tackle threats to health and ecosystems. They take action on climate change, contribute to sustainable development and address the collective need for safe and nutritious food and clean water, energy and air (Adisasmito *et al.*, 2022)
Pathogen/Pathogenic agent	An infectious agent or organism capable of causing disease in a host, e.g. viruses, bacteria, fungi, protozoa, internal parasites such as worms and external parasites such as lice and mites
Prevalence	The proportion of the host population with infection, disease or antibody presence, often expressed as a percentage. A measure of how widespread an infection, disease or exposure to an infectious agent is at a point in time (Jakob-Hoff *et al.*, 2014)
Qualitative risk assessment	An assessment where the outputs of the risk assessment (the likelihood of the outcome or the magnitude of the consequences) are expressed in qualitative terms such as 'high', 'medium', 'low' or 'negligible' (WOAH, 2022)
Quantitative risk assessment	An assessment where the outputs of the risk assessment are expressed numerically (WOAH, 2022)
Ranching/Ranched wildlife	Rearing in a controlled (e.g. fenced, restricted) environment of animals taken as eggs or juveniles from the wild, sometimes sourced from a long-term managed wild population (CITES, 2022; Kock and Caceres-Escobar, 2022)
Risk	The product of the likelihood of the occurrence and the likely associated magnitude of the consequences of an adverse event or effect to animal or human health; consequences may be biological, economic, environmental, cultural, etc., as defined by a specific risk-analysis question (adapted from Jakob-Hoff *et al.*, 2014)
Risk analysis	The process composed of hazard identification, risk assessment, risk management and risk communication (WOAH, 2022)
Risk assessment	The evaluation of the likelihood and the consequences of entry, establishment or spread of a pathogenic agent within a specified animal population or environment (Jakob-Hoff *et al.*, 2014)
Risk communication	The interactive transmission and exchange of information and opinions throughout the risk-analysis process concerning risk, risk-related factors and risk perceptions among risk assessors, risk managers, risk communicators, the general public and other interested parties (WOAH, 2022)
Risk factor	Any physical or contextual variable that contributes to the likelihood or impact of an outcome of concern (e.g. a disease occurring in an individual or population, cross-species transmission) (adapted from WHO, FAO and OIE, 2020)

Term	Definition
Risk management	A process of identifying, selecting and implementing measures that can be applied to reduce the level of risk (WOAH, 2022)
Sustainable wildlife use	The legal and equitable use and commerce of wildlife and wildlife products that ensure long-term species survival and ecosystem functions and protect the livelihoods of the people who depend on them (Kock and Caceres-Escobar, 2022)
Traditional food market	A market that includes wet markets, informal markets and farmers' markets that sell foods of animal origin/non-animal origin/dried goods and where live animals are sometimes housed and slaughtered on site (WHO, OIE and UNEP, 2021)
Transmission	The process by which a pathogen passes from a source of infection to a new host (adapted from Jakob-Hoff *et al.*, 2014). Pathogens may be transmitted from one individual to another by a variety of routes, both directly (through close contact) and indirectly (through contact with products or contaminated materials, which are called fomites) or via vectors (adapted from Wildlife Health Australia, 2018). See also Cross-species [pathogen] transmission/spillover
Wet market	A marketplace (informal markets, legal and illegal) selling fresh meat, fish, produce, and/or other perishable goods (including vegetables), as distinct from dry markets, which sell durable goods such as fabrics and electronics. The products sold at wet markets may include live animals intended for human consumption or meat. In these markets, live animals may be sold, killed and butchered on the premises (Kock and Caceres-Escobar, 2022; Campbell *et al.*, 2021)
Wild animal	An animal (terrestrial or aquatic) that has a phenotype unaffected by human selection and lives independent of direct human supervision or control (WOAH, 2022)
Wild meat	Meat derived from wild animals (wild harvested or farmed). Wild meat harvested from wild animals in tropical and subtropical countries is used for food and non-food purposes, including for medicinal use (International Alliance Against Health Risks in Wildlife Trade, 2022; CITES, 2022; SCBD, 2011; CITES, 2019). See also Bushmeat and Game meat
Wildlife	Living things that are neither human nor domesticated, including animals, fungi and plants. For the purposes of the Guidelines, Wildlife means wild animals and captive wild animals (WOAH, 2022)
Wildlife market	A venue (physical or online) where wildlife commerce is active. It entails trade in live animals, animal parts and/or products containing, or manufactured from, wild animals. The animals may have been bred in captivity or caught in the wild (adapted from International Alliance Against Health Risks in Wildlife Trade, 2022; Broad, 2020)
Wildlife product	Products derived from any wild species and any part or derivative of a wild species (IPBES, 2020)
Wild-sourced (or wild-caught)	Wild animals, fungi, plants or their products collected or harvested from free-living (non-captive, unrestricted) populations that may or may not be managed sustainably (Kock and Caceres-Escobar, 2022)
Wildlife supply chain	A connection of all the parties, resources, businesses and activities involved in the marketing or distribution through which wildlife and wildlife by-products reach the end user (OIE, 2021a)
Wildlife trade (and use)	Commercial and non-commercial trade (involving money or barter) in wild animals – live or dead – and any products derived from them. It includes legal (regulated and unregulated) and illegal trade, both domestic and international. Wildlife use includes the consumption of bushmeat and the use of animals for tourism, research, farming and other work. It includes capture, collection, handling, transportation, relocation, translocation, marketing and slaughter (adapted from OIE, 2021a). In these Guidelines, 'wildlife trade' is used throughout the text in place of 'wildlife trade and use', but it should be understood to refer to both
Zoonosis/Zoonotic disease	An infectious disease that can be spread between animals and humans; the infectious pathogen can be spread by food, water, fomites or vectors (WHO, FAO and OIE, 2019)

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Annex 1
Considerations Specific to Wildlife Trade

Overarching Considerations

- There are more wild animal species than domestic animal species, yet comparatively little is known about the microbial communities, including pathogens, associated with wildlife species.
- Wildlife species may be legally protected, listed in CITES appendices and/or in a threatened category of the IUCN Red List. In many cases, wildlife hunting and wildlife trade is regulated or prohibited by local, national or international law.
- At present, identification, traceability and movement control are only possible for some wildlife species (e.g. collection animals, companion animals), products and derivatives.
- There is a wide range of uses of wildlife species, including for food, traditional medicine, medical research, ornaments and trophies, companion animals, zoological collections, fur, hides and bones.
- There is a wide range of individuals and groups directly and indirectly involved in, benefiting from or impacted by wildlife trade, in a wide range of social, cultural and economic contexts. For example:
    - » In addition to consumers, the wildlife supply chain includes numerous individuals pursuing different livelihood opportunities, e.g. rural hunters, harvesters and various levels of buyers, including urban vendors, commercial retailers and restaurants.
    - » Use of wildlife is part of the livelihoods, culture and traditions of numerous indigenous peoples and local communities.
- Wildlife trade occurs in a variety of physical settings (e.g. at small, local markets; at larger and more complex markets; and along supply chains of varying length and complexity).
- Wildlife may be wild-sourced or captive-bred and subsequently ranched or farmed.
- Wildlife farming systems, specifically open systems, and wildlife that escape from holding sites or farms may introduce invasive species and transmit disease to native species and domestic animals.
- Wildlife trade and related supply chains are highly variable and complex (this is true for both legal and illegal trade).
- Wildlife trade for local, in-country use is likely to be informal and less regulated than international wildlife trade.

Disease and Health Considerations

- Drivers of disease emergence may differ locally and regionally.
- Wildlife trade presents opportunities for contact between species that do not normally mix (e.g. species from differing geographic locations).
- There are animal husbandry and welfare requirements unique to each species and scenario (e.g. requirements for transport conditions or for short-term versus long-term captivity).
- Reference values for, and knowledge of, host biology and physiology are often missing.
- Baseline knowledge of pathogens may be limited or absent for certain species.

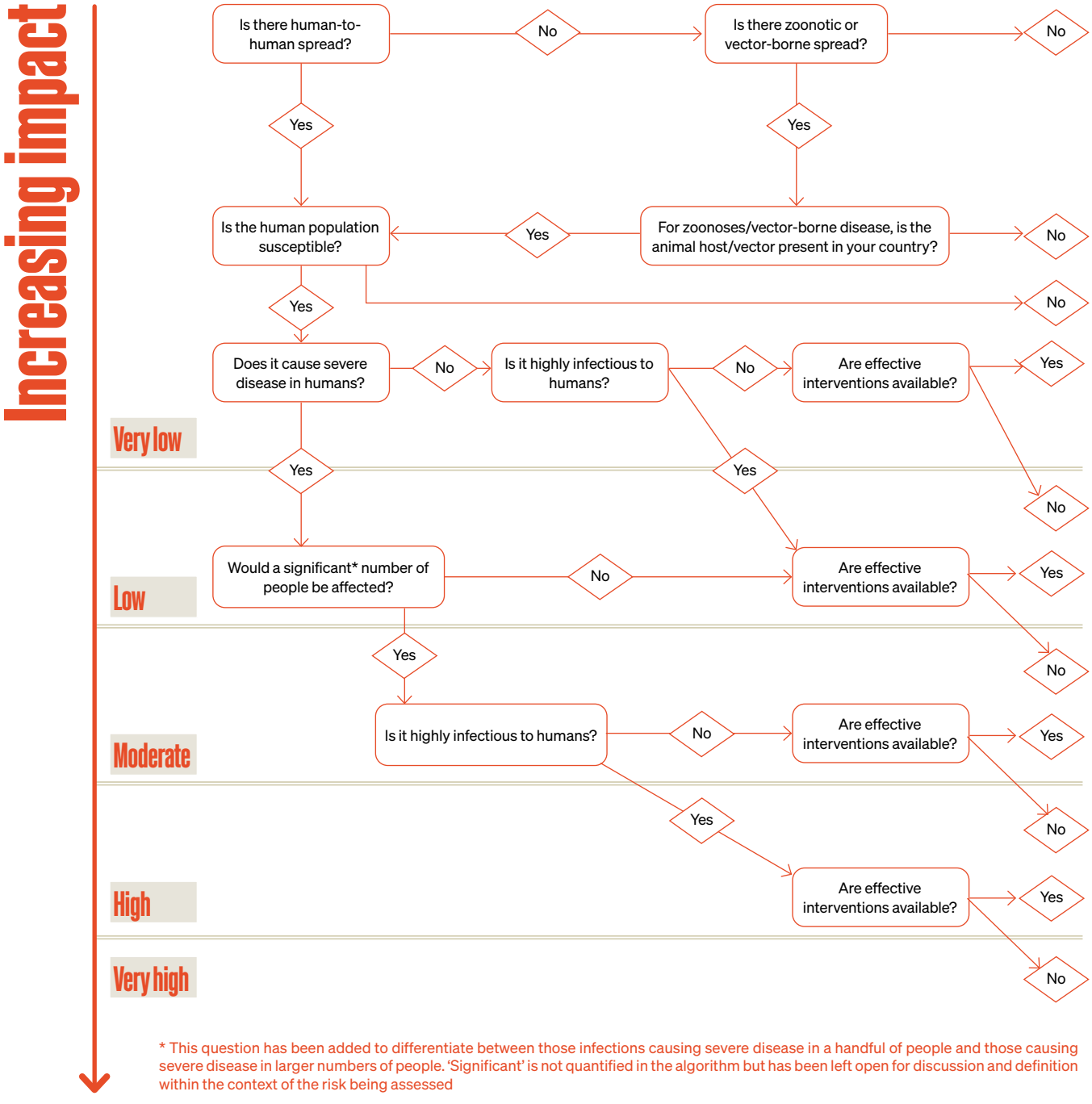
- Knowledge of pathogens found in particular species (or even at higher taxa levels) may be limited, since it comes from studies within specific time periods, scenarios or geographic locations.
- Pathogen transmission pathways and risk factors may be unknown or not well understood and cannot necessarily be inferred from another species in the same genus, family or higher taxa.
- It can be challenging to collect biological samples representative of the taxonomic diversity of pathogens across space and time.
- Sample shipment to diagnostic laboratories may be delayed if a species falls under conservation regimes, as permits may be required (e.g. CITES permits).
- There may be limited or no validated diagnostic tests for some species. There are known challenges in validating diagnostic tests for wildlife (Campbell *et al.*, 2022).
- There is a need for specific training (e.g. in handling, biosecurity/biosafety) for all actors and personnel involved, from harvesters to end users. In addition, there is a need for specialists trained in wildlife health monitoring and management (e.g. wildlife veterinarians, wildlife pathologists).
- Disease surveillance and disease control in wildlife are challenging and may be limited by local and regional capacity.
- Standards for identifying and reporting potential disease risks may not be established among the relevant authorities and regulators.

Lists of Protected Species

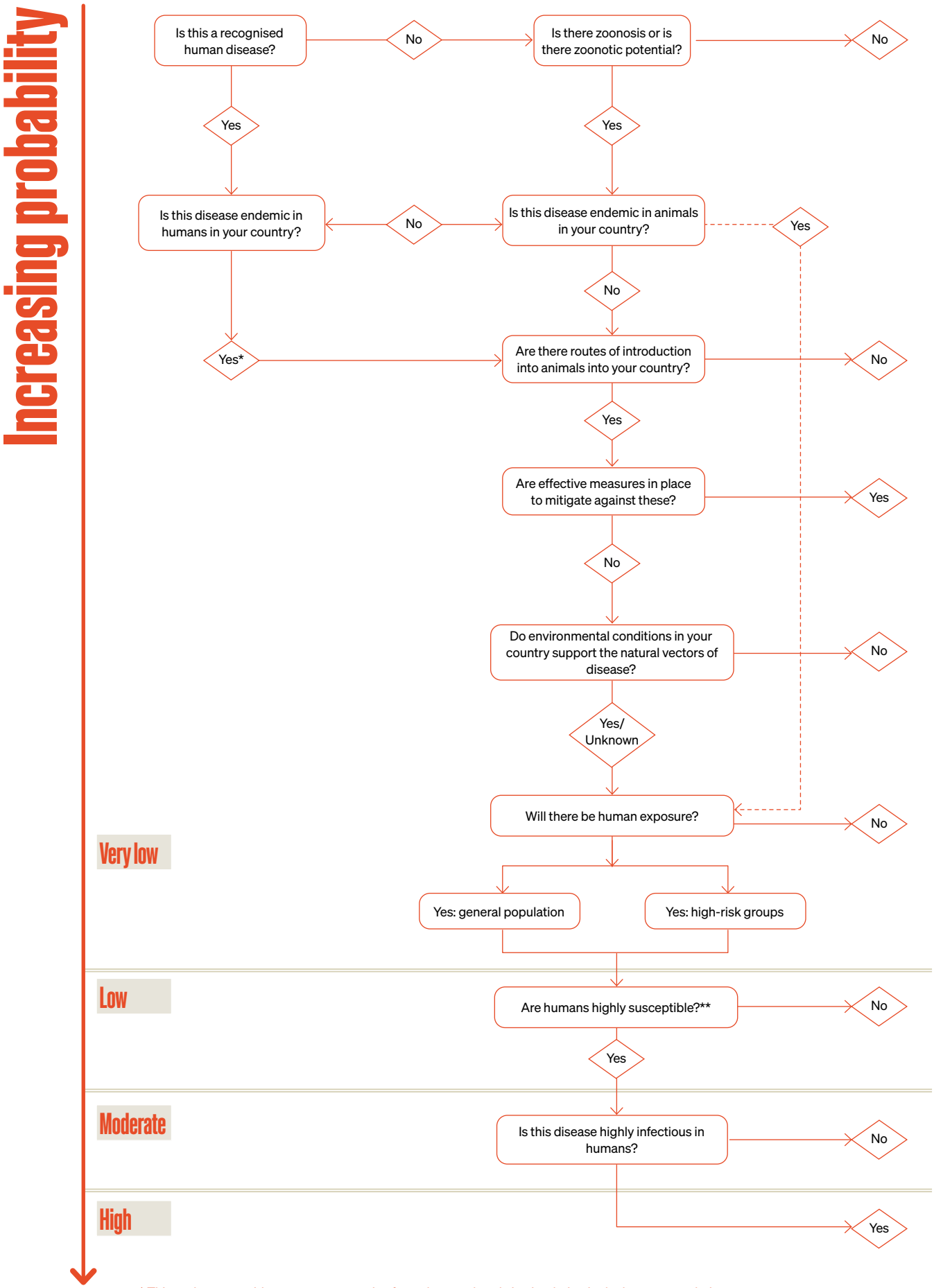
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement between governments that aims to ensure that international trade in wild animals and plants does not threaten their survival.
- The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species is the world's most comprehensive information source on the extinction risk of animals, fungi and plants. The IUCN Red List provides information about a species' range, population size, habitat, ecology, use and/or trade, threats and conservation actions.

Annex 2
Example: National Model for Risk Analysis (UK)

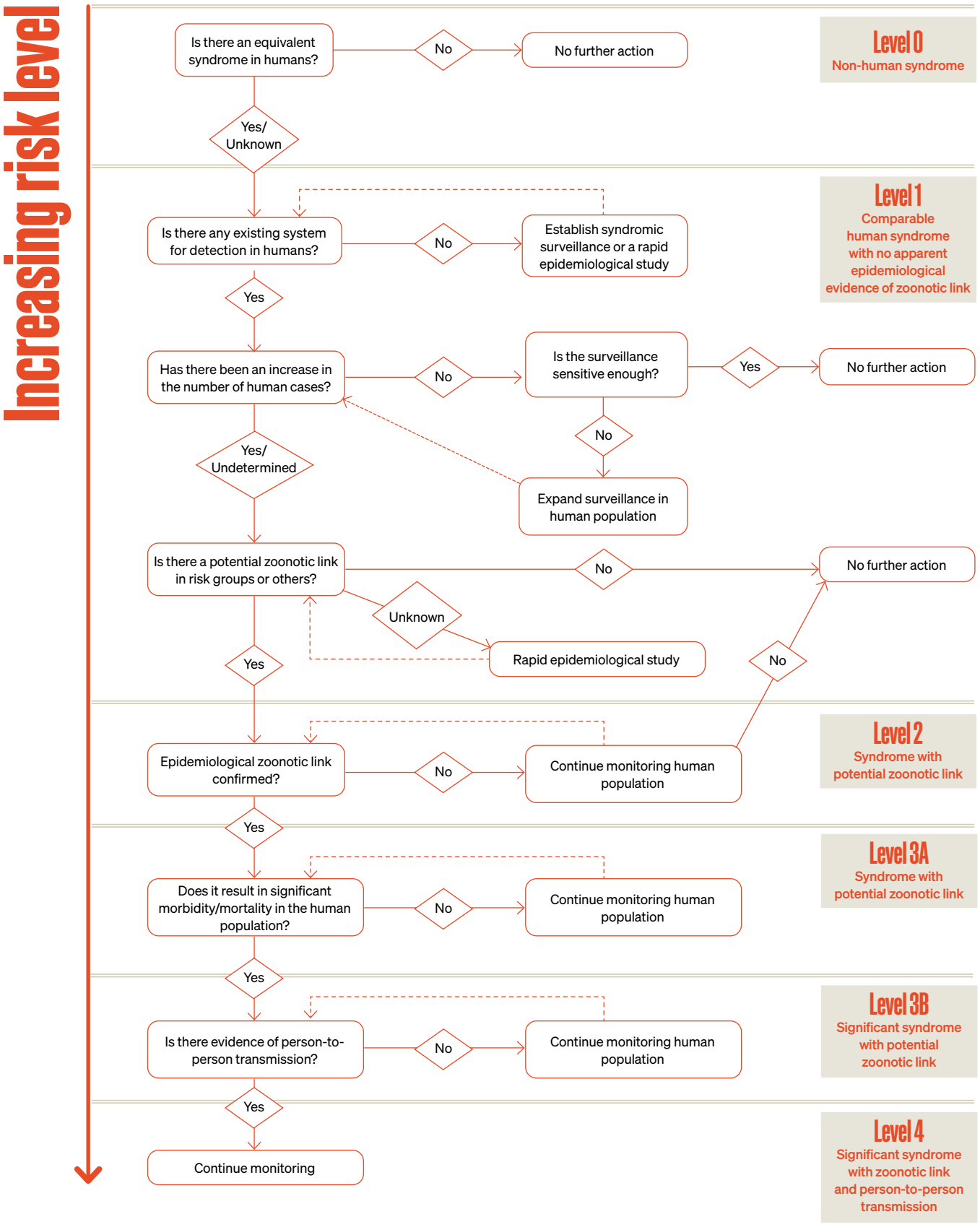
The UK has a multi-sectoral cross-government horizon scanning and risk analysis group, which is made up of its key government agencies and called the Human Animal Infections and Risk Surveillance (HAIRS) group. In this Annex you will find the templates and algorithms that HAIRS uses to make its assessments.

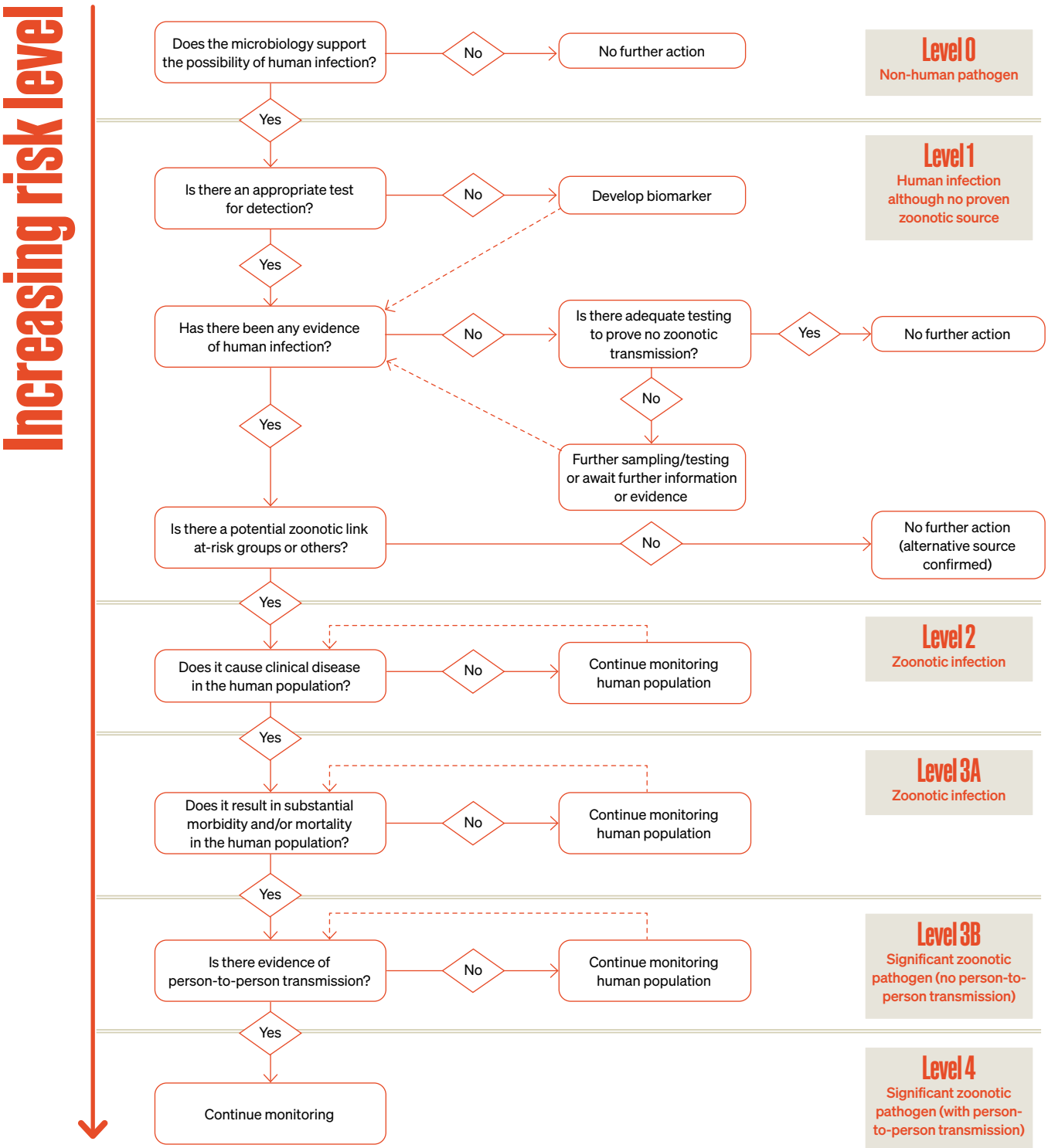


* This question has been added to differentiate between those infections causing severe disease in a handful of people and those causing severe disease in larger numbers of people. 'Significant' is not quantified in the algorithm but has been left open for discussion and definition within the context of the risk being assessed



* This pathway considers reverse zoonosis of a pathogen already in circulation in the human population
** Includes susceptibility to animal-derived variants


Increasing risk level
Is there an equivalent syndrome in humans?
No
No further action
Level 0
Non-human syndrome
Yes/ Unknown
Is there any existing system for detection in humans?
No
Establish syndromic surveillance or a rapid epidemiological study
Level 1
Comparable human syndrome with no apparent epidemiological evidence of zoonotic link
Yes
Has there been an increase in the number of human cases?
No
Is the surveillance sensitive enough?
Yes
No further action
No
Yes/ Undetermined
Expand surveillance in human population
Is there a potential zoonotic link in risk groups or others?
No
No further action
Unknown
Rapid epidemiological study
Yes
No
Level 2
Syndrome with potential zoonotic link
Epidemiological zoonotic link confirmed?
No
Continue monitoring human population
Yes
Level 3A
Syndrome with potential zoonotic link
Does it result in significant morbidity/mortality in the human population?
No
Continue monitoring human population
Yes
Level 3B
Significant syndrome with potential zoonotic link
Is there evidence of person-to-person transmission?
No
Continue monitoring human population
Yes
Level 4
Significant syndrome with zoonotic link and person-to-person transmission
Continue monitoring


Increasing risk level
Does the microbiology support the possibility of human infection?
No
No further action
Level 0
Non-human pathogen
Yes
Is there an appropriate test for detection?
No
Develop biomarker
Level 1
Human infection although no proven zoonotic source
Yes
Has there been any evidence of human infection?
No
Is there adequate testing to prove no zoonotic transmission?
Yes
No further action
No
Yes
Further sampling/testing or await further information or evidence
Is there a potential zoonotic link at-risk groups or others?
No
No further action (alternative source confirmed)
Yes
Does it cause clinical disease in the human population?
No
Continue monitoring human population
Level 2
Zoonotic infection
Yes
Does it result in substantial morbidity and/or mortality in the human population?
No
Continue monitoring human population
Level 3A
Zoonotic infection
Yes
Is there evidence of person-to-person transmission?
No
Continue monitoring human population
Level 3B
Significant zoonotic pathogen (no person-to-person transmission)
Yes
Continue monitoring
Level 4
Significant zoonotic pathogen (with person-to-person transmission)

Annex 3
Examples of disease risk-reduction measures for each of the critical control points/interfaces along the generic wildlife supply chain using the hierarchy of controls

Table 9 contains examples of risk-reduction measures as described in Section 2, Hierarchy of Controls. Examples of real-world interventions are given in grey. The fifth step in the hierarchy of controls, the use of personal protective equipment, has not been included here as it is standard best practice for reducing pathogen transmission risks and applies to all scenarios in the table.

Table 9. Example measures to reduce disease risk at each critical control point or interface along the generic wildlife supply chain (Figure 3) using the hierarchy of controls (Figure 8) (WHO, OIE and UNEP, 2021; Gortazar *et al.*, 2014; Petrovan *et al.*, 2021)

Critical control points	Risk avoidance	Substitution	Engineering	Administrative controls
Free-ranging wildlife	Change legislation to prohibit trade and consumption of certain wildlife (e.g. all species of bats) or parts or products Limit human and domestic animal access to natural areas/wildlife habitats	Discourage use or extraction of free-ranging wildlife for protein by facilitating substitution with other sources of protein*	Implement harvest, farming and marketing practices that minimise contact between wildlife and humans The Australian Standard for the Hygienic Production of Wild Game Meat for Human Consumption includes guidelines on the use of vehicles during harvesting. Their aim is to keep carcasses cool and protect them from contamination (Commonwealth of Australia and each of its States and Territories, 2007)	Implement policies to manage drivers of disease emergence Coordinate collaborative wildlife health surveillance programmes to monitor, investigate, respond to and report disease in free-ranging populations The Centers for Disease Control and Prevention have developed recommendations to lower the risk of SARS-CoV-2 spreading between people and wildlife. The recommendations include reducing the number of individuals involved in wildlife capture operations and using logbooks for workers who have had contact with wildlife (CDC, 2023)
				Require national government to implement One Health collaboration Swiss legislation mandates the government to develop a structure for coordinated work on One Health topics. The Swiss Federal Act on Controlling Communicable Human Diseases (Epidemic Act) provides an example of when, how and who to involve when dealing with specific topics such as detecting, monitoring, preventing and combating zoonoses (Swiss Federal Council, 2022)

Critical control points	Risk avoidance	Substitution	Engineering	Administrative controls
Captive wildlife (wildlife farms)	Place restrictions on farming or captive rearing of certain wildlife In British Columbia, mink farming is to be completely phased out by 2025 (British Columbia Government, 2021a) Restrict or supervise collection of free-ranging wildlife to populate captive wildlife facilities; use captive-bred wildlife instead	Discourage use or extraction of free-ranging wildlife for food and other products (e.g. fur) by facilitating substitution with other sources*	Use wildlife-specific handling equipment and facilities that maximise welfare outcomes and minimise contact between humans and wildlife Develop tools to improve traceability in farmed non-conventional species	Require captive breeding facilities to be licensed or registered In British Columbia, Canada, mink farms must be licensed (British Columbia Government, 2021b) Regulate and inspect facilities for compliance with national or international guidelines In Australia, veterinary leaders and advisors within the zoo industry developed the National Zoo Biosecurity Manual to document best practices for biosecurity (Woods and Reiss, 2011) CITES has published guidance for inspection of captive breeding and ranching facilities (Lyons *et al.*, 2017)
Harvest, capture, hunting	Ban harvest or hunting in particular areas or of particular high-risk wildlife*	Incentivise communities that rely on hunting wildlife for their subsistence or livelihoods to identify alternative sources of protein and/or income derived from wildlife* In Laos, the development of eco-tourism in Nam Et-Phou Louey National Park has provided an alternative source of income The Convention on Biological Diversity report Livelihood Alter-natives for the Unsustainable Use of Bushmeat discusses substitution methods and examples (Campbell *et al.*, 2021)	Use techniques or tools that reduce the risk of pathogen transmission during harvest, capture or hunting The American Veterinary Association developed disease precautions for hunters including recommendations to keep the head and spine intact when boning out a carcass and to avoid abdominal shots, as they lead to meat contamination (AVMA, 2023)	Introduce surveillance or biosafety requirements for harvest, capture and hunting (limited in scope and geographic range) The State of Michigan (United States of America) has carcass transportation restrictions and requires specimen submissions from hunter-killed deer for chronic wasting disease surveillance (Michigan Department of Natural Resources, 2023a; 2023b.) Vaccinate hunters and harvesters Implement specific hunting rules based on community Australia has developed a partnership approach to assist indigenous communities to harvest turtles and dugongs sustainably (Australian Department of the Environment and Heritage, 2005) Raise awareness of safe bushmeat use The EBO-SURSY project has developed several capacity-building tools and resources (WOAH, 2022b) Enforce animal welfare requirements Examples include the Terrestrial Animal Health Code chapter on the welfare of reptiles killed for their skins, meat and other products (WOAH, 2022c) and the Canada and European Union Agreements on International Humane Trapping Standards (ECCC, 2015; European Community, Government of Canada and Government of the Russian Federation, 1998)

Critical control points	Risk avoidance	Substitution	Engineering	Administrative controls
Slaughter, butchering, processing	Prohibit slaughter, butchering or processing of wildlife at markets		Dedicate a location (away from consumers) where wildlife can be slaughtered, butchered or processed (e.g. dedicated abattoirs)	Develop guidance and training materials on biosecurity, hygiene and sanitation for personnel involved in slaughter, butchering or processing
			Improve cold chain at all relevant points along the wildlife supply chain	Implement ante- and post-mortem inspections
			Install plexiglass barriers to avoid direct exposure of consumers to live animals	Regulate individuals and organisations that slaughter, butcher or process wildlife
			Require hand-washing facilities to be available where wildlife is slaughtered, butchered or processed	
Trade of live animals (companion animals, sanctuaries, zoos, laboratories, food)	Restrict trade of certain wildlife China has reformed laws to increase restrictions on the trade or raising of wildlife for food (Li *et al.*, 2021)			Engage stakeholders in risk management Review and revise regulations relating to individuals and organisations involved in wildlife trade Implement surveillance for pathogens prior to trade (informed by disease risk assessment); implementation should consider sample type, testing algorithms, reporting requirements and the most appropriate interface or control point Use temporary holding facilities or quarantine to complement health screening protocols for wildlife prior to translocation and release into the wild (Woodford, 2001) The IUCN has produced Guidelines for the Management of Confiscated, Live Organisms (IUCN, 2019) Provide sanitary and biosecurity guidelines, training and enforcement The United States Fish and Wildlife Service provides occupational safety and health guidance for wildlife inspections and handling for those involved in law enforcement (United States Fish and Wildlife Service, 2017) The United Nations Office on Drugs and Crime has produced guidance on reducing pathogen transmission risks for frontline workers (UNODC, 2020)
Local holding	Prohibit holding or farming of specific wildlife			Require pathogen or novel pathogen surveillance (informed by disease risk assessment); implementation should consider sample type, testing algorithms, reporting requirements and the most appropriate interface or control point Minimise the number of personnel in direct contact with wildlife

Critical control points	Risk avoidance	Substitution	Engineering	Administrative controls
Local transport	Prohibit transport of live wildlife of a specific species or of all species within the same taxa, e.g. all primates		Require wildlife transport cages that meet biosafety and biocontainment standards and are suited to the animals being transported Reduce or prevent mixing of wildlife animals with other wildlife or with domestic animals	Develop traceability systems for wildlife and wildlife products
Local markets	Prohibit sale of live wildlife or high-risk species at markets		Consider compartmentalisation and zoning within market settings	Require pathogen screening (informed by disease risk assessment); implementation should consider sample type, testing algorithms, reporting requirements and the most appropriate interface or control point Raise awareness of public health advice
Cross-border transport	Restrict cross-border transport of certain wildlife The Vietnam CITES Administration decided not to add guinea pigs to the list of wildlife species that can be imported and raised in captivity for commercial sale		Develop or maintain fit-for-purpose quarantine facilities	Educate on disease risk Enforce border controls for international wildlife trade Introduce or enhance health inspections and quarantine controls Australia set import conditions for non-human primates (Australian Department of Agriculture Fisheries and Forestry, 2017) The Terrestrial Animal Health Code includes guidance on quarantine controls for non-human primates (WOAH, 2022d and 2022e) Implement effective traceability systems for wildlife and wildlife products
International holding				Quarantine wildlife entering the country (based on disease risk assessment)

Critical control points	Risk avoidance	Substitution	Engineering	Administrative controls
International markets/distribution	Prohibit international trade of all species CITES Appendix I lists the most endangered of the CITES-listed species (CITES, 2023)	Replace international wildlife trade market with sustainable, domestically sourced animals		Implement pathogen screening by importing or exporting country (informed by disease risk assessment); implementation should consider sample type, testing algorithms, reporting requirements and the most appropriate interface or control point See case example of the trade in salamanders Australia has enacted legislation to control the export of wild game meat and wild game meat products (Australian Department of Agriculture Fisheries and Forestry, 2021) Develop and implement demand-reduction strategies The Arcus Foundation (2020) has published strategies to tackle illegal ape trade at its source CITES (2022a) has produced guidance on developing and implementing demand-reduction strategies to combat illegal trade in CITES-listed species Enforce animal welfare requirements Examples of animal welfare requirements include IATA's Live Animals Regulations (IATA, 2023) and the CITES Guidelines for the Non-Air Transport of Live Wild Animals and Plants (CITES, 2022b)

* Based on multi-criteria decision-making and risk assessments relating to alternative approaches
CITES: Convention on International Trade of Endangered Species of Wild Fauna and Flora
EBO-SURSY: Ebola virus disease surveillance and capacity building (now covers five major pathogens in ten countries from West and Central Africa)
IATA: International Air Transport Association
IUCN: International Union for Conservation of Nature
UNODC: United Nations Office on Drugs and Crime

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