GUIDELINES FOR COUNTERING ZOONOTIC SPILLOVER OF HIGH CONSEQUENCE PATHOGENS IN THE SOUTHEAST ASIA REGION

International Network for Governmental Science Advice

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International Network for Governmental Science Advice

(INGSA)-Asia Regional Chapter

Sunway City, Malaysia

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Reviewers

Before publication the guidebook was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of the review is to provide candid and critical comments that will assist the institutions in making the published guidebook as sound as possible and to ensure that the publication meets standards for objectivity, evidence, and responsiveness to the goals of the project. We thank the following individuals for their input:

Simon Anthony, University of California, Davis
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Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the guidebook or its conclusions or recommendations, nor did they see the final draft of the guidebook before its release.

Data Gathering Workshops

Workshop #1 (Virtual, over VTC)
Session 1, Friday, May 20, 2022
Session 2, Tuesday, May 24, 2022
Session 3, Wednesday, May 25, 2022

Workshop #2 (Virtual, over VTC)
Session 1, Tuesday, July 12, 2022
Session 2, Tuesday, July 19, 2022
Session 3, Wednesday, July 20, 2022

Workshop #3 (In person, Bangkok, Thailand with portions by VTC for select participants)
September 9-11, 2022

Workshop #4 (In person, Singapore, with portions by VTC for select participants)
November 11-13, 2022

Workshop #5 (In person, Kuala Lumpur, Malaysia with portions by VTC for select participants)
June 1-3, 2023

Preface

In early 2022, the International Network for Governmental Science Advice (INGSA)—Asia Regional Chapter began a collaboration with the U.S. National Academies of Sciences, Engineering, and Medicine (the National Academies) to explore ways to help prevent and mitigate the consequences of "zoonotic spillover" of high-consequence pathogens (HCPs) that originate in the live animal supply chain in the Southeast Asian region. When the project began, the world was in the middle of the worst pandemic in a hundred years. COVID-19 has killed millions of people around the world and the consequences will reverberate for decades. It is in this context that INGSA and the National Academies decided to collaborate to jointly produce a guidebook for those working to prevent and mitigate zoonotic spillover, with a specific focus on Southeast Asia and China. The diverse interface among wildlife, livestock, pests, and people at live animal markets and in agricultural settings make the region a hotspot for zoonotic spillover events that could affect people in the region and beyond. The region contains a combination of environmental, social, and economic conditions such as rapid population growth, increased mobility, urbanization, and environmental impacts through deforestation and climate change that increase and accelerate the opportunities for spillover.

To inform the project, INGSA-Asia and the National Academies organized a series of data-gathering workshops to bring local, regional, and international experts together to discuss the mechanics of spillover, the essential elements and barriers to activities that address the risks of spillover, best practice measures to prevent and contain outbreaks, the strengths and weaknesses of operational tools to combat zoonotic diseases such as the WHO Tripartite Zoonoses Guide and One Health approaches, and engage experts and responsible parties who regulate or otherwise influence the management and operation of the animal supply chain in the region. In May and July 2022, INGSA-Asia and the National Academies gathered dozens of experts by video-teleconference (VTC) to discuss the state of knowledge about the problem, what might be improved, and what might be added to existing efforts. Meeting by VTC was the only way to gather a large international group of stakeholders together during the pandemic but allowed a wide range of subject-matter experts to engage and a broad set of voices from the region to be heard. Once COVID-19 travel restrictions eased, the group met sequentially—first in Bangkok, Thailand, and then in Singapore—to deepen knowledge sharing among disciplines and across levels of governance, extend conversation on potential recommendations and other guidance, and draft material based on the workshops. The group met in-person one final time in Sunway City, Malaysia in mid-2023 to give initial impressions and comments on a guidebook draft and conduct participatory exercises using the guidebook's key messages. Overall, the workshop sessions—held in real time while global discussion on pandemic mitigation and response were happening—captured important and diverse perspectives on how to address the problem from key regional experts and project team members in Cambodia, China, Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand, Vietnam, the United States, and other countries. The in-person workshops were critical and allowed the group to gather to discuss the problem, hear from local health and regulatory authorities regarding the tailoring of solutions and training to the Southeast Asian region, and consider how to incorporate country-specific cultural perspectives to enhance potential for high uptake and impact.

The information gathered and advice offered during this process has informed the creation of this guidebook, and the guidebook represents the collective knowledge of the project participants. Modules 2 through 7 are designed as stand-alone documents focused on one or more aspects of the zoonotic spillover problem in the region. Module 8 is unique and is included as a tool to help users apply and tailor the lessons, messages, and recommendations from the guidebook modules to a wide range of individuals and experts involved in combating zoonotic diseases in the region.

Many experts assisted in the production of the guidebook, as members of the project advisory committees, as presenters and participants at the workshops, and as co-leaders, writers, editors, and reviewers of the modules. Their tireless work on this critical topic is foundational to this project and they are acknowledged in the front matter. In addition, each module lists key co-leaders who, along with the National Academies' and INGSA project staff, have the final responsibility for the contents of the guidebook. The guidebook is available for free download on the INGSA website. In the future, additional material designed for specific audiences will be derived from the guidebook modules and published in English and in several additional languages. This material will also be posted on the INGSA website and distributed to key stakeholders.

The goal of this project was to enhance existing efforts through regional adaptation and illustration, allowing those doing this critical work to see pathways for new opportunities and begin to address and overcome the barriers they face. The guidebook is designed to engage a broader audience, particularly in the science policy interface to bridge existing knowledge gaps, build trusted networks in the region, and develop effective policy instruments that will support and augment the ongoing efforts on the ground. Through its creation, we feel that the collaborative efforts of INGSA-Asia, the National Academies, and all participants involved in the project have contributed to strengthening efforts to prevent zoonotic spillover in the region and serve as an example for collaborative efforts by others in the region and internationally. We hope this guidebook—together with other international, regional, and national documents—will serve as a valuable resource to inform those working to combat zoonotic disease and zoonotic spillover in the Southeast Asian region and in the world.

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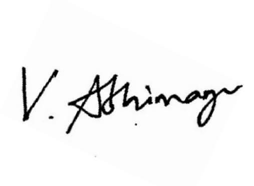

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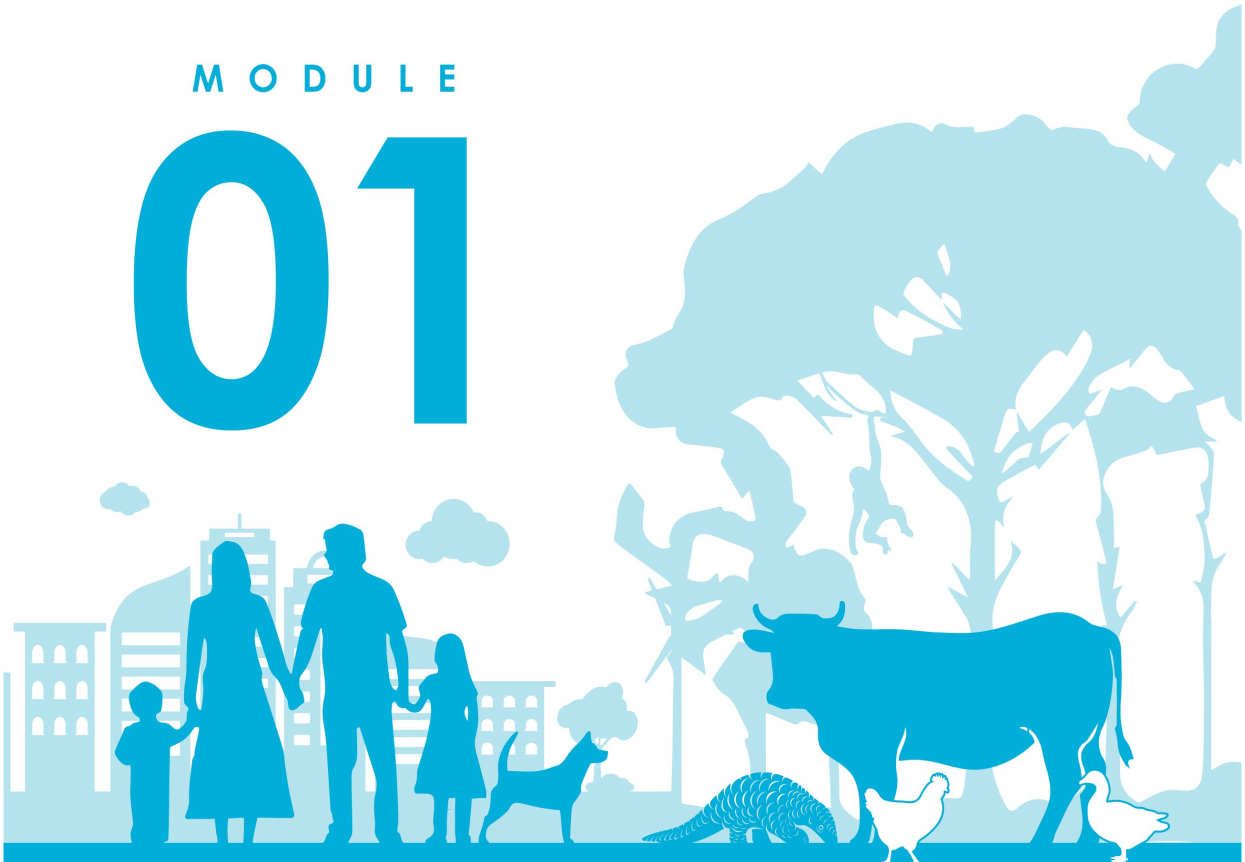
TABLE OF CONTENTS

MODULE

01



Introduction

Co-Authors
Meghan Davis & Abhi Veerakumarasivam

Introduction

Infection that occurs via the transmission of pathogens from animals to humans (zoonotic infection) represents a significant public health issue in Southeast Asia and in many regions of the world (Nguyen et al., 2024; WHO, 2020b). Several factors make Southeast Asia an important and particularly complex region to consider both for transmission of established zoonotic diseases and emergence of high-consequence pathogens (HCPs) with pandemic potential. These factors include the extensive interactions among wildlife, domestic animal species, and humans in the live animal supply chain (Saba Villarroel et al., 2023).

In an effort to better understand the drivers, pathways, and key factors that can contribute to spillover, the International Network for Government Science Advice (INGSA)- Asia Regional Chapter in partnership with the U.S. National Academies of Sciences, Engineering, and Medicine (NASEM) undertook a project to develop a guidebook with a goal to inform prevention and mitigation of zoonotic spillover originating in the live animal supply chain in Southeast Asia. Understanding the factors that lead to pathogen spillover in the region, and identifying points for intervention can help reduce the risk that a HCP from the region could contribute to a pandemic. Such efforts are critical to inform efforts of pandemic prevention and mitigation.

INGSA and NASEM convened committees of experts who organized a series of workshops to explore what is known on countering zoonotic spillover and how to address the major challenges in the region [1]. The information gathered and advice offered during the workshop series, along with the expertise of the regional and global committees assembled by INGSA and NASEM, informs the following guidance.

Several organizations, including the World Health Organization (WHO),[1] Food and Agriculture Organization of the United Nations (FAO),[2] World Organisation for Animal Health (WOAH),[3] and the United Nations Environment Programme (UNEP)[4] have published useful guidelines for prevention of zoonotic spillover. This new report is not intended to replace those works, but instead to complement them with region-specific recommendations and examples. This guidebook draws from those earlier reports to provide a clearinghouse of those references, with suggestions on how best to use them and illustrations and elaboration on topics of particular interest to the Southeast Asia region that may not be covered in the original guidance documents and reports. This guidebook is designed to help those working at international, national, regional, and local levels in Southeast Asia who want to implement evidence-based strategies to prevent zoonotic spillover. A goal of this work is to elaborate on shared communication and decision-making among community, practitioner, and policymaker groups of relevance to national and regional efforts.

[1] One Health High-Level Expert Panel. 2023. *Prevention of Zoonotic Spillover: From Relying on Response to Reducing the Risk at The Source.* Geneva, Switzerland: WHO. https://www.who.int/publications/m/item/prevention-of-zoonotic-spillover.

[2] FAO. 2023. White paper on zoonotic spillover prevention.https://www.fao.org/one-health/highlights/highlights-detail/new-white-paper-on-zoonotic-spillover-prevention/en. (Accessed April 2, 2024).

[3] WOAH. 2023. Wildlife Health. https://www.woah.org/en/what-we-do/animal-health-and-welfare/wildlife-health/. (Accessed March 18, 2024).

[4] UNEP. 2020. Preventing the next pandemic- Zoonotic diseases and how to break the chain of transmission. https://www.unep.org/resources/report/preventing-future-zoonotic-disease-outbreaks-protecting-environment-animals-and. (Accessed April 12, 2024).

Who Should Use this Guidebook?

The guidebook is designed to be a tool to be used by those working to reduce the risk of zoonotic spillover in Southeast Asia. It also may serve as an inspiration and resource for others to adapt. Readers who seek to gain an overall understanding of the issues and strategies for addressing them can read the guidebook in sequence from beginning to end. Readers who are facing specific challenges, such as cross-border trafficking of wildlife, may prefer to access only specific modules or use this document to identify relevant reports and organizations that can provide assistance.

What is One Health?

Countries are widely moving towards organizational plans that implement One Health strategies for public health goals (de la Rocque et al., 2023); that is, increasingly they are using integrated approaches that bring key communities together to conduct zoonotic spillover prevention, disease surveillance, and outbreak response with a goal to improve and enhance the health of people, animals, and the environment (see Figure 1.1). Current One Health efforts incorporate principles of sustainability, address challenges of climate change, and acknowledge the valuation of ecosystem services. One Health approaches are complementary to planetary health and ecohealth approaches (de Castañeda et al., 2023), which place high value on rapid and widespread response to challenges of global environmental change and ecosystem degradation, but distinct in the focus on health-related outcomes (Talukder et al., 2024).

Future outbreaks with the potential to escalate to pandemic levels are both devastating and avoidable (Mishra et al., 2023). Proactive identification and management of their root causes effectively can reduce the frequency of these outbreaks and their consequences. To do this, we must understand the drivers of pandemics. Additionally, we will address the "why" behind global pandemics. The three deep drivers of pandemics include: (1) people consuming animal-sourced food products, (2) globalization, and (3) change, including climate change, demographic change, land-use change, and cultural changes.

The best response in terms of pandemic preparedness is the prevention of initial spillover events, which requires robust response capabilities and multisectoral coordination to be truly effective. The second best is early warning through strong surveillance systems that enable swift action and coordination among different sectors. The third is the application of countermeasures: rapid diagnoses, quarantines, and vaccines, underpinned by effective risk communication to ensure public understanding and compliance. Strengthening systems and response capacity through investment in a skilled workforce, enhanced coordination and communication among human, animal and environmental sectors, surveillance capacity and laboratory infrastructure capacity, and investment in risk communication and participatory approaches for community engagement are critical to prevent spillover and mitigate when an outbreak occurs.

Operational Costs Involved in One Health

When responses do occur within a One Health framework, activities are coordinated among human health, environmental health, and animal health domains. There are financial costs to such an approach, but experts conclude that there are substantial net benefits. Annual financial benefits of such One Health approaches have been estimated at $125 billion given investments of $25 billion annually in a number of sectors (Grace, 2014).

1. Sharing resources across sectors.
    - In most countries, the three sectors involved in One Health—that is, human health, animal health, and environmental health—do not have the same funding sources or budgets. The World Bank has estimated that resource sharing can save 10-30% through use of common services and joint facilities between human and animal health sectors (Le Gall et al., 2018).
2. Offsetting resources and costs needed for response by focusing on prevention of endemic and neglected zoonotic diseases.
    - Economic estimates suggest that endemic zoonoses (e.g., brucellosis, tuberculosis, cysticercosis) cost around $86 billion US dollars annually, but control programs that address these diseases in animal hosts before they are transmitted to humans require only a quarter of that cost (around $21 billion) (Grace, 2014).
3. Reducing human and financial costs of outbreaks by detecting early signals and responding before outbreaks spread regionally or globally.
    - Delays in response can increase case numbers and outbreak costs. In addition to the toll of health impacts and mortality, the financial costs of pandemics have been rising, from between $30-$50 billion for SARS in 2003 to over $11 trillion for COVID-19 (World Bank and FAO, 2022).
4. Preventing even a fraction of potential pandemics through activities to reduce upstream drivers.
    - The World Bank estimates that preventing even just one in five pandemics would have a 25% expected annual rate of return on investment (Le Gall et al., 2018).
5. Other needs in operationalizing a One Health approach in the context of zoonotic spillover include:
    - Providing tools to de-risk or minimize pandemic drivers. This can only be achieved through bringing together human, animal, and ecosystem health sectors and treating them as an interconnected system.
    - Generating insights to support innovation. The multisector and multi- or trans-disciplinary nature of One Health has influenced integrated agricultural and health development, e.g., through application of genomic information to understand disease pathways through the animal value chain (FAO, 2022).
    - Engaging diverse communities and other stakeholders. Participatory approaches that engage community leadership and knowledge are critical to produce feasible and sustainable interventions (Virginia Department of Health, n.d.).

Most global activities through the FAO-WHO-WOAH-UNEP Quadripartite Collaboration on One Health and the World Bank have focused on how to operationalize One Health ideas and strategies at global and national levels (FAO et al., 2022). This guidebook is designed to fill a gap for operations at the local level and to be the foundation for more hands-on technical training and assistance in the future.

FIGURE 1-1: An illustration of the One Health approach

The definition and application of One Health has been evolving, driven by established and emergent global health security threats (Mackenzie and Jeggo, 2019). At its core, One Health uses integrated approaches to address challenges at the intersection of human health, animal health, and environmental health—and the latter increasingly has included separate consideration of plant health (Figure 1-1). The 2021 definition advanced by the One Health High-Level Expert Panel an advisory panel to the Joint Tripartite (FAO, WOAH, and WHO) and the UNEP —specifically includes consideration of ecosystems and plant health and prioritized issues of sustainability and response to climate change. It also codified the centrality of multi- and trans-disciplinary efforts at all levels of society, which have been foundational to One Health approaches since its inception and have important implications for surveillance and response activities.

Best practices for One Health response include mapping expertise and engaging disciplines not traditionally involved in public health efforts. This is because of the need to create a collaborative team of technical experts and to engage resources from multiple fields. Critically, key stakeholders (Box 1-1) from a One Health perspective also may include people and organizations that are not traditionally engaged in health-related activities, such as those in transportation, manufacturing or industry, marketing, law, and other fields. At national levels, key leaders typically include those in Ministries of Health or Public Health (human domain), Ministries of Agriculture (animal and plant domains), and Ministries of the Environment or Natural Resources (animal, plant, and environment domains), although livestock and wildlife may be administered through different ministries. Each of these ministries or departments may have distinct mandates or goals, may promulgate or administer different regulations or policies, and may receive differential funding for these activities. With coordination, all of them can be more effective.

Another critical component of One Health approaches is the use of holistic approaches and systems thinking to address challenges. In this context, holistic means coordinated activities among multiple disciplines, sometimes through explicit coordinating units (e.g., Thailand's Coordinating Unit for One Health). Further, One Health approaches informed by systems thinking are those that consider not just associations and linear relationships, but also non-linear relationships, feedback loops, and the potential for emergent behaviour. In this, policies and procedures for response may contain contingencies that will vary based on the current status of a situation. For example, the use of personal protective equipment (PPE) may be mandated only when the incidence or prevalence of disease is above a certain threshold, with the requirement for PPE relaxed when the incidence or prevalence falls below that point—this is an example of how a current status of an outbreak can feed back to inform policy and intervention mechanisms.

It is important to acknowledge that other approaches have been developed to address these issues, including planetary health, ecosystem approaches to health, participatory epidemiology, socio-biological methods/models, mixed methods, team science, systems approaches, the science of team science, and many more. Some of these can be seen as elements of the One Health approach promoted in this guidebook, while others simply have alternative foci. For example, ecohealth refers to the need to consider the coupled interaction between humans and wild animals within the ecosystem context. One Health may be better integrated with the traditional environmental health approaches, which tend to emphasize characterization and mitigation of toxicant exposures to human populations, than ecohealth and planetary health approaches are. Instead, the field of ecohealth focuses on understanding the ways in which environmental and ecological changes, including those caused by human activities (habitat destruction, pollution, and the wildlife trade) can affect both the health of wild animal populations and the risk of zoonotic disease transmission to humans. Understanding these distinctions can be important in terms of the communication among different disciplinary groups or experts, and at various levels of governance, as understanding of what One Health, ecohealth, and other frameworks can differ based on stakeholder.

Organisation of the Guidebook

The guidebook is organized into eight sections and appendix materials. The current module, the Introduction, helps to provide orientation and motivation for the development of these recommendations and their use by different groups of users. This work reflects the joint efforts of the committees and invited experts who participated in the workshop series and authorship of the guidebook. The remaining modules may be accessed in order or piecemeal, depending on the needs of the user. These modules reflect partnerships in leadership and authorship between regional and technical experts.

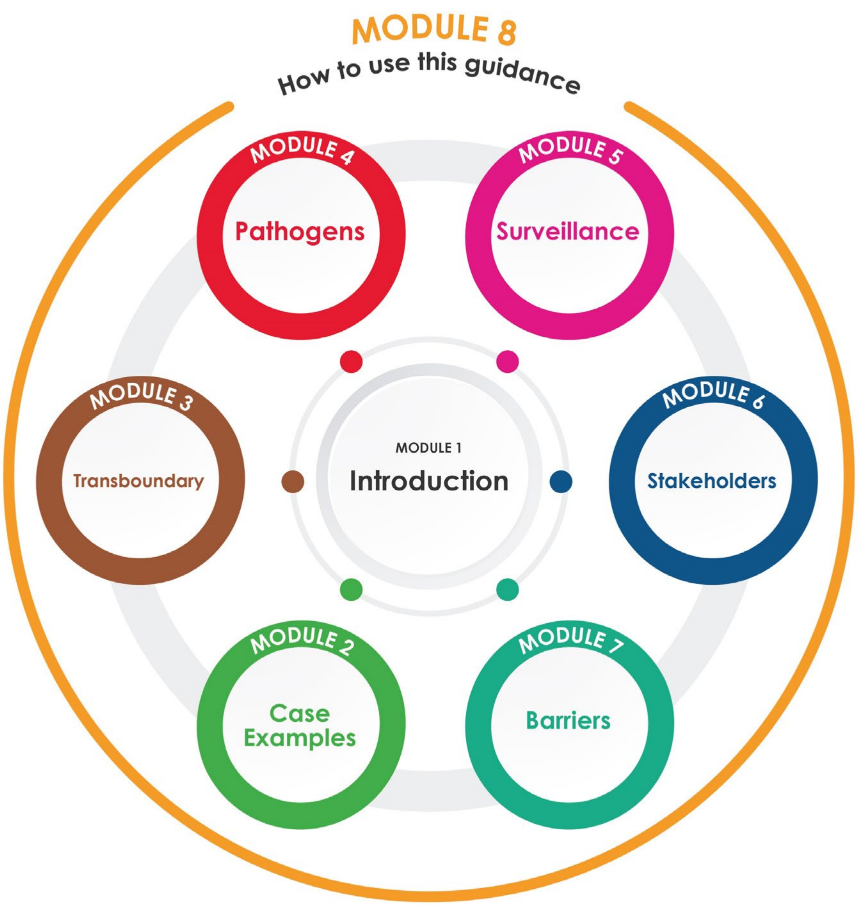


FIGURE 1-2 Organisation of the guidebook.

BOX 1-1
A Note on the Term "Stakeholder"

The term stakeholder is used in this guidebook. However, while ubiquitous in countless official documents across disciplines, cultures, and sectors, we want to acknowledge that this term has colonial and financial connotations for some people. The term was originally used to describe a person who physically held bettors' money during games. The definitions subsequently evolved into: a person, company, etc., with a concern or interest (esp. financial) in ensuring the success of an organization, business, system, etc. and one who is involved in or affected by a course of action which is how we use it in this guidebook.

Introspectively, public health practitioners, social scientists, historians, and business holders, among others, have advocated to banish the word from modern usage because of the history of stakeholder meetings claiming to engage interested parties while dismissing the perspectives of the public or individuals who are directly affected by policy or regulatory decisions. Furthermore, in some nations or communities, intrinsic to the concept of a stake is ownership, which may be at odds with their indigenous concept of sharing, pointing to the colonial roots of possession and power.

Sarah Bentley argues that typically, when public health researchers and practitioners use the term stakeholder, the reality is we are often purposely empowering those who may have been excluded from decision-making in the past. We are turning the table and making stakeholders of individuals and communities who haven't had a voice. While our intent with "stakeholder" is one of inclusivity and representation, it is imperative to understand any inadvertent use of insensitive language the term brings.

The authors of this guidebook have considered several alternatives to the term stakeholder, but none fully captures the limitless nature of the relationship between people, their roles, and the context in which they interact. The guidebook uses the term to represent people and communities with interests in the issues and roles to play in finding solutions while simultaneously recognizing both the bias implicit for some in the term and the wider need to decolonize research across the globe.

MODULE

02

HOW THE PAST INFORMS THE FUTURE

Opportunities in Southeast Asia to Prevent & Respond to Zoonotic Spillover

Co-Authors
Raina Plowright & Kelvin Lim

How the Past Informs the Future: Opportunities in Southeast Asia to Prevent and Respond to Zoonotic Spillover

INTRODUCTION

In this module, the authors address the pressing issue of zoonotic diseases in Southeast Asia (SEA) and their overall impact on the public health systems. Given the prevalence of the COVID-19 pandemic, several countries have witnessed public health emergencies and emerging infectious diseases (EID) outbreaks, such as SARS, MERS-CoV, avian influenza, and Nipah virus, highlighting the significance of understanding zoonotic spillover events. Multiple factors make SEA susceptible to EIDs, including its rich biodiversity, land-use changes, dense human settlements, extensive interface and interactions between humans and wildlife, high-density livestock and poultry, and the prevalence of traditional markets, along with both socioeconomic and ecological changes. Addressing these challenges requires a comprehensive and interdisciplinary approach involving scientists, governments, conservation organizations, local communities, and law enforcement agencies. In this module, we present a series of eight mechanistic steps that shed light on how pandemic pathogens can infiltrate and proliferate within the wildlife trade system, from reservoir hosts to wildlife trade to humans. Through a series of key interventions and theoretical and real-life case examples, we have identified strategies to minimise pathogen persistence in live animal supply chains, especially those involving wildlife, ways to reduce animal-human contact and protect individuals at risk, and the importance of effective monitoring and surveillance of zoonotic diseases. The goal of this module is to collectively develop comprehensive and mechanistic strategies to address the challenges posed by zoonotic spillover events in the region.

GLOBAL EPICENTRE: WHY SOUTHEAST ASIA SERVES AS A HOTSPOT FOR EMERGING INFECTIOUS DISEASES

Over the last couple of decades, Southeast Asia and China have gained global attention regarding public health emergencies, food safety incidents, and EID outbreaks such as severe acute respiratory syndrome (SARS), Middle East respiratory syndrome coronavirus (MERS-CoV), H5N1 influenza, coronavirus disease (COVID-19), and Nipah virus (Vourc'h et al., 2022). Over 60% of emerging infectious disease cases are caused by zoonosis, or infectious diseases shared between animals and people and over 70% of these originate in wildlife (Jones et al., 2008; Lee, 2023; Murray et al., 2015). These diseases are caused by pathogens, such as bacteria, viruses, and parasites, which naturally transfer between species in a process known as spillover.

It is important to note the difference between zoonotic disease cases, which oftentimes refer to instances where an individual or group of individuals has been diagnosed with a specific disease, and zoonotic disease events, which encompass a broader range of ecological, environmental, and epidemiological dynamics surrounding disease transmission. In general, the potential risk of zoonotic infectious diseases is increased by any situation that leads to increased contact between wildlife-to-humans, wildlife-to-livestock, or wildlife-to-wildlife, increased infection and shedding in wildlife, and increased behaviours of humans that lead to exposure (Plowright et al., 2017).

Nestled between the Indian and Pacific Oceans, the SEA region can be classified into two major ecological zones: the continental zone, which includes Thailand, Vietnam, and Myanmar, and the insular region, including Indonesia, Malaysia, and the Philippines (Hayami, 2001). Southeast Asia comprises eleven (11) countries: Lao PDR, Myanmar, Cambodia, Thailand, Indonesia, Darussalam, Malaysia, Singapore, Brunei, Vietnam, and Timor-Leste (Figure 2-1). The continental zone is characterized by major river basins while the insular zone is dominated by tropical rainforests (Figure 2-2) (Hayami, 2001). With a population of 690 million in 2023, Southeast Asia has experienced tremendous progress and development in recent years - from 2008 to 2017, its population underwent a substantial growth of 11.6%, with projections showing a population of 720 million by 2027. Its economic growth is also expected to rise as the gross domestic product (GDP) grew to an average of nearly 5% per year from 2000 – 2016 (Lee and Hansen, 2019; OECD/FAO, 2017).

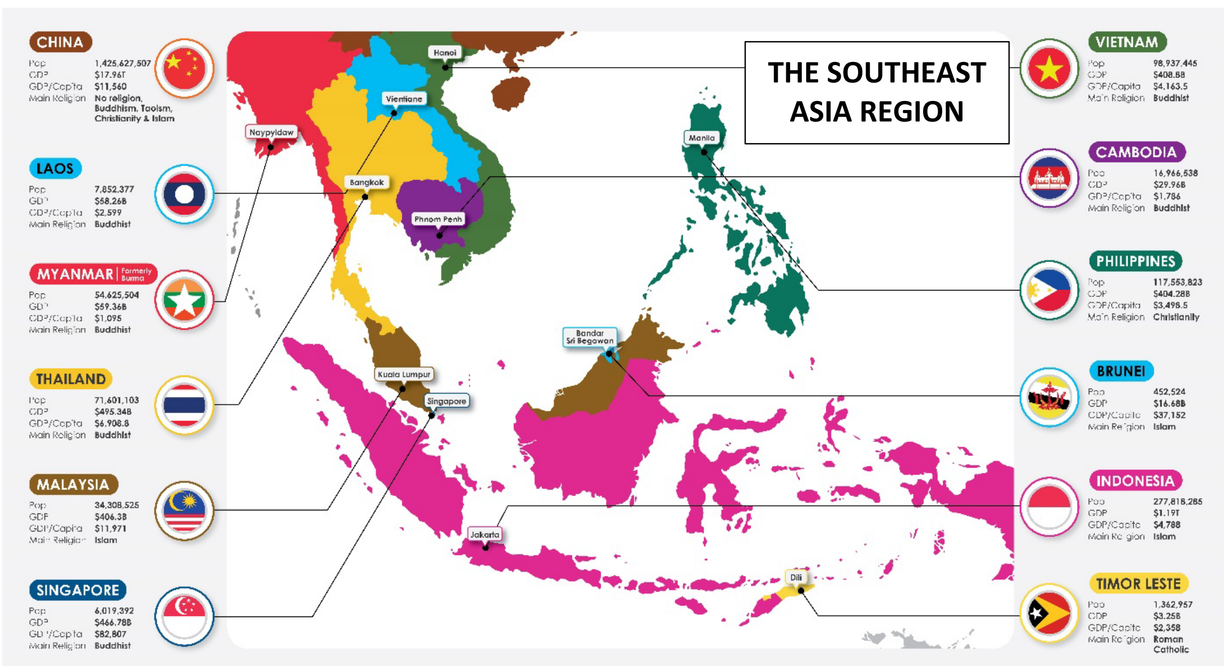


FIGURE 2-1 Map of the Southeast Asia region (partial).

FIGURE 2-2 (Top left) Mondulkuiri Province in Cambodia. Photo credit: Adam Roberts © Wildlife Conservation Society (WCS); (top right) Tonle Sap Lake and a Floating Village in Cambodia. Photo credit: Cristian Samper © WCS; (bottom) Nam Et-Phou Louey National Park protection area in northern Laos. Photo credit: Dominique le Roux © WCS.

In the last few decades, climate change and profound changes in human ecology, such as rising urbanisation, deforestation, agricultural expansion, wildlife consumption and trade, increased global travel, and human encroachment on animal habitats, shifted land-use patterns leading to closer and more frequent human and animal interactions, have substantially increased the probability of future disease outbreaks (Saba Villarroel et al., 2023). Several crucial factors that significantly and jointly contribute to Southeast Asia's susceptibility to EIDs make up the reasons why this region serves as a zoonotic hotspot.

Biodiversity

FIGURE 2-3 Southeast Asia is home to a plethora of wild animals including the Malay tapir (Tapirus indicus) (top left), North Sulawesi babirusa (Babyrousa celebensis) (Bottom-left), sun bear (Helarctos malayanus) (middle), and macaque monkeys (top and bottom right). Photo credits: Julie Larsen & Bill Meng © WCS and K. Yoganand.

In the last few decades, there has been a rise of zoonotic diseases within the intertropical region. As of 2020, there are 364 billion pigs, 27 billion 223 million chickens, and 1 billion 587 million cattle (Morand, 2022). These numbers are important since emerging zoonoses can be transmitted from wildlife to an intermediary species, which are generally domestic or traded species. Transmission among intermediary hosts can lead to natural selection for viral strains that are more capable of infecting the human population.

Traditional Markets, Livestock Farming, and Food Safety

Agriculture and livestock farming often serve as a vital source of economy, sustenance, and livelihood in Southeast Asia, adding over 10% to the region's total GDP (Ru et al., 2023). In countries such as Indonesia, the Philippines, Thailand, and Vietnam, it employs roughly a third of the workforce (Alavi, 2011; Saba Villarroel et al., 2023). The reliance on livestock production and meat consumption in Southeast Asia is driven by rising incomes and urbanisation.

FIGURE 2-4 Photos of traditional markets in Thailand (left) and Indonesia (right). Photo credit: Pixabay and Pexel.

Traditional markets, especially informal markets selling live animals and their products, and where live animals are sometimes housed and slaughtered on-site, are common in the region, and other low- and middle-income countries (Figures 2-4, 2-6) (Naguib et al., 2021). Together with farming and agriculture, these practices offer local communities many benefits including employment, improved household nutrition, food security, and economic well-being (Bardosh et al., 2023). The expansion rate of these sectors varies, with poultry farming growing substantially in Thailand and Malaysia compared to Vietnam, Indonesia, and Cambodia (Hassan, 2014).

Human activities such as intensive farming and logging, linked to deforestation and road construction inadvertently bring vulnerable human populations into close contact with wildlife, some of which are competent reservoir hosts, increasing the risks of zoonotic spillover events (Figure 2-5). Deforestation has led to biodiversity loss, leaving competent hosts of zoonotic pathogens to thrive and dominate low-diversity environments (Gibb et al., 2020). Given the ongoing COVID-19 pandemic, the origin of the SARS-CoV-2 virus has brought attention to the potential role of traditional markets in disease emergence (Konda et al., 2020). This is often due to poorly regulated sourcing and transportation of animals, lack of adequate biosecurity measures, and the constant mixing and trading of animals (Engel and Ziegler, 2020; Greatorex et al., 2016; Pruvot et al., 2019).

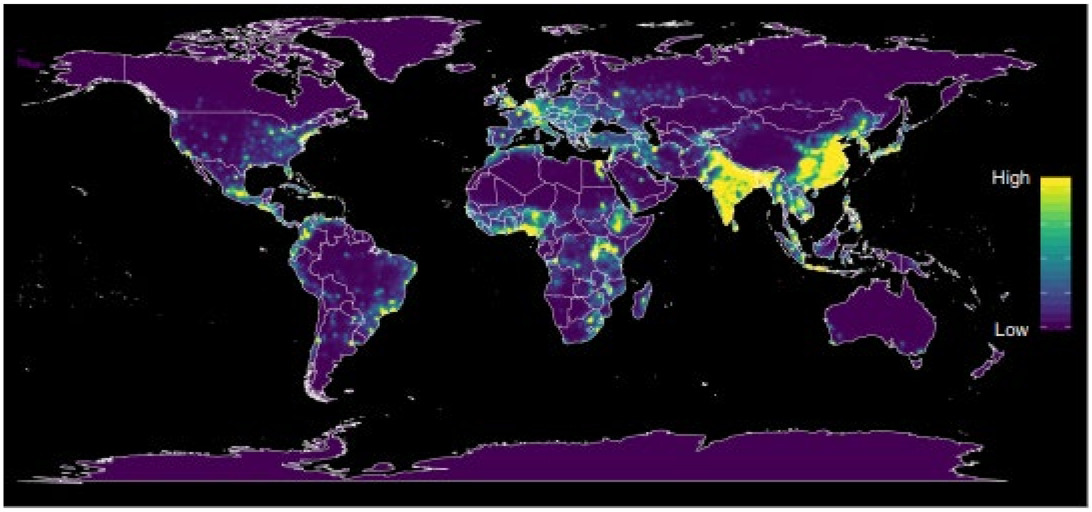


FIGURE 2-5 Heat map depicting the estimated risk distribution of zoonotic disease emergence after correcting for reporting bias. Photo credit: Allen et al., 2017.

Since the early 1990s, Southeast Asia and China have collectively contributed more than half the advancements in international livestock cultivation, and this growth is expected to continue (Jiao et al., 2021). Nevertheless, the increased proximity of humans and animals in these situations creates opportunities for spillover.

FIGURE 2-6 A large live animal market in Guangzhou, China, in April 2014. Note the mixture of multiple avian species in close proximity. Photo credit: Gregory Gray.

Mitigating zoonotic disease risks in these environments necessitates collaborative efforts among policymakers, researchers, and local communities. Implementing rigorous biosecurity measures and hygiene protocols is crucial to prevent disease transmission while integrating modern surveillance system aids in early detection and rapid response to potential outbreaks. Minimising the trade of wildlife taxa that are known to or potentially host high-consequence pathogens (HCP) should be included as a key prevention strategy. Educating market vendors and consumers about safe food handling practices is also vital, as is encouraging sustainable and responsible agricultural practices and wildlife trade. Therefore, a holistic approach, emphasizing evidence-based interventions, fostering community awareness, cross-disciplinary collaboration, and promoting responsible trade and farm/food safety practices from farm to fork can help to ensure a more resilient and sustainable future for SEA, preserving its cultural practices and traditions while safeguarding public health and biodiversity. More information can be found on this in 'Module 6: Strategies to Engage Diverse Stakeholders Across the Live Animal Value Chain to Address Risk."

Socioeconomic Factors

In Southeast Asia, the growing demand for animal protein, rapid population growth, rising disposable incomes, deforestation, and progressive urbanisation have fuelled an increased consumption of animal-based foods (Jiao et al., 2021). Between 2009 and 2018, Southeast Asia witnessed a large surge in meat production, particularly in countries such as Vietnam and Thailand, where poultry farming has experienced a 56% increase, while pig farming increased by 23% (Jakobsen and Hansen, 2020). The escalating consumption of meat and seafood in SEA is projected to rise by 33% by 2030, with a 78% increase from 2017 to 2050 (Neo, 2018). This surge reflects a growing demand for meat consumption driven by rising disposable incomes and urbanisation. At the same time, underlying social and economic factors, such as poverty and food insecurity, contribute to limited access to healthcare, lower vaccination rates, and heightened susceptibility to infectious diseases. Typically, areas with high levels of poverty and social inequalities have lower vaccination rates and tend to be least prepared to handle a pandemic. Poverty and social inequalities in affected areas can lead to differential morbidity despite improved housing, land drainage, mosquito repellents, nets, and electric fans (Farmer, 1996). Some of these life-saving items are out of reach of those most at risk of EIDs. Lastly, areas that tend to be most impacted by EIDs also have high gender inequality and low attendance of children in schools. These factors underscore the urgent need to address social and economic disparities to enhance resilience and preparedness against future pandemics.

Ecology

Urbanisation changes the ecology of animal reservoirs, vectors, and pathogens, leading to declining biodiversity and increasing competitive dominant species that are also competent hosts of zoonoses (Blasdell et al., 2022; Gibb et al., 2020). Ecological systems are undergoing profound changes due to anthropogenic-caused urbanisation, land-use change, and climate change, causing major pathogen spillover from wildlife to human populations. For example, changes in land use, including deforestation, in subtropical Australia have disrupted natural bat habitats. This displacement, coupled with specific climate conditions, contributes to the spillover of Hendra virus from bats to horses and subsequently humans, as bats feed in human-dominated encroachments such as in agricultural areas where there are horses (Eby et al., 2023). Climate change plays an increasingly important role in spreading infectious diseases transmitted by vectors like ticks and mosquitoes (Franklinos et al., 2019). Other research indicates that resulting changing assemblages of wild mammals may increase viral sharing among species (Carlson et al., 2022). Climate change may also impact infectious disease spread by altering the frequency and intensity of extreme weather events, with which Southeast Asia is not unfamiliar, such as tropical storms, heavy rains, typhoons, monsoons, floods, and earthquakes being common (Syakbanah and Fuad, 2021; Torti, 2012). These natural events can disrupt healthcare infrastructure and its preparedness for managing emerging infectious diseases.

Wildlife Trade and Trafficking

Addressing the challenges posed by zoonotic spillover requires thorough examination of all aspects of the wildlife trade supply chain, as interventions must be strategically implemented at different points along the supply chain to manage potential risks and curb zoonotic disease transmission (FAO, 2011; Ludher and Kumar, 2018). Anthropogenic activities contributing to the spillover risk and emergence of zoonotic infectious diseases are international and domestic legal wildlife trade, illegal and unregulated wildlife trade and trafficking. Southeast Asia plays a major role in both legal and illegal wildlife and pet trade globally, contributing to nearly a quarter of the illegal wildlife trade worldwide. This includes the supply and demand dynamics for rare and exotic pets, as well as consumption practices (Krishnasamy and Zavagli, 2020; Lin et al., 2021; Rivera et al., 2021). The commercialization of wildlife trade has led to a greater supply of wild meat to urban consumers and international markets (Milner-Gulland et al., 2003; Swamy and Pinedo-Vasquez, 2014). Wildlife trade and trafficking increase the risk of spillover due to exchanges of bodily fluids and blood among humans and wildlife animals during various stages of the wildlife trade (Figures 2-7, 2-8, and 2-9). Thus, the risk of zoonotic diseases associated with live or dead animal movement, especially of mammalian and avian species is real and significant and can potentially elevate the probability of zoonotic pathogens being propagated through chains of transmission. Consequently, individuals working alongside the supply chain, including hunters, transporters, consumers, and local market sellers are exposed to a heightened risk of contracting zoonotic diseases (Box 2-1).

FIGURE 2-7 (Left) A common palm civet *Paradoxurus hermaphroditus* left in a cage to be traded at a wildlife farm in Vietnam. Photo credit: WCS Vietnam. (Center) Large rat cage in Cambodia. Photo credit: Lucy Keatts at WCS. (Right) Monitor lizards being traded in Laos. Photo credit: Lucy Keatts at WCS.

The scope of the wildlife trade supply chain involves a vast network of animals, people, and activities. This involves everything from manufacturing and processing to the regulations and governance surrounding the hunting, capture, farming, transport, and distribution of wildlife and their associated products (FAO, 2011; Ludher and Kumar, 2018). Managing the risks associated with spillover demands an interdisciplinary and intersectoral collaborative approach that considers the interplay of factors along this complex trade network (Stephen, 2021). Governments, conservation organizations, and law enforcement agencies must collaborate to enforce stringent oversight of both legal and illegal wildlife trading as well as pet ownership. Additionally, education and awareness campaigns are crucial in discouraging the demand for exotic pets and promoting responsible behaviour among consumers (Verissimo and Wan, 2019). In the region, hunting is common for both trade and household consumption. These practices often display opportunistic and indiscriminate characteristics, with a variety of wildlife species, such as rodents, pangolins, carnivores and bats, being targeted (Engel and Ziegler, 2020). These wild animals are hunted at random and taken from their natural habitat. Subsequently, they are exploited for various purposes, such as collectibles, food items, servings in restaurants, merchandise for sale, pets, and medicinal purposes, and are found in open-air traditional markets, or marketed through online platforms and social media channels (Galindo-González, 2022; OECD/FAO, 2022).

Examples of Wildlife Supply Chain Structure: Various Points of Entry and Amplification

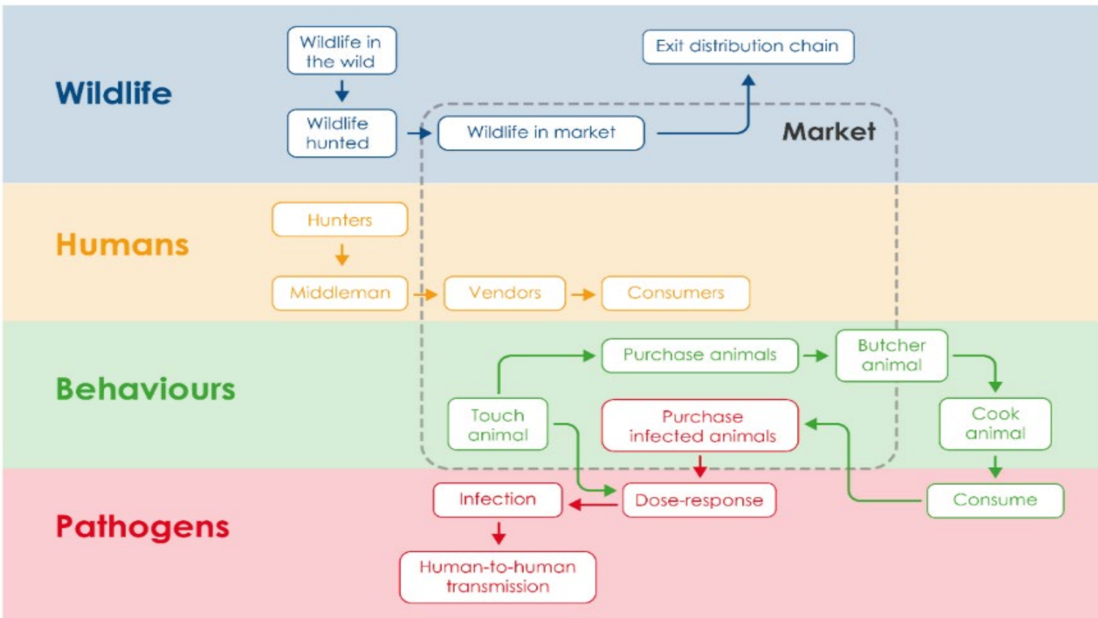


FIGURE 2-8 Conceptual model describing the potential for pathogen spillover and zoonotic disease transmission in the wild meat trade in Laos. Adapted from: Pruvot et al., 2019.

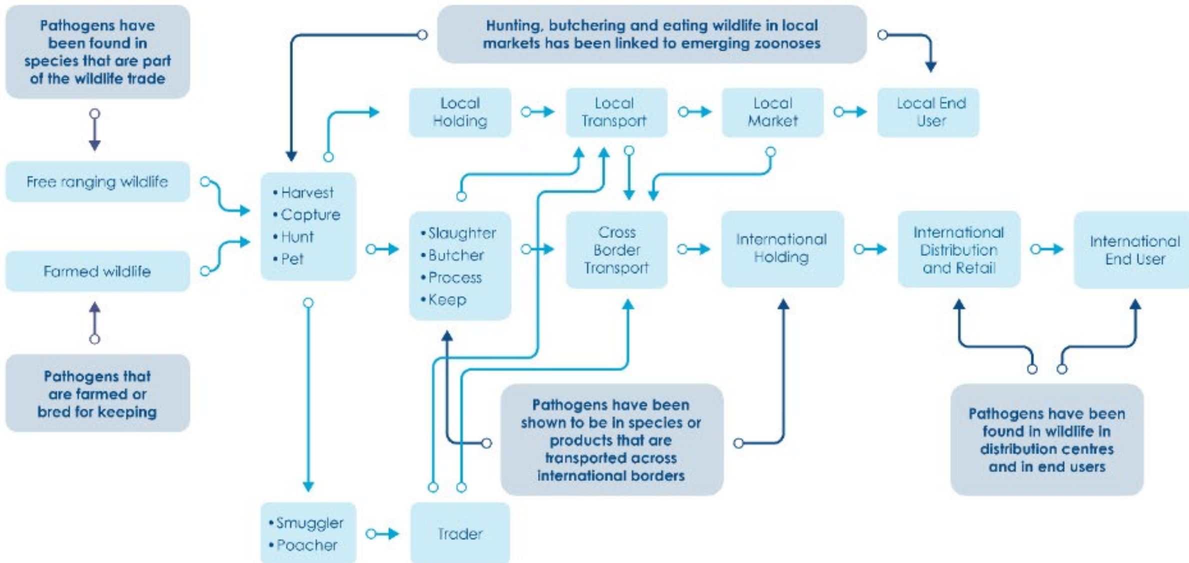


FIGURE 2-9 Pathogen detection and nodes for pathogen surveillance in the wildlife trade supply chain. Adapted from Stephen, 2021.

BOX 2-1
Avian Influenza in Southeast Asia

FIGURE 2-10
As part of a One Health study for avian influenza, veterinary workers collected an orotracheal swab specimen from a healthy chicken at Ha Vi live bird market in Vietnam, in July 2019. Vi Market is the largest live wholesale poultry market in Hanoi, Vietnam. It is estimated that 80,000-100,000 birds are slaughtered each day. The market includes 200 registered shops occupying a total of 20,000 square meters. Swab samples collected from healthy chickens indicate these birds have active influenza A virus infections. Photo credit: Gregory Gray.

Avian influenza, or bird flu, is a viral disease of birds that has caused significant animal, public health, and economic consequences. While it is devastating to poultry, the concern has been that it may acquire the ability for human-to-human transmission. In 1996, China detected the first H5N1 outbreak in poultry. One year later in Hong Kong, the first human case was detected. Thereafter, an epidemic of highly pathogenic avian influenza (HPAI) H5N1 infections emerged in Southeast Asia in December 2003, affecting Cambodia, Indonesia, Laos, Thailand, and Vietnam. It is now considered endemic in poultry in many SEA countries and has caused sporadic zoonotic infections. Aside from public health impacts, it has also caused disruptions in poultry production and trade. Wild birds have likely contributed to its spread in SEA, but domestic poultry trade appears to have played a key role in the generation and maintenance of HPAI virus circulation (Gutiérrez et al., 2009).

Unfortunately, high-risk poultry trading practices continue to persist, which impact the risk of infection and spread of HPAI within poultry. For example, a study of poultry trading behaviours in Vietnamese live bird markets demonstrated that middlemen, who are mobile, highly connected poultry traders that travel between farms and live bird markets to buy and sell birds, increase the likelihood of mixing poultry from different sources (Sealy et al., 2019). They are also more likely to be open for business for an extended period. This facilitates a network of live bird markets that can maintain circulation of influenza viruses. Rigorous quarantine, hygiene, and sanitation protocols must be established for people who traffic or sell animals to avoid the transmission of pathogens.

STRENGTHENING BARRIERS: DEFINING ZOONOTIC SPILLOVER AND STRATEGIES FOR TRANSMISSION CONTROL

Zoonotic spillover is the passage of a microbe from a non-human vertebrate animal to a human (Plowright et al., 2017; Temmam et al., 2019). It occurs when a microbe that usually circulates in animal populations 'jumps' to humans. Most zoonotic spillovers are from endemic pathogens in domestic animals, impacting over 2 billion people and resulting in 2 million deaths worldwide each year (World Bank, 2021). By contrast, spillover from wildlife has caused most new and emerging human diseases and recent pandemics (Bernstein et al., 2022; Jones et al., 2008), including COVID-19, which had resulted in at least 7.8 million deaths as of December 2023 (WHO, 2023f).

Zoonotic spillover is a complex process that occurs along a pathway. This process happens in several steps, where an animal pathogen must overcome many barriers to infect a human. The movement of a pathogen through each barrier is facilitated by human drivers and influenced by factors such as time, distance, changes in evolution and ecology, and random events. First, the pathogen circulates in its natural reservoir host, such as a mammal, or bird. Certain conditions can influence the prevalence and intensity of infection in the reservoir host population and the amount of pathogen excreted from the hosts. Next, a recipient host (for example, a human, domestic animal, or traded animal) needs to encounter the pathogen in the environment, known as pathogen exposure. Finally, the pathogen must be compatible with the recipient host, and the recipient host must receive a sufficient dose through the correct route of transmission for spillover to occur. It is important to note that only a small number of pathogens are compatible with humans. For example, most viruses cannot bind and enter human cells or evade our innate immune system, and an even smaller number of pathogens can spread from one person to another.

Pandemic Prevention

Pandemic prevention refers to a comprehensive set of proactive strategies and measures aimed at reducing the risk of infectious diseases on a global scale (Coccia, 2022). It involves several complementary approaches aimed at controlling and mitigating the impact of outbreaks including:

1. **Primary pandemic prevention:** These strategies focus on factors that reduce spillover risk factors by interrupting the transmission pathway of infectious diseases from animals to humans. These interventions target various points along this pathway to prevent the initial transmission (or spillover event) and the establishment of the pathogen in human populations (OHHLEP: Markotter et al., 2023; Vora et al., 2022). Some examples of this include implementing regulations to reduce deforestation or habitat destruction, minimising trade and consumption of certain taxa of wild animals, enforcing stricter biosecurity measures in animal markets, or promoting sustainable agricultural practices to reduce the frequency of spillover events. By understanding the factors contributing to spillover, such as the destruction of tropical forests, agricultural expansion and intensification, and wildlife trade and hunting, pandemic prevention can focus on mitigating these risk factors.
2. **Secondary pandemic prevention**: Secondary prevention focuses on detecting and containing the spread of pathogens once they have spilled over into humans (Vora, 2022). It involves early detection through surveillance, contact tracing, case isolation, and diagnostics, along with treating infections, implementing targeted lockdowns or restrictions, ramping up healthcare policy and supplies to manage surges in cases, and recruiting and retaining healthcare workers.

In this module we explore primary pandemic prevention, focusing on evidence-based strategies aimed at controlling risk factors associated with disease transmission from animals to humans.

A One Health approach, which is a comprehensive approach that optimizes the health of the environment, animals, and people, will be needed to address both primary and secondary pandemic prevention and will involve identifying (Galindo-González, 2022) and addressing anthropogenic drivers of spillover such as land-use change, climate change, and wildlife trade (Keesing et al., 2010; OHHLEP et al., 2022b). This definition has been explored further in Module 1 of this guidebook. Barriers to zoonotic spillover are illustrated in Figure 2-11. Whole-of-government actions will need to be taken and at the same time, research should continue to develop greater biological insight into zoonotic spillover and drivers of different pathogens and systems. To support decision-makers on what they can do now to mitigate these drivers, this module highlights some key examples of zoonotic diseases in the Southeast Asia region.

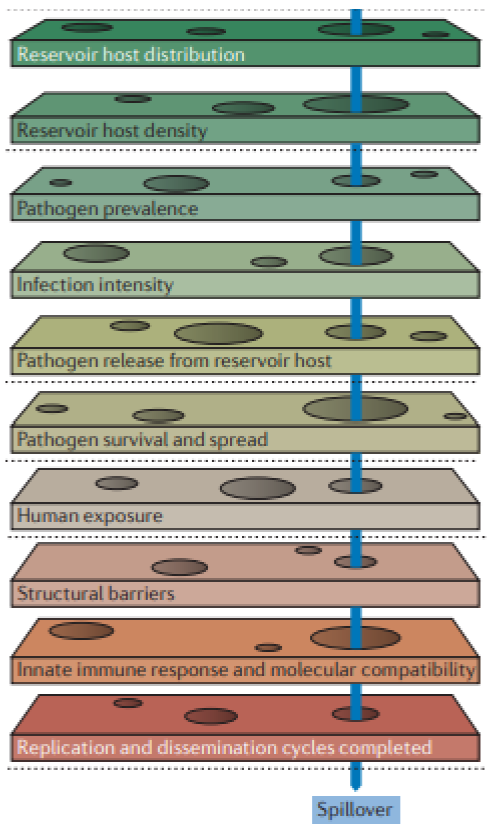


FIGURE 2-11 Barriers to zoonotic spillover. In many disciplines, determinants of spillovers are being studied. A pathogen needs to navigate through a variety of barriers to transmit from one species to another. If any of the barriers do not allow for the pathogen to pass through, then a spillover cannot occur. Spillover of some pathogens requires that gaps (depicted as holes) in all the barriers align within a narrow window in space and time, indicated by the blue arrow. Adapted from Plowright et al., 2017.

From Source to Spillover: Understanding Mechanisms of Zoonoses and Evidence-Based Guidelines for Intervention

Pathogens can make the physical jump from animals to humans in any number of ways. These include direct contact with infected animals or their bodily fluids; consumption of contaminated food sources; vector-borne disease transmission which occurs via mosquitoes, ticks, and fleas; environmental exposure; and occupational hazards for individuals working closely with animals. Understanding these different pathways is essential for preventing and managing zoonotic diseases and protecting human health.

FIGURE 2-12 Environmental stressors and wildlife trade can rearrange natural barriers to spillover and increase their permeability. Adapted from Plowright et al., 2017.

We have developed a mechanistic and structured way of viewing the risk of zoonotic spillover through wildlife trade (see Figure 2-12). We summarize the components of the wildlife trade and where interventions could prevent the entry of new zoonotic pathogens into the trade or prevent the propagation and amplification of new zoonotic pathogens through populations of traded animals. We focus on points where the chain of transmission that leads to outbreaks in humans could be prevented.

Preventing Movement of High-Risk Reservoir Host Species into Farms and Trade and Preventing Contact of Reservoir Hosts with Traded or Farmed Animals

In Southeast Asia, small-scale trade, hunting, and farming in wildlife coordinated by locals has transitioned to coordinated, domestic and international trade networks (IPBES, 2019). In 2016, wildlife farms and markets hired approximately 14 million people in China alone (Arranz and Huang, 2020). Global awareness surrounding the scale of legal and illegal domestic and international trade of animals has been heightened in the wake of the COVID-19 pandemic. The United States is the main market for wildlife pets, where millions of live animals are imported from EID hotspot countries. This global trade occurs without effective surveillance or regulatory oversight, posing potential risks to public health (Smith et al., 2009). Within the wildlife trade supply chain (Figures 2-8 and 2-9), it is important to consider the groups of individuals and activities from local hunters, transporters, and butchers to live animal market sellers, retailers, and pet shop owners, restaurant and culinary trade, and to international trade actors (Ludher and Kumar, 2018). Addressing the challenges and vulnerabilities within the components of these supply chains and across wildlife trade requires a comprehensive and holistic One Health approach to reduce overall risk.

Importing live animals, especially in the absence of regulations and biosecurity control measures brings the risk of importing pathogens that can infect native wildlife, livestock, and people. COVID-19 most likely developed from bat-origin coronaviruses (Rothan and Byrareddy, 2020). It has also been associated with a seafood market in Wuhan, China, where wild live animals were sold (Lam et al., 2020). However, to date, the origin of SARS-CoV-2 has not been established (NIH, 2022). Recognizing this interplay underscores the need to identify, understand and address the risks posed by the wildlife trade to effectively mitigate the spread of zoonotic diseases.

Strategies to Reduce the Risk of Zoonotic Diseases in Farming and Trade

The key issue is how to prevent these pathogens from entering the wildlife trade and the supply chain where they could have the opportunity for amplification, evolution, and exposure to humans. We suggest three strategies to reduce the probability of the introduction of these viruses into the animal trade:

1. Reduce the probability that free-ranging wild animals contact people or trade animals.
2. Reduce the probability that free-ranging wild animals are infected and shedding viral pathogens by improving landscape immunity.
3. Reduce the probability that high-risk host taxa (known to host pandemic potential viruses) enter the wildlife trade.

1) Reduce the probability that free-ranging wild animals contact people or traded animals

One primary driver of zoonotic disease outbreaks is land-use change. Wild animals are less likely to use human-dominated areas if they have sufficient food and habitat in unmodified landscapes (Plowright et al., 2024). If resources are fleeting, animals need adequate habitat to locate places for roosting, resting, socializing, finding food and water, and engaging in migratory or nomadic movements. Deforestation and loss of habitat, particularly those providing resources during times of scarcity or high energetic demand, can force animals to seek alternative resources within human landscapes (Eby et al., 2023; Plowright et al., 2024). Additionally, it has been shown that landscape fragmentation along with certain smallholder farmers' behaviours along these patches of forests can increase the likelihood of human-animal contact events (Bloomfield et al., 2019). Consequently, ecological countermeasures such as wildlife habitat conservation play a pivotal role in diminishing the occurrence of wild animal contact with traded animals, along with other targeted landscape-based interventions (Figure 2-13). For instance, in Australia, the spillover of the Hendra virus is thwarted by the blossoming of native trees, which lure bats away from areas with horses (refer to Case Study 1). An effective intervention addressing the fundamental cause of spillover involves the restoration and preservation of winter flowering habitats for Pteropodidae bats in Australia (Eby et al., 2023). After the 1998-1999 Nipah virus outbreak in Malaysia, mango trees and other trees preferred by bats were removed from the vicinity of piggeries (refer to Case

Study 2), potentially explaining the absence of subsequent Nipah virus outbreaks in pigs in Malaysia.

FIGURE 2-13 Depiction of reforestation initiatives which help to redirect bat populations away from local and agricultural communities. This is crucial for preventing disease transmission.

To further amplify the spatial separation between reservoir hosts and potential spillover hosts, several recommendations can be considered:

- Enforcing stricter risk-based regulations on wildlife trade and ensuring that traded animals meet health conditions, including undergoing thorough disease monitoring can help prevent the introduction of potential pathogens into trading networks.
- Implementing comprehensive wildlife habitat conservation and restoration programs can enhance the availability of natural resources for wild animals, reducing their incentive to venture into human- and livestock-dominated areas.
- Promoting public awareness and education about the risks associated with wildlife trade and zoonotic disease transmission can encourage responsible behaviour and informed decision-making among traders and consumers.

2) Reduce the probability that free-ranging wild animals are infected and shedding viral pathogens by improving landscape immunity

Viral pathogens circulate in their natural populations, rarely causing disease in their reservoir hosts. Moreover, many viruses are found at either low prevalence or are rarely detected at all in their natural hosts. For example, Nipah and Ebola viruses may circulate within a given population, causing local outbreaks in bats before moving to another susceptible population before dying out (Plowright et al., 2015). When animals are exposed to stressors, such as habitat loss, or they are unable to gain enough energy from available habitat, they can go into “allostatic overload” or stress, where energy is shifted away from energy-expensive processes such as reproduction and immunity (McEwen and Wingfield, 2003; Plowright et al., 2024). Therefore, anthropogenic activities that disrupt ecological systems can trigger the infect-shed-spill-spread cascade, such as land use change, deforestation, and climate change (Plowright et al., 2021; Reaser et al., 2022). Stress increases the likelihood that wildlife will release (or shed) pathogens in ways and locations that lead to the infection of other animals of the same or different species (called spillover). One is more likely to see higher infection prevalence and shedding during those periods (Becker and Banerjee, 2023; Eby et al., 2023).

Landscape immunity is defined as ecological conditions that maintain and strengthen the immune function of wild species within a particular ecosystem (Reaser et al., 2022). Ensuring that wild animals have the habitat and resources they need for sufficient energy to sustain an immune response is fundamental to reducing the risk of pathogen infection and shedding from reservoir hosts (Plowright et al., 2021). To enhance landscape immunity, it is essential to focus on biodiversity conservation, habitat restoration, and minimising habitat fragmentation. (See Case Example 2 on Nipah virus outbreak.) Some real-life examples of ecological countermeasures to improve landscape immunity include agroforestry to provide food and shelter for bats while receiving the benefits of bat predation of agricultural insect pests (Voigt and Kingston, 2016), restoration of critical food plants along animal migratory routes (Reaser et al., 2022), and the creation of protective buffers around areas of aggregation such as caves where bats roost (Plowright et al., 2024). These efforts can help maintain the balance of ecosystems and support the overall health and resilience of wild animal populations. By providing suitable conditions for wildlife, we can alleviate stressors and promote optimal immune responses in wild animals (McEwen and Wingfield, 2003).

3) Reduce the probability that high-risk host taxa enter the wildlife trade

The wildlife trade, particularly in high-risk host taxa known to harbour pandemic potential viruses, poses significant risks for zoonotic disease transmission to humans, discussed further in 'Module 3: Efforts to prevent transboundary disease outbreaks in the Southeast Asia Region.' Certain host taxa have a higher likelihood of harbouring viruses that are zoonotic and have pandemic potential. For example, bats not only harbour more viruses than rodents (Luis et al., 2013), but the viruses they harbour are more likely to be virulent in people (Guth et al., 2022). Eliminating bats from the wildlife trade would be a sensible step to ensure that undiscovered bat pathogens do not have the opportunity for amplification, evolution, and exposure to people (Osofsky et al., 2023). Primates, rodents, and birds are other taxa that are associated with pandemic potential viruses (Zhou et al., 2021). Other species that have been identified as susceptible bridging hosts for human pathogens could also be excluded from trade. For example, civets and raccoon dogs can be infected by SARS-CoV-1 and SARS-CoV-2, respectively, and may be able to maintain chains of infection in captivity under some circumstances (Korath et al., 2022; Mallapaty, 2023). More information on this can be found in 'Module 4: How to Identify and Characterize Priority Pathogens to Guide Efforts to Address Zoonotic Disease Spillover?'

To combat the probability that high-risk hosts enter the wildlife trade, countries should implement strict regulations and policies based on scientific evidence and risk assessments. While the majority of Southeast Asian countries have indicated presence of provisions to regulate wildlife trade, especially CITES-listed and/or protected wildlife, there remains inconsistencies in the legal framework to tackle the different nodes of the supply chain (ASEAN Secretariat, 2021). Risk assessments on zoonotic disease risk introductions can take reference from lessons applied in the regulation of trade in domestic livestock or food safety regulation (Campbell et al., 2022). Additionally, raising public awareness about the risks associated with wildlife trade is crucial. Media campaigns, community outreach programs, and collaboration with local non-governmental organizations (NGOs) and wildlife conservation groups can be designed to educate consumers and stakeholders about the potential health risks of consuming high-risk species such as civets and pangolins, which have been implicated in zoonotic outbreaks in the past (Mahapatra et al., 2015). More information on this can be found in 'Module 8: Applying Participatory Methodologies to Countering Zoonotic Spillover." For additional information on alternative livelihood solutions, refer to "Module 6: Strategies to Engage Diverse Stakeholders Across the Live Animal Value Chain to Address Risk."

Another useful tactic is to enhance law enforcement and monitoring efforts to combat illegal wildlife trade by increasing resources and capacity. Malaysia, for example, has established wildlife crime units within its enforcement agencies to tackle wildlife trafficking (Ariffin, 2015). Similarly, Indonesia has implemented stricter penalties for wildlife smuggling (Shepherd et al., 2020). Singapore has introduced stiffer penalties for illegal trade in species protected under CITES, and stronger enforcement powers e.g., making clear that items used to deliberately conceal and/or convey wildlife products can be seized and forfeited (Republic of Singapore, 2021). In addition, a domestic trade ban on elephant ivory has also been implemented (Yeo et al., 2024). Collaborative transboundary efforts among Southeast Asian countries, such as intelligence sharing and joint operations, can help identify and dismantle wildlife trafficking networks. More information on this can be found in 'Module 3: Efforts to Prevent Transboundary Disease Outbreaks in the Southeast Asia Region.' Providing sustainable alternative livelihoods to communities engaged in wildlife trade is important as well. Initiatives such as community-based ecotourism have been successful in reducing dependence on wildlife trade. For example, the Kinabatangan Wildlife Sanctuary in Borneo, Malaysia has supported community-based tourism and provided economic opportunities while protecting wildlife habitats.

Case Study 2-1: Ecological Interventions to Halt Spillover of Hendra Virus Within Bat Species in Australia

FIGURE 2-14 Flying foxes are known reservoir hosts of viruses of the family Paramyxoviridae, including Hendra and Nipah viruses. Some of the flying foxes are known to roost in colonies in the middle of urban settlements such as this Lyle's flying fox *Pteropus lyeli* colony in Phnom Penh city in Cambodia. Photo credit: K. Yoganand.

The black flying fox, a nomadic nectareous bat species, is a reservoir host of Hendra virus–a henipavirus (family Paramyxoviridae) that has a 57% fatality rate in humans and 75% fatality rate in horses (Figure 2-14). If infected bats feed in trees within horse paddocks, and contaminate the grass with urine, horses that consume or sniff the grass can become infected and serve as a bridging host for the virus to infect humans (Field et al., 2012; Plowright et al., 2015).

Like any other nectivore, black flying foxes depend on having a constant supply of food, and as a result, historically, they moved nomadically from site-to-site to feed on nectar from ephemeral blossoming events in native forests. There are extensive feeding habitats that provide nectar for bats in the summer, but few trees provide nectar in the wintertime and these trees have been selectively cleared for agriculture and development. The lack of food during the cold seasons drives an ecological shift in bats' behaviour: bats move into agricultural and urban areas to find food from weedy or ornamental trees planted by humans, including from trees in horse paddocks (Eby et al., 2023).

Viral shedding is more likely to occur from bats in these new overwintering habitats compared to bats in their historic winter habitats (Becker and Banerjee, 2023). However, after an El Niño-driven shortage, all bats are likely to be shedding the virus, especially the bats in novel overwintering habitats that are also feeding in proximity to horses. These bats are probably shedding more viruses because they are nutritionally stressed. However, if there is a native forest flowering event in winter, the bats will move away from areas with horses and no spillover event will occur (Eby et al., 2023).

The risk of spillover is the highest after long periods of food shortage when there's no flowering event during the winter seasons. If there's a flowering event during winter or there are no food shortages, there's very little risk of spillover. An ecological intervention to stop the spillover of Hendra (countermeasure) is replanting winter flowering trees (Eby et al., 2023).

General concepts that can be applied to other viruses:

- Two events aligning at the same time, the allocation of animals into novel habitats and the stress that drives pathogen shedding are important for driving spillover.
- An easy countermeasure is to replant the habitats that provide food at periods of high energy demand or resource bottlenecks.

Case Example 2-2: Nipah virus outbreak in Malaysia and Singapore (1998-1999)

Nipah virus (NiV) emerged in Malaysia in 1998 during an outbreak in commercially farmed pigs, most likely after viral spillover from the large flying foxes (*Pteropus vampyrus*; Figure 2-15) (Looi and Chua, 2007). The intensification of both the pig and mango industries in Malaysia likely enabled the conditions for spillover (Pulliam et al., 2012). At the time of spillover, the pig population on the index farm was ~ 30,000 animals. Moreover, mangoes, jackfruit, and durian were grown on the farm and several mango trees were close to pig enclosures (Pulliam et al., 2012).

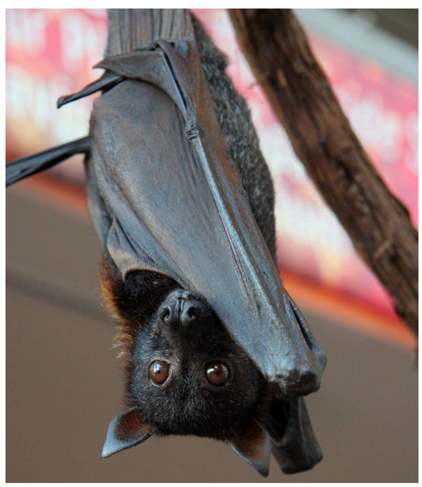


FIGURE 2-15 Flying fox. Photo credit: Flickr

The virus was probably introduced into the pig population by infected flying foxes dropping partially consumed fruit into the pig enclosure. Bat saliva or urine containing Nipah virus may have been consumed by the pigs. Modelling studies suggest that the virus was introduced multiple times. At first, the virus may have caused an explosive but short epidemic in which it burned through the susceptible pig population and then went extinct. However, multiple reintroductions into the partially immune pig population allowed the virus to maintain slower chains of transmission that allowed viral persistence until the farm was depopulated in 1999 (Pulliam et al., 2012). Pigs were the source of infection for farmers and abattoir workers, and transportation of pigs across Malaysia and into Singapore resulted in a widespread outbreak of febrile encephalitis (with a reported >250 cases in Malaysia and 11 cases in Singapore) and a fatality rate close to 40% in humans in Malaysia and Singapore (Lo and Rota, 2008). When transporting animals from farms to abattoirs or slaughterhouses, a truck is used for large-scale transportation involving over 100 pigs at a given time at longer distances. Smaller-scale transportation is sometimes performed by individuals with a motorbike. Containment of excreta from the animals (i.e., saliva, faeces, urine, etc.) could happen during the route of transportation from one place to another.

The beginning of the outbreak is correlated with the intensification of pig farming in Malaysia and the spatial overlap of mango and pig production. The bat reservoir hosts had probably been present, and at least periodically infected with the Nipah virus, for a long time before the pig farms were present. The spread of the virus from the index farm is a consequence of the transportation of animals and animal products, the absence of viral surveillance, and the absence of risk assessment control.

The outbreak caused widespread public fear in Malaysia and Singapore and nearly collapsed the billion-dollar pig farm industry. Singapore prohibited pig importation from Malaysia (Looi and Chua, 2007). In Malaysia, the outbreak ceased after the following responses:

- Allowing pig farming only in designated pig farming areas, which have the necessary infrastructure for biosecurity and waste management
- Performed national surveillance and testing of pig populations.
- Movement restrictions of pigs and pork (local, intrastate and interstate), with compensation for the loss of pigs
- Culling of pigs within infected areas, which can include infected or uninfected farms within a 10km radius of the outbreak
- Spatial separation of wildlife resources from livestock production facilities e.g. removal of fruit trees around farms.
- Some additional solutions include:
- Training of farmers in early detection of disease and reporting, good hygiene practices, and management of sick animals (Looi and Chua, 2007).
- Enhance training and increased use of personal protective equipment by farm and abattoir workers.
- It was also found out that non-accredited farms sold Malaysian pigs to accredited farms, and the virus slipped through into Singapore. Thereafter, Singapore strengthened its accreditation process and implemented zoning and compartmentalization policies to improve the safety of the imported food supply.

Like the Nipah virus case study, poultry farms with intensive breeding for meat or eggs are often in open farming settings. A truck can carry 100 to 1,000 chickens and travel long distances. In some villages, the seller is carrying a few chickens via motorbike and traveling to nearby villages to sell. The excreta of the animal and the diseases they harbour can be carried from one place to another. Moreover, there is usually very little biosafety practice when processing the meat.

Reduce persistence and amplification of a pathogen once it enters the wildlife trade

Once a pathogen enters the wildlife trade, efforts need to be made to reduce the probability that the pathogen will persist and be amplified through animal-to-animal transmission. The persistence of a virus in any population is influenced by multiple variables related to the biology of the pathogen, including the route of transmission, survival outside of the host, infectious period, transmission rate, generation time, host range, and whether the virus causes lasting immunity in its host. Also critical to persistence are the attributes of the host population, including size, structure, and turnover. Essentially the viral characteristics interact with host characteristics to determine if the virus can maintain a chain of transmission through time and space, and therefore potentially spread throughout populations from facility to facility and even across borders. A pathogen with a short infectious period, high transmission rate, fast generation time, and generating lasting immunity in its hosts, might quickly burn through a population of susceptible animals before it can be passed onto another facility with naive animals (as probably occurred the first time Nipah virus was introduced into a pig farm (Pulliam et al., 2012). A pathogen with a long infectious period but a low transmission rate might persist for a long time in a population if there is a turnover of susceptible hosts through periodic introductions into the population (Plowright et al., 2019). For example, feline enteric coronavirus in domestic cats was predicted to become persistent in catteries that contained over five animals, but smaller catteries would become reinfected by larger catteries (Foley et al., 1999). Many pathogens are expected to have a threshold population size which is basically determined by the ratio of the infectious and recovery rates (Drake et al., 2019).

Within the live animal supply chain, it may be possible to reduce the likelihood of a pathogen persisting by altering the population structure of animals within trade, reducing the population size of hosts, fragmenting the population into smaller subgroups, and reducing connectivity among these groups to break chains of transmission. For example, routine depopulation of poultry (24-hour closure and disinfection) in several Chinese and Hong Kong markets broke the chains of transmission of avian influenza, reduced the prevalence of environmental detection of this virus and may have reduced the number of suspect or confirmed human cases (El-Zoghby et al., 2013; Offeddu et al., 2016). The frequency of such 'rest days' may be important, particularly to reduce risk for human exposure, given that many studies identified re-contamination within days of market re-open, which suggests that the use of rest days monthly or less frequently is unlikely to have a strong impact (Offeddu et al., 2016). Another strategy is to eliminate residential animals, which can serve as reservoirs for exposure of new animals entering the market, e.g., through bans on overnight housing of animals (Offeddu et al., 2016). Lastly, husbandry practices could also help to mitigate captivity-induced stress and isolate species, populations, or individuals from each other (Lin et al., 2021). 'Module 5: How to Design and Conduct Risk-Based Surveillance for Zoonotic Diseases at the Human-Animal Interface' will delve deeper into the critical role of animal surveillance and veterinary services in monitoring known zoonotic pathogens.

Case Study 2-3: Transmission risk increases along wildlife supply chains in Vietnam

FIGURE 2-16 Rat slaughter at a large market (left) and a rat vendor stall displaying live rats in cages in a large market (right) in Dong Thap Province, Vietnam, in October 2013. Source: Huong et al., 2020. Photo credit: WCS Viet Nam.

In the early 2000s, the live rat trade in the Mekong Delta region was valued at about $2 million, producing up to 3,600 tons of live rats per year for human consumption (Van Cuong et al., 2015; Huong et al., 2020). In 2013-2014 researchers sampled and PCR tested rats at different points in the value chain for the presence of coronaviruses in three southern provinces in Vietnam. Coronavirus detection increased along the supply chain from those sold by traders (~20%) to those sold in large markets (32%) to those sold and being served in restaurants (~55%). This indicates a 10-fold increase in virus levels when compared to free-ranging rodents and further dramatic amplification of viral load in the environment that is consistent with other classic models of amplification. The authors explain that high viral levels and amplification are likely a result of admixing five rat species, overcrowding and subsequent stress, close contact, and low biosafety (Figures 2-16 and 2-17). The high viral load also increases opportunities for viral recombination, when separate viruses infect one cell and mix and match genetic components (Huong et al., 2020). Additional information can be found in the case study in 'Module 3: Efforts to Prevent Transboundary Disease Outbreaks in the Southeast Asia Region.'

FIGURE 2-17 Rodents are being traded at the Cambodia and Vietnam border, Kandal Province in Cambodia. Source: Virology unit, IPC (Predict II project). Photo credit: Vibol Hul.

Control the pathogen contaminating the environment (reduce pathogen load and indirect transmission routes)

The role and relative importance of the environment as a route of transmission or reservoir for pathogens will vary by pathogen, environmental, and host factors. Specifically, pathogen factors include the ability to persist in the environment, and certain pathogens (e.g., parasite eggs, Gram-positive bacteria, and anthrax spores) have physical barriers that potentiate longer-term survival. Nonetheless, even enveloped viruses and Gram-negative bacteria can survive for days, and sometimes longer, given suitable conditions of moisture (including humidity) and protection from inactivation (e.g., from UV light and chemicals) by organic material or other natural or built environment factors. For example, some pathogens might remain viable in a dark, moist cave environment than they would in a sunny environment or where they would be subjected to desiccation by air movement. Host factors include behaviours that influence the route of exposure, and physiological factors and co-morbidities that influence both susceptibility (how likely the host is to become infected) and pathogen shedding (how much and for how long the host sheds infectious pathogens).

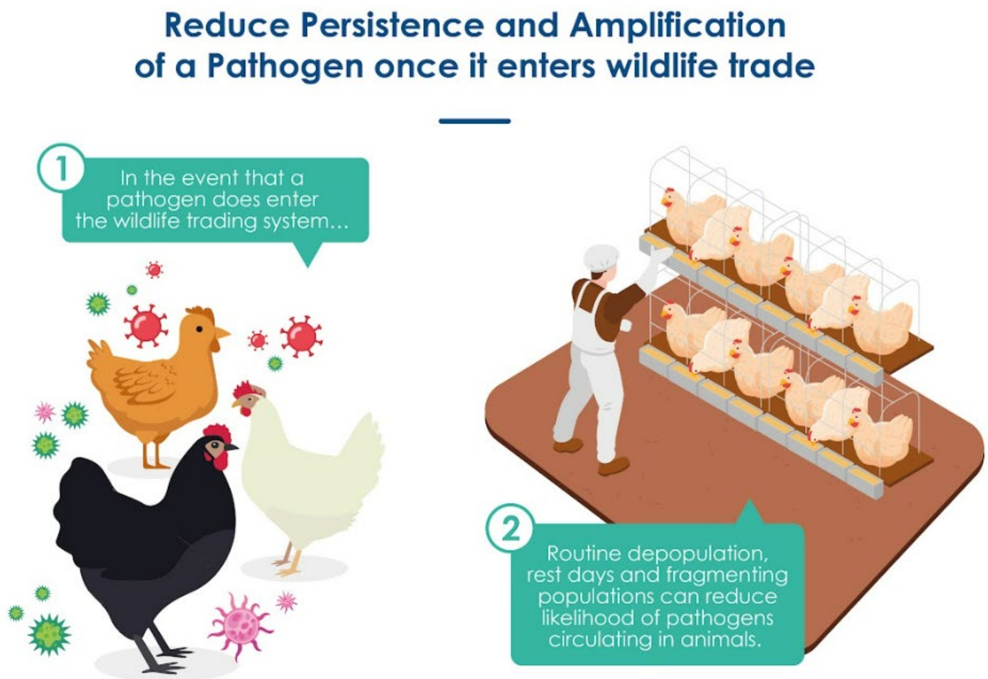


FIGURE 2-18 In the event of pathogen entry into animal trading systems, decontamination of buildings and animal housing is crucial.

Therefore, control strategies to address indirect transmission routes through the environment or limit the persistence of environmental reservoirs of pathogens need to be informed by the specific pathogen characteristics that would enhance their survival and can address environmental and host factors suitable for intervention. These should address all environmental media: water, air, food or feed, and soil, dust, and surfaces. There are standard and codified practices to minimise pathogen loads in animal production systems. Minimum practices should foster biosecurity and hygiene standards, along the entire value chain and follow standard food safety regulations, as outlined in FAO's Biosecurity and Agricultural Management Act of 2007. Depopulation, vaccination, and market-rest days are additional interventions used to reduce pathogen load in livestock and trade-related facilities (Figure 2-18). Attention to sources of feed for the animals also is important, given the potential for live animals or animal products used to feed market animals to be a source of introduction of zoonotic pathogens, or for pest animals to contaminate grains and other feed products. Risk factors, e.g., increased interspecies mixing of live animals, with increased animal densities can heighten risks (Lin et al., 2021; Woo et al., 2006). Conditions in the trade should minimise stress and contact (Figure 2-19). Additionally, animal slaughtering locations for livestock and wildlife within markets should be kept separate. While these efforts may reduce some risks, shifting national and global food systems away from livestock-sourced foods is another strategy to reduce global pathogen loads with potential climate, biodiversity, and health co-benefits (Kaczensky, 2023; Ramey et al., 2022; Wegner et al., 2022).

FIGURE 2-19 November 2016 photo from a pig farm in China, demonstrating the ease in which passerine birds, rodents, and other mammals can mix with the pigs and share viruses. Also, insects can move swine secretions between barns. Modern swine husbandry calls for better isolation of the pigs. Photo credit: Gregory Gray.

Decontamination

The first principle of decontamination is the removal of faecal and other organic material that might serve to protect pathogens from chemical or physical agents meant to inhibit or inactivate them. Water safety, sanitation, and hygiene best practices provide the foundation for this work—attention to clean water sources, water treatment, management of human and animal faeces through latrines and waste/wastewater treatment facilities, and routine cleaning of surfaces. Treatment by chemical (e.g., disinfectant) or physical (e.g., UV light) processes may be indicated, depending on the pathogen, and attention to the potential for some pathogen strains to be resistant to disinfectants and chemotherapeutics may also need to be considered. The frequency of cleaning and treatment of the environment is a final factor, related both to the speed and degree of re-contamination and to the frequency of use of the environment by susceptible hosts. In this, some understanding of the inoculation dose needed to infect a host—literally the number of bacteria, virions, or parasite eggs, which will vary by pathogen—can help drive decisions regarding the frequency of decontamination that is needed. Even simple provision of a sufficient number of hand-washing stations in suitable areas can be an important part of decontamination strategies.

Administrative controls

Buildings, where animals are housed, transported, slaughtered, or their products processed, may benefit from the use of administrative controls, which are policies or procedures for when, how, and where to perform certain tasks. These controls were originally designed for occupational health uses to reduce worker exposures to hazards and can be used to reduce both human and animal exposures and to limit environmental contamination by zoonotic pathogens.

Decontamination activities may be part of administrative controls that also include isolation of certain activities or segregation of personnel according to job task, workflow procedures (doing task A before task B), and movement controls (single direction rather than bidirectional movement of people or animals through a space or building). Administrative controls often must be tailored to the pathogen(s) in question, to the task, and to the facility. For example, this could include restricting high-contamination activities to a part of a building with better ventilation or sewage. Locations for animal slaughtering within markets can be kept separate. Another example of an administrative control focused on animal populations would be all in – all out strategies, whether these are applied at the food animal production level or the animal market level, allowing the environment to be fully cleaned and decontaminated prior to re-population or the next market event (rest days and overnight bans). Allowing even a few resident animals (including pests such as rats and mice) or failure to decontaminate between cohorts or market days may allow for some pathogens to persist over time, and even provide selective pressure to drive survival of pathogens of concern that can infect multiple species of hosts or survive better in environmental conditions.

FIGURE 2-20 Photo illustrating wastewater management system in a traditional market in Bangkok, Thailand in 2022. Note the presence of standing water, which contributes moisture that can enhance virus and Gram-negative bacterial survival, and ad hoc modification of water discharge systems, which could create further opportunities for the persistence of pathogens in engineered spaces that would not be in contact with surface disinfectant. Also note the chair, which could signal the potential for human-environment interaction with this location. Photo credit: Meghan Davis.

Engineering controls

Where resources allow, modification of buildings or other facilities can be an effective strategy to reduce exposure and prevent environmental persistence of pathogens. For example, laboratories with biosafety level 2 or 3 designation (BSL 2, BSL 3) have varying requirements for ventilation, including negative pressure cabinets or spaces, air, and water filtration systems to prevent pathogen escape, non-porous surfaces well suited to chemical and physical decontamination, and other engineering measures, such as built-in UV lights, to allow for routine or periodic surface treatment. While modifying animal markets or processing facilities to comply with BSL specifications is likely to be resource-intensive to be feasible or practical, a combination of targeted engineering controls—ventilation, water systems, wastewater, and waste management systems—with administrative controls can be a more cost-effective way to target interventions to high-risk activities or environments (Figure 2-20). For example, if there is a procedure that tends to produce droplets or aerosols where there is a concern for airborne pathogens, installation, or upgrade of ventilation systems in that location, or movement of that activity to an area with better ventilation, would be important to consider. Facility installation or upgrade should also consider principles of biosecurity and biocontainment.

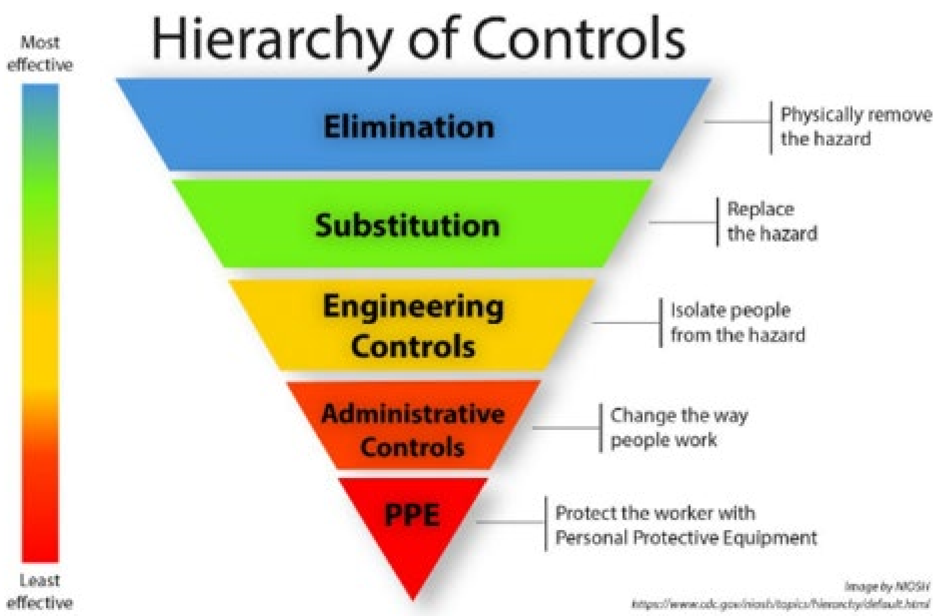


FIGURE 2-21 Hierarchy of controls for reducing pathogen contamination in the environment, demonstrating that measures to eliminate, substitute, or provide engineering controls for a hazard are more effective than administrative controls and use of personal protective equipment, e.g., masks, gloves, and boots. Source: U.S. National Institute of Occupational Safety and Health.

In occupational health, engineering and administrative controls are considered more effective than use of personal protective equipment (PPE) by workers to limit exposures, but typically, organizational policies and decisions often include control measures at all three of the levels in the Hierarchy of Controls (Figure 2-21). Consultation with occupational safety and health professionals, including occupational medicine or nursing practitioners and industrial hygienists, can be useful during facility design and during the development of policies and procedures in this context.

Interspecies Interactions: Ways to Reduce Animal and Human Behaviours that Increase Exposure Throughout the Supply Chain

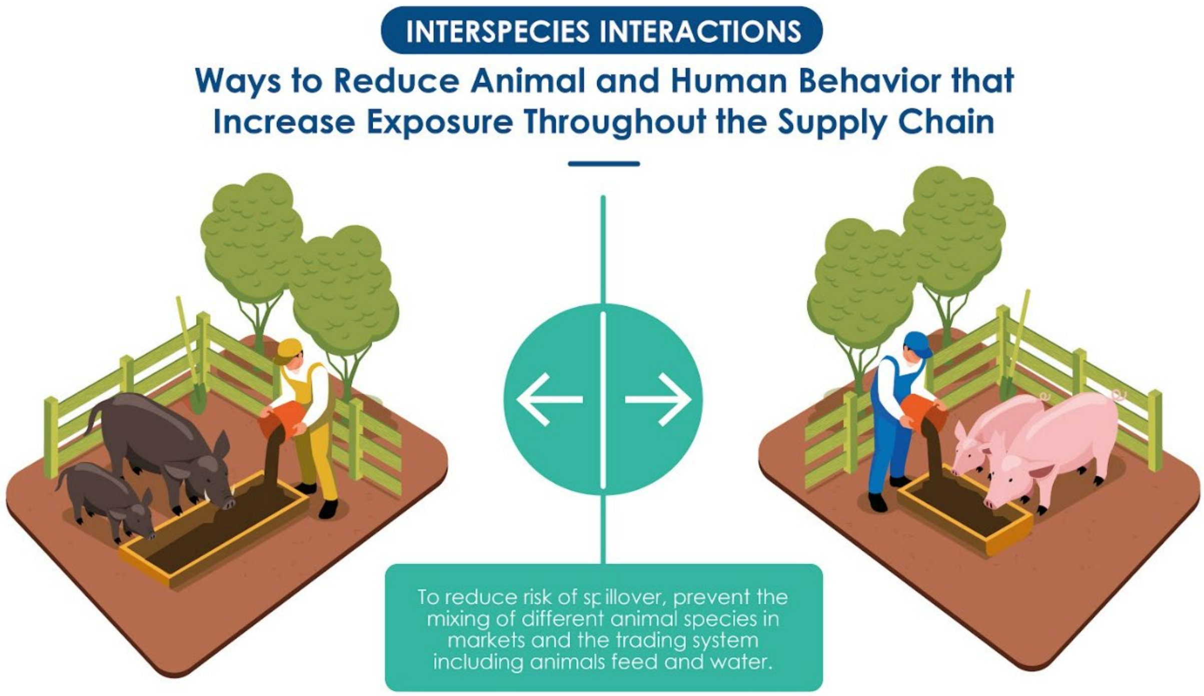


FIGURE 2-22 To reduce the risk of spillover, it is imperative to prevent the mixing of different animal species in markets and trading systems, including during water and feed.

Reducing interactions between animals and humans throughout the live animal supply chain is crucial in minimising the potential for zoonotic disease transmission. Factors that are prominent in Southeast Asia that bring together naive hosts with pathogens include deforestation, fragmentation of natural habitats, agricultural intensification, crowding, urbanisation, globalization, and rising human populations. The growing population also has increased demand for animal-sourced food, which is driven by increasing population, urbanisation, and wealth (Hatab et al., 2019). There are challenges associated with meeting this demand, especially in countries that lack the proper infrastructure. In areas where people prefer live animals and fresh meat, oftentimes the animals are moved from rural to urban areas or from urban to peri-urban farms. And yet, despite the increasing affordability of refrigeration, the demand for live animals or fresh meat in traditional markets persists. Many people believe fresh meat is safer, and tastier (Roesel and Grace, 2015). Risks posed by traditional markets to human health, in the context of emerging infectious diseases, include the presence of high-disease-risk taxa and live animals (both domesticated and wild), unsanitary conditions, large and dense markets, increased interspecies mixing and animal densities, and multinational animal sourcing as well as lengthy supply chains (Galindo-González, 2022) (Figure 2-22). There are various strategies that can be implemented to address behaviours that increase exposure, and they should target the different stages of the supply chain, from wildlife collection to transportation, market handling, and consumption (Figures 2-8 and 2-9). For more information, refer to 'Module 6: Strategies to Engage with Diverse Stakeholders Across Key Points in the Live Animal Value Chain.'

Implementing Regulations and Enforcement Measures to Restrict Wild Animal Sales in Live Animal Markets

Certain animal taxa such as rodents, bats, primates, carnivores, and ungulates might have elevated zoonotic spillover potential. More information on this can be found in 'Module 4: How to Identify and Characterize Priority Pathogens to Guide Efforts to Address Zoonotic Disease Spillover?' Additionally, the presence and sale of live animals in traditional markets creates an elevated risk of viral pathogen transmission; mixing of live animals (interspecies and intraspecies) in both storage and slaughter areas can facilitate pathogen shedding and viral recombination in new hosts (Galindo-González, 2022; Woo et al., 2006). For example, new strains of influenza A virus can emerge when two circulating subtypes infect one cell in an organism; this is the case when a circulating human subtype encounters a circulating poultry subtype (Figure 2-23) (Koçer et al., 2014).

FIGURE 2-23 Live animal markets with multiple species in close proximity. Photo credit: Gregory Gray.

Therefore, a major risk factor for infectious diseases includes visiting or mixing animals in live poultry markets (Aguirre et al., 2020). This is true also for swine influenza variant virus, while infrequent in humans, infections occur due to exposure to infected pigs in live markets, as indicated in cases in the US (Galindo-González, 2022). For instance, housing domestic pigs within or in close proximity to wild boar habitats, using different feed sources for domestic pigs than those foraged by wild boars, separating slaughter areas, and preventing the cross-breeding between wild boars and free-ranging domestic animals can help to lessen the occurrence of both direct and indirect interactions between wild and domestic pigs, which could facilitate viral spillover of African Swine Fever (ASF) (Denstedt et al., 2021). These mechanisms are discussed in further detail in 'Module 3: Efforts to Prevent Transboundary Disease Outbreaks in the Southeast Asia Region.' Additional factors can also impact immune system responses and raise the transmission of disease: heightened stress levels of captive animals due to high-density confinement, new environments, and unfamiliar interspecies contact; caged animals are commonly injured and have open wounds, which facilitates the transmission of pathogens (Galindo-González, 2022). One major risk factor in the 1997 H5N1 outbreak in Hong Kong was exposure to live poultry in the marketplace (Wan et al., 2011).

Improve Hygiene Standards and Sanitation in Live Traditional Markets to Reduce the Risk of Zoonotic Disease Transmission

Lack of good hygiene is a major risk factor for human health in traditional markets, both through limited or unenforced biosecurity controls in markets themselves and through hygiene risks that magnify along supply chains. Lapses in hygienic practices in traditional markets without live animals, have been linked to bacterial and parasitic infections, through various means including improper handling or storage of carcasses, polluted water, or proximity to other contaminants, improper waste disposal and inadequate sanitation measures (Lin et al., 2021; Lo et al., 2019; Woo et al., 2006). To mitigate these risks, proper sanitation practices, vendor handwashing, routine cleaning practices, separation of different species, and quarantine protocols can help contain potential pathogens and reduce the risk of cross-species transmission. Enhancing the traceability and labelling of wildlife products also plays a vital role. Implementing tracking systems that can certify the origin of traded species can promote transparency, while ensuring the legality of the supply chain, and inform consumers about potential risks associated with certain products (Campbell et al., 2022).

Redesign market infrastructure and layout to decrease disease transmission from high-population-dense structures, stacked cages, and mixing of different animal species

Many traditional markets are characterized by high population density, with vendors, buyers, and animals in proximity. Such crowded conditions create an environment conducive to disease transmission, as respiratory droplets, animal faeces, and other bodily fluids from animals can easily spread. Additionally, stacked cages, commonly used in some traditional markets, can facilitate the proximity of different animal species, increasing risk (Figures 2-24 and 2-25). When animals are housed in vertically stacked cages, their bodily fluids or waste can easily encounter animals housed in neighbouring cages, allowing pathogens to easily spread (Galindo-González, 2022).

To mitigate these risks, consider redesigning the infrastructure and layout of wet markets to ensure adequate spacing between animal stalls, adopt cage-free or open-air enclosures, or implement physical barriers to prevent direct contact between animals.

Additional recommendations include:

- Implement crowd management protocols to promote physical distancing among visitors, vendors, and animals. Examples include controlling the number of customers allowed in the market at a given time.
- Provide adequate ventilation and proper airflow within market structures to help disperse and dilute the buildup of airborne pathogens. Additional information on this can be found in 'Module 3: Efforts to Combat Transboundary Disease Outbreaks in the Southeast Asia Region.'
- Within live market settings, physically separate areas for slaughter and carcass processing from retail areas where customers interact.

Additionally, the consumption of meat from wild animals facilitates spillover, by putting humans in close contact with fresh meat, offal, and animal blood that can host different pathogens. Although there are trade-offs where reduced consumption of wild meat could lead to enhanced risk from intensively raised domestic animals, promoting and stimulating sustainable and legal alternatives, such as captive breeding programs or domesticated species, can reduce the pressure on wildlife populations, and demand for wild-caught animals and minimise interactions between humans and wildlife animals. This could subsequently be shared as best practices.

FIGURE 2-24 (Left) Examples of stacked cages in a rat market in Dong Thap Province, Vietnam. Photo credit: WCS Vietnam. (Right) Examples of stacked cages with various wild and domestic bird and mammal species being sold in a pet market in Vientiane, the capital city of Laos. Photo credit: K. Yoganand.

FIGURE 2-25 Hunted wild animals, including carnivores and rodents being sold for meat in a traditional fresh market in Laos. Photo credit: WCS Lao PDR.

Other complex factors such as awareness of disease risk, direct imposition of national animal health regulations, and societal expectations can impact these processes as well (Hidano et al., 2018; Verelst et al., 2016). To manage diseases shared with wildlife requires strategic development that reduces pathogen transmission between wildlife, domestic animals, and humans. In each country and region where outbreaks occur, the control measures should be adjusted to the specific local setting, while considering the population size, farming practices, disease risk factors, and religious and social traditions and beliefs (Box 2-2). These locally specific factors will ultimately determine which measures are feasible and can be realistically implemented. Additional information can be found in 'Module 7: How to Enhance Zoonotic Disease Management by Addressing Knowledge Gaps and Implementation Barriers.'

BOX 2-2
Emerging Threat: *Streptococcus suis* Transmission from Pigs to Humans

Streptococcus suis is a pathogen commonly found in pigs that causes severe systemic illness in people if consumed, causing certain clinical conditions such as meningitis, septicaemia, and arthritis. The number of reported cases in humans has significantly increased in Southeast Asia, and it is typically seen as an occupational hazard involved in pig handling amongst farmers, abattoir workers, and carcass cutters in Western countries, Japan, China, and Hong Kong. Its significance as a foodborne illness in Southeast Asia is important, considering the consumption of meals containing raw pork, blood, and other related products.

Socio-behavioural factors play a role in controlling the disease. For example, a food safety campaign was implemented in the Phayao province in Thailand in 2011-2013, which led to a decreased incidence of human cases (Segura et al., 2020). This includes educational lectures for residents and dissemination of print materials explaining the pathogen, risk behaviours such as the consumption of raw pork products, and major symptoms of the disease, including appropriate culturally sensitive messages targeting at-risk populations such as alcohol drinkers and adult men. As changing consumption practices may be difficult due to strong traditions, practices, and financial implications, risk communication approaches that respect these traditions and engage with community, religious, and social leaders can be effective.

Reduce Probability of Animals in Allostatic Overload Throughout the Supply Chain

1. Reduce susceptibility (i.e., stress, reduce overcrowding, provide adequate nutrition, coinfections)
2. Reduce opportunities for continued exposure.

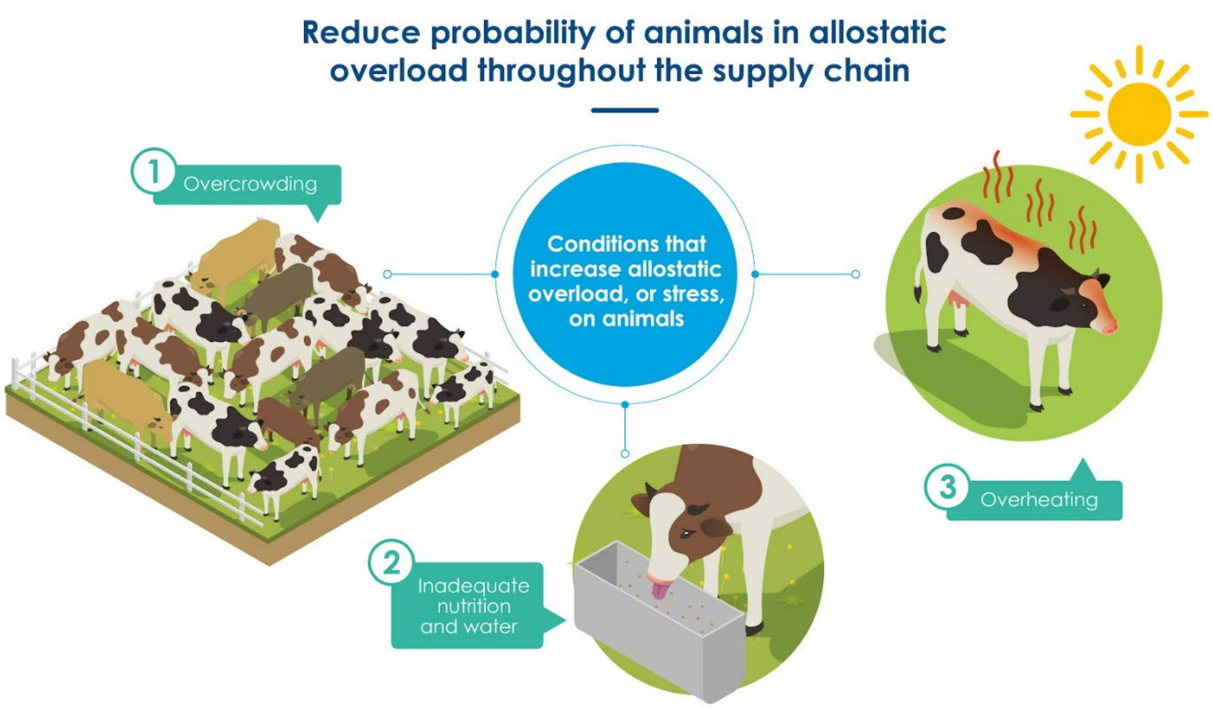


FIGURE 2-26 Conditions that cause allostatic overload, or stress, on animals.

Allostatic load is a measure of the cumulative stress and energy budget of an individual. When energy outputs are higher than energy inputs, or animals are exposed to repeated stressors, then animals can enter allostatic overload (McEwen and Wingfield, 2003). Animals within the wildlife trade are at high risk of allostatic overload through the stress of overcrowding, overheating, noise and other disturbances, and inadequate nutrition or water (Figure 2-26). When animals are in allostatic overload, they shift resources away from immune function and towards life-sustaining functions and can become more susceptible to circulating viruses and more likely to excrete high loads of these viruses (Hing et al., 2017; Plowright et al., 2024).

One intervention to reduce the probability of pathogen infection and shedding, is to reduce the allostatic overload of animals within the wildlife trade. This could be achieved by reducing overcrowding, providing comfortable environmental conditions, and providing adequate calories and nutrients and plentiful water. Such measures not only address the risk of spread of pandemic pathogens but also the basic welfare of the animals in wildlife trade.

Protect Humans at Risk of Infection

FIGURE 2-27 Protective measures to prevent transmission.

The impact of the COVID-19 pandemic on global production and manufacturing demonstrated the need for constant supply of personal protection equipment, particularly for individuals most at-risk (i.e., individuals working alongside the animal market and supply chain). Health and market workers are the first responders to infectious disease outbreaks (Grasselli et al., 2020) and they need PPE products such as face masks, gloves, and protective gowns to prevent direct contact with bodily fluids and contaminated surfaces (Verbeek et al., 2020). These individuals. Concurrently, other people need PPE to protect themselves from contracting or spreading these diseases via face masks and shields. The constant stock of life-saving medical devices such as ventilators and PPE become precious commodities during moments of intense health crisis. In severe cases of COVID-19, patients cannot breathe without the use of a ventilator due to fluid-filled lungs that no longer deliver adequate oxygen (Buheji et al., 2020). Surgical masks and PPE should be selected or based on the route of disease transmission identified for the infectious disease, for example, airborne, contact, or droplet (Figure 2-27). To select proper PPE, designated healthcare personnel should first identify the transmission pathway of the disease and work to anticipate the exposures that will occur during patient care. The National Institute for Occupational Safety and Health has created the PPE-Info database, which includes descriptions of test methods, regulations, and consensus standards for PPE across various workplace hazards (Sieber et al., 1996).

More recommendations for identifying the proper PPE include: (1) job hazard analysis, (2) infectious disease hazard analysis, (3) PPE selection, and (4) PPE evaluation (Jones et al., 2020). The use of PPE and adoption of standard hygienic practices among health workers should be encouraged. Supply of protective materials and equipment should be improved. Another important strategy is vaccination, which can protect individuals from specific infectious diseases and reduce disease spread. Additionally, measures to reduce aerosol exposure, such as improving ventilation and installing air filtration systems, can help prevent airborne disease transmission (Horwood et al., 2023). Education and awareness campaigns are also crucial in promoting good hygiene practices, such as handwashing. Overall, a comprehensive, One Health approach involving both individuals and community-level interventions is necessary to protect individuals at risk of emerging infectious diseases.

Quick Detection of Spillovers upon Entering Human Populations: Monitoring and Surveillance of People at Risk

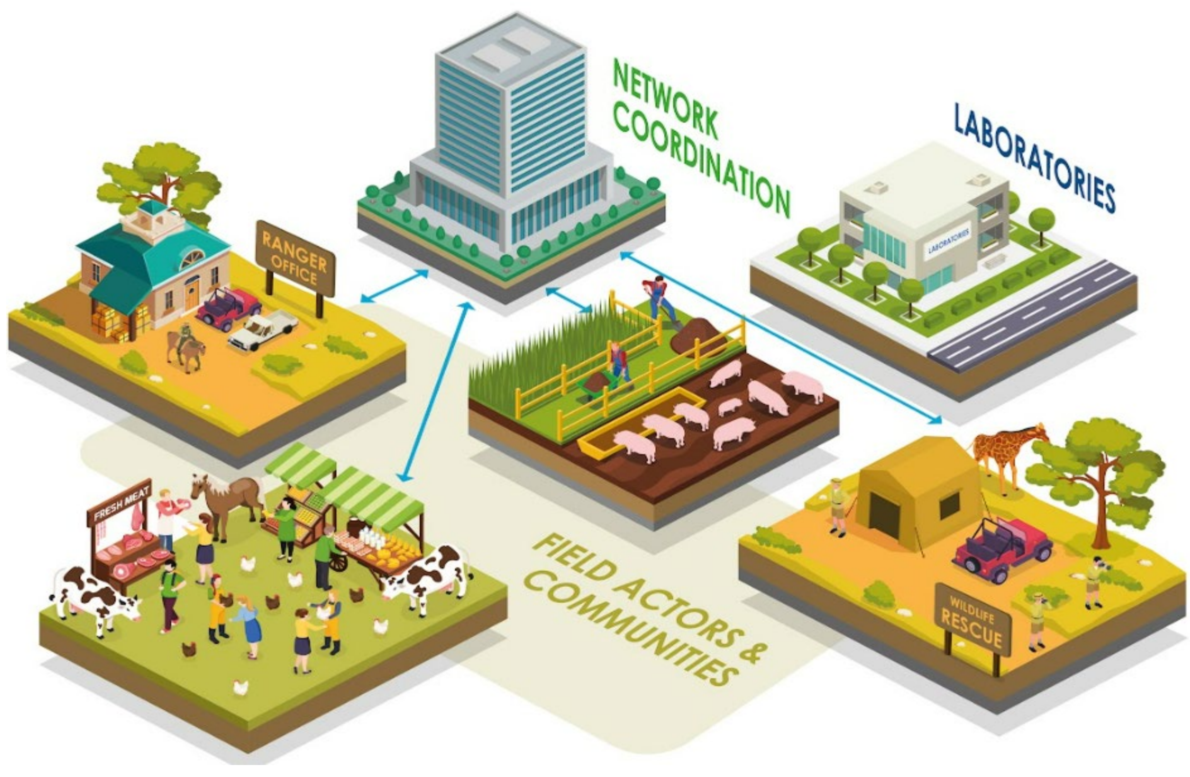


FIGURE 2-28 Detecting microbe spillover when entering human populations: monitoring and surveillance of people at risk.

Two of the greatest barriers in establishing effective and sustainable microbe spillover surveillance are cost and effort. There is just not enough money or detection capability available to conduct surveillance for the millions of animal microbe spillovers in all sites where spillovers could infect humans. There are too many animal species and unique animal microbes in diverse geographical areas. Additionally, field workers and laboratories capable of conducting such spillover surveillance are relatively few. To illustrate, it has been estimated that the earth currently has 6,399 unique species of mammals which, in total, harbour ~40,000 unique species of viruses (Carlson et al., 2019a). A large portion of animal microbes have yet to be characterized, so tools to detect them do not exist. In a 2018 study, Carroll et al. (2018) estimated that there were 1.67 million not-previously-discovered viruses in mammal and bird hosts.

Hence, a data reduction strategy is needed to make such spillover surveillance possible and sustainable. If we embrace the statistic that 60% of human infections have an animal origin, and of these 75% are zoonotic in nature, it seems logical to conduct spillover surveillance where large populations of animals come in close and frequent contact with humans (Jones et al., 2008). Several scientists are embracing the notion that the most efficient approach is to conduct spillover surveillance at specific human-animal interfaces (Gray et al., 2021; Wille et al., 2021).

If spillover surveillance cannot be conducted at the human-animal interface as described above, a secondary strategy might be to conduct surveillance for disease syndromes of most concern in geographical areas known to have previously been the site of novel human pathogen emergence. For instance, if one is concerned about pneumonias caused by novel zoonotic respiratory viruses, one might perform periodic novel viral pathogen detection studies among patients hospitalized with pneumonia in geographic emerging infection disease hotspots (Gray et al., 2021; Xiu et al., 2020). Another strategy is to focus surveillance on high-risk interfaces, where wildlife is coming into frequent and recurrent contact with people or their livestock, such as live mammals and bird markets, extractive industries, and areas of land-use change (Huong et al., 2020). More information on this can be found in 'Module 5: How to Design and Conduct Risk-Based Surveillance for Zoonotic Diseases at the Human-Animal Interface.'

One can further reduce the scope of spillover surveillance by focusing on pathogen families known to have high spillover potential, particularly when these spillovers have caused epidemics. One might additionally reduce the scope of spillover surveillance by focusing on species of animals that are prone to novel virus generation within those families. For instance, for multiple reasons, pigs (*Sus domesticus*) have previously been prone to novel influenza A virus and novel coronavirus generation so focusing a portion of spillover surveillance on large pig farms seems appropriate if one is concerned about these microbes (Morse et al., 2012; Wardeh et al., 2021; Webster et al., 1997). Additionally, some animal species seem to have lower species barriers for sharing specific microbes with humans. This is true again for pigs and influenza A (Borkenhagen et al., 2019). Finally, one may further reduce the effort required for spillover pathogen surveillance by employing relatively cost-effective, pan-species diagnostics. Serological assays are useful as they can detect host exposure to a pathogen within a period of months to years, whereas active infections may only be detectable over days or weeks. Other pan-species assays can detect different species within a microbial family and are particularly effective in detecting and characterizing new microbial variants (Vlasova et al., 2022; Xiu et al., 2020). These pan-species assays might be supplemented with periodic, unbiased, next-generation sequencing assays and novel pathogen discovery software pipelines, when targeting molecular assays might miss spillover of an unexpected microbial group (Ramesh et al., 2021). More information on this can be found in 'Module 4: How to Identify and Characterize Priority Pathogens to Guide Efforts to Address Zoonotic Disease Spillover?'

System-Level / Governance Changes (e.g., Regional and National Strategic Plans)

The Association of Southeast Asian Nations (ASEAN) recognizes the obstacles facing the veterinary and animal health community in Southeast Asia. The ASEAN Strategy for Exotic, Emerging, Re-emerging Diseases and Animal Health Emergencies was agreed in May 2021 (ASEAN, 2021), which sought to provide a regional framework for animal health and zoonosis. The ASEAN Coordinating Centre for Animal Health and Zoonoses (ACCAHZ) was initiated in 2012 to facilitate and provide a framework for cooperation and coordination amongst ASEAN member states in response to an increasing risk of introduction and spread of emerging and re-emerging zoonotic diseases. This was formally agreed by the ASEAN Member Countries in 2016, and the agreement entered into force in September 2021, reinforcing the region's commitment to combat the threat of zoonotic diseases. Once established, the center is expected to provide policy and technical advisory support to the relevant ASEAN sectoral working groups e.g., ASEAN Sectoral Working Group for Livestock. This sets the stage for the discussion and development of regional implementation mechanisms for animal health emergencies, and regional strategies for the prevention, control, and eradication of transboundary animal diseases and zoonoses.

Other than for livestock, at the Special ASEAN Ministerial Meeting on Illegal Wildlife Trade in 2019, the ASEAN Ministers responsible for CITES and Wildlife Enforcement on Illegal Wildlife Trade have committed to strengthen cooperation to address wildlife trade in ASEAN (USAID, 2019). The ASEAN Centre for Biodiversity, which focuses on the conservation and sustainable use of biological diversity and coordinated efforts amongst ASEAN Member States, has also placed emphasis on this topic amongst its key stakeholders, illuminating the issues between animal and human health, wildlife habitat protection, wildlife trade, using a One Health approach. Multiple global partners have also committed to work with ASEAN Senior Officials. The U.S. Agency for International Development (USAID) supported the convening of the first multisectoral meeting to develop a regional strategy for preventing transmission of zoonotic diseases from wildlife trade. This is led by the ASEAN Working Group on the CITES and Wildlife Enforcement (USAID, 2022). The ASEAN Strategy for Preventing Transmission of Zoonotic Diseases from Wildlife Trade was adopted in 2022 by the ASEAN Senior Officials on Forestry (ASEAN, 2022). Organizations, including WOAH, FAO, and the U.S. Centers for Disease Control and Prevention (CDC) have supported various field epidemiology training programs (FETPs) for veterinarians and animal health officials. The Emergency Centre for Transboundary Animal Diseases (ECTAD) in FAO Regional Office for Asia and the Pacific has been providing support in developing and implementing the Regional Field Epidemiology Training Program for Veterinarians hosted by Thailand (Pinto et al., 2023) that trains new cohorts annually from across the region as well as applied epidemiology training programs for veterinarians in the countries. Field Training Program for Wildlife, Ecosystems, Biodiversity, and Environment is a training program developed by FAO and provides country-adapted training based on the results from the Environment Sector Stakeholder Mapping and Needs Assessment Tool. It is intended to complement FETPs and FETPVs for the wildlife and environment sectors.

Southeast Asia has been a beneficiary of funding from several international partners. For example, with funding from the Australian Government, the FAO is helping ASEAN to strengthen regional mechanisms to address animal and zoonotic diseases with pandemic potential and support in development of ACCAHZ. This is done through an ASEAN-Australia-FAO regional technical assistance project called Strengthening Mechanism in Animal Health for a Resilient ASEAN or (SMART-ASEAN) project.

At the national level, countries in Southeast Asia have undertaken unique measures to prevent zoonotic spillover. For example, Singapore's approach recognizes that people's well-being and health are interconnected with that of animals and wildlife in our community. The country implements several measures to protect animals which in turn safeguard public health. They include biosurveillance initiatives to bolster its pre-border, border, and post-border defences against zoonotic diseases and utilization of complementary animal biosecurity/quarantine and wildlife rehabilitation centres for early disease monitoring and surveillance. Thailand's approach recognizing the endemic, imported, and emerging infectious diseases that threaten its country implemented a National Strategic Plan for Emerging Infectious Diseases. It aims to operationalize One Health policies from integrated human-animal-wildlife surveillance systems to enforcement of Communicable Diseases Law, with coverage of biosecurity and infection control measures in hospitals and zoological parks. Vietnam has developed a One Health Strategic Plan for Zoonotic Diseases, co-developed by the Ministry of Agriculture and Rural Development, together with the Ministry of Health and related ministries and agencies. This approach not only sets out the initiatives to combat disease spillover but also identifies core One Health competencies and gaps in funding or donor support to drive participation or involvement from government and non-government actors.

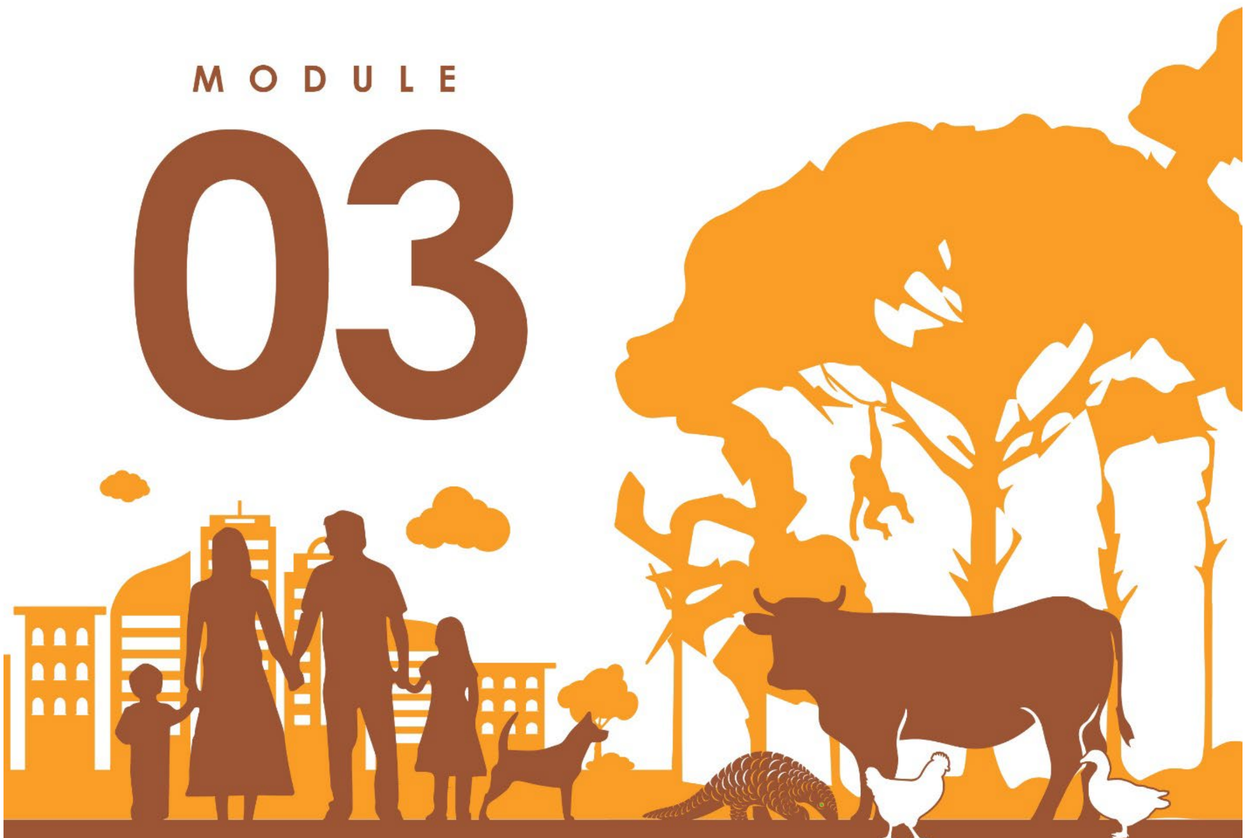
Conclusion

In this module, we presented eight crucial mechanistic steps that shed light on how pandemic pathogens can infiltrate and proliferate within the wildlife trade system. Through a series of key interventions, some theoretical and others drawn from real-life case examples, we have identified potential strategies to disrupt each of these mechanisms, aiming to limit pathogen circulation in the wildlife trading system. Given the challenges posed by global risk drivers such as climate change and urbanisation, and the current trends of population and economic growth in Southeast Asia and identified risks of emerging and re-emerging zoonoses, it is vital not to underestimate the importance of preventing zoonotic spillover.

Many of the strategies in this guidebook will be aimed at underscoring and implementing the One Health concept, recognising the close link between human, animal, and environmental health. By adopting a One Health approach, we can design programs, policies, and initiatives in an interdisciplinary and intersectoral manner, given the complexity of animal supply chains and movements in Southeast Asia, which are directly tied to the livelihoods and aspirations of people. This way, we can effectively minimise the risks of incursion, transmission, and spread of zoonotic pathogens. As we move forward, the fight against zoonotic spillover demands sustained commitment and collaboration from all interested parties.

MODULE

03



Efforts to Prevent Transboundary Disease Outbreaks in the Southeast Asia Region

Co-Authors
K. Yoganand & Dominic Travis

Efforts to Prevent Transboundary Disease Outbreaks in the Southeast Asia Region

INTRODUCTION

Many global agreements and processes have been created to support domestic animal trade and disease risk, while very few exist for wildlife trade. Within the context of zoonotic epidemic prevention, we propose the application of a transboundary approach to address the challenges associated with wildlife and wildlife trade (legal and illegal). This approach presents a unique opportunity to achieve a mutually beneficial outcome: countering biodiversity loss while enhancing disease risk management.

Recognizing that the implementation of control points cannot be achieved by a single discipline, ministry, or agency, we emphasize the need for collaborative efforts across the entire wildlife trade supply chain. To ensure comprehensive risk reduction, it is imperative to develop and implement controls and standards at a systems level. Such an endeavour requires a profound understanding of the system itself, coupled with the establishment of effective partnerships for the implementation of prevention and mitigation strategies.

The problem statement underscores the critical role of biodiversity, encompassing macro- and microorganisms alike, in maintaining the health of ecosystems. However, a significant driver of the extinction crisis is wildlife trade, which not only contributes to biodiversity loss but also disrupts the flow of ecosystem services essential to the well-being of communities in the Southeast Asia region. Moreover, wildlife trade creates favourable conditions for the emergence and transmission of zoonotic diseases, leading to increased risks of epidemics at local, regional, and global levels.

In light of these challenges, it is important to seek solutions that address the interconnected goals of reducing biodiversity loss and sustaining public health. This chapter aims to achieve the following key objectives:

1. Develop a comprehensive understanding of transboundary in the context of One Health and its practical application to zoonotic disease risk reduction.
2. Analyse and highlight existing successful cases of transboundary collaboration within the Southeast Asia region, serving as proof of concept in preventing disease transmission.
3. Conceptualize wildlife trade as a transboundary system in Southeast Asia, exploring efforts to understand and regulate this complex system effectively.
4. Advocate for a transboundary approach to regulating wildlife trade in Southeast Asia, emphasizing its potential to promote public health, conserve biodiversity, and promote ecosystem services for local and global communities.

Throughout this module, we delve into the transboundary dimensions of spillover risk within wildlife trade supply chains, recognizing the complex interdependencies and connections that demand collaborative and coordinated efforts to mitigate the outbreak of transboundary diseases. By examining case examples and analysing existing strategies, we aim to provide insights into the transformative potential of transboundary approaches to counter zoonotic spillover of high-consequence pathogens in the Southeast Asia region.

UNDERSTANDING THE CONCEPT OF TRANSBOUNDARY AND ITS APPLICATION TO DISEASE RISK REDUCTION

The Significance of Transboundary Approaches to Disease Risk Reduction

In the realm of disease risk reduction, One Health approaches allow us to operationalize transboundary solutions to address the complex challenges posed by infectious diseases. These approaches recognize the need for collaborative efforts to counter problems complex or vast enough to cross geopolitical and ecological borders, and encompass the intersection between environmental, human, and animal health. By embracing a transboundary perspective, we can efficiently address and mitigate the risks associated with disease transmission.

The Role of Microbial Diversity in Understanding Transboundary Disease Spread

We live in a world covered by invisible microbes, the diversity of which is difficult to quantify (Achtman and Wagner, 2008). Microbial diversity encompasses a wide range of unicellular organisms, such as bacteria, archaea, protists, and fungi, thriving throughout the biosphere (Figure 3-1). These microorganisms define the limits of life and create conditions conducive to the survival and evolution of all living beings (Dunlap, 2001). This diverse microbial ecosystem provides invaluable benefits to humans known as 'ecosystem services', directly contributing to well-being and sustainability (Natural Capital and Ecosystem Services). Understanding the vast range of microbial diversity is essential not only for comprehending the architecture of ecosystems and their functions, but also to the dynamics of emerging and transboundary diseases (Gibbons and Gilbert, 2015). By exploring the interplay between microbes, hosts, and their environment, we can gain insights into the pathways and mechanisms through which microbes, and thus diseases, exist and spread across boundaries (e.g., species, habitats, built environments, etc.).

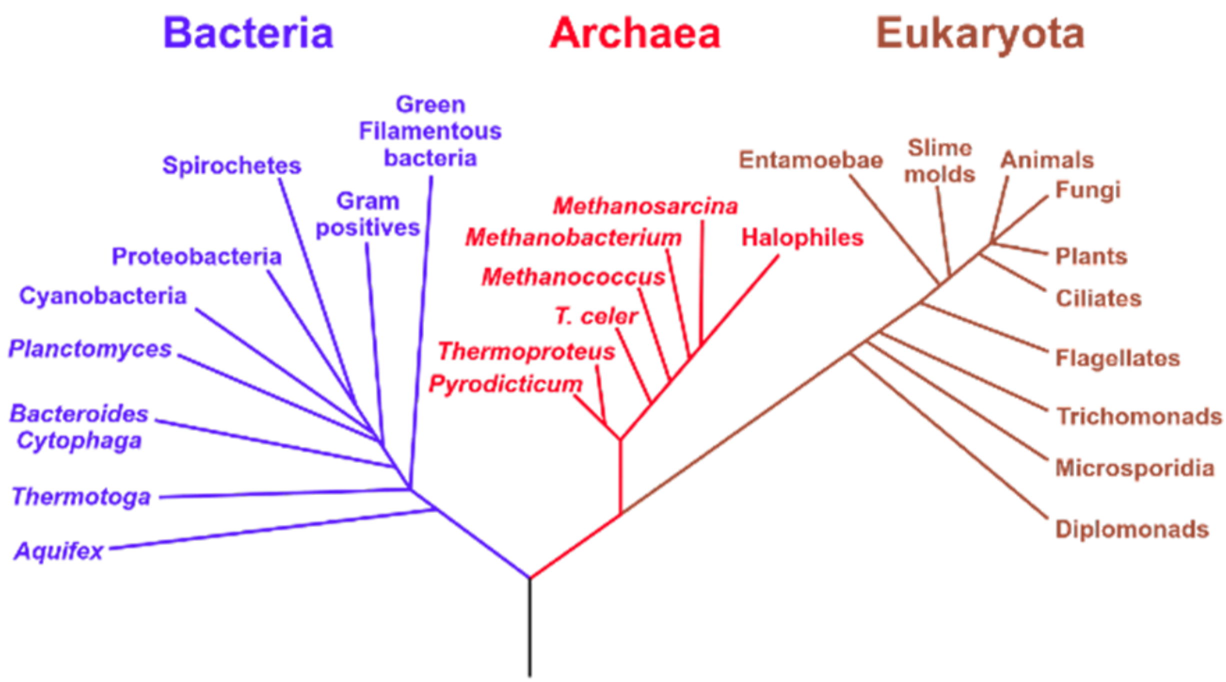


FIGURE 3-1 A phylogenetic tree of living things, based on RNA data, showing the separation of bacteria, archaea, and eukaryotes proposed by Woese et al., 1990. Image modified by Eric Gaba, NASA Astrobiology Institute.

While humans and other mammals harbour immense microbial biodiversity, only a fraction of these microbes cause disease in humans (National Research Council, 2007). According to the Microbiology Society (2013), it is estimated that less than 1% of bacteria cross the human defensive 'boundary' and cause harm. The relationship between host, microbes, and the environment is complex, as depicted by the epidemiological triad concept (Figure 3-2). These intricate systems interactions can result in increased health and vigour (e.g., a healthy microbiome) or lead to disease and pathology. Considering the diversity of potential pathogens and pathways for spread, comprehending the ecology of transboundary diseases becomes a complex task, necessitating the examination of mechanisms at cellular, organismal, and system levels.

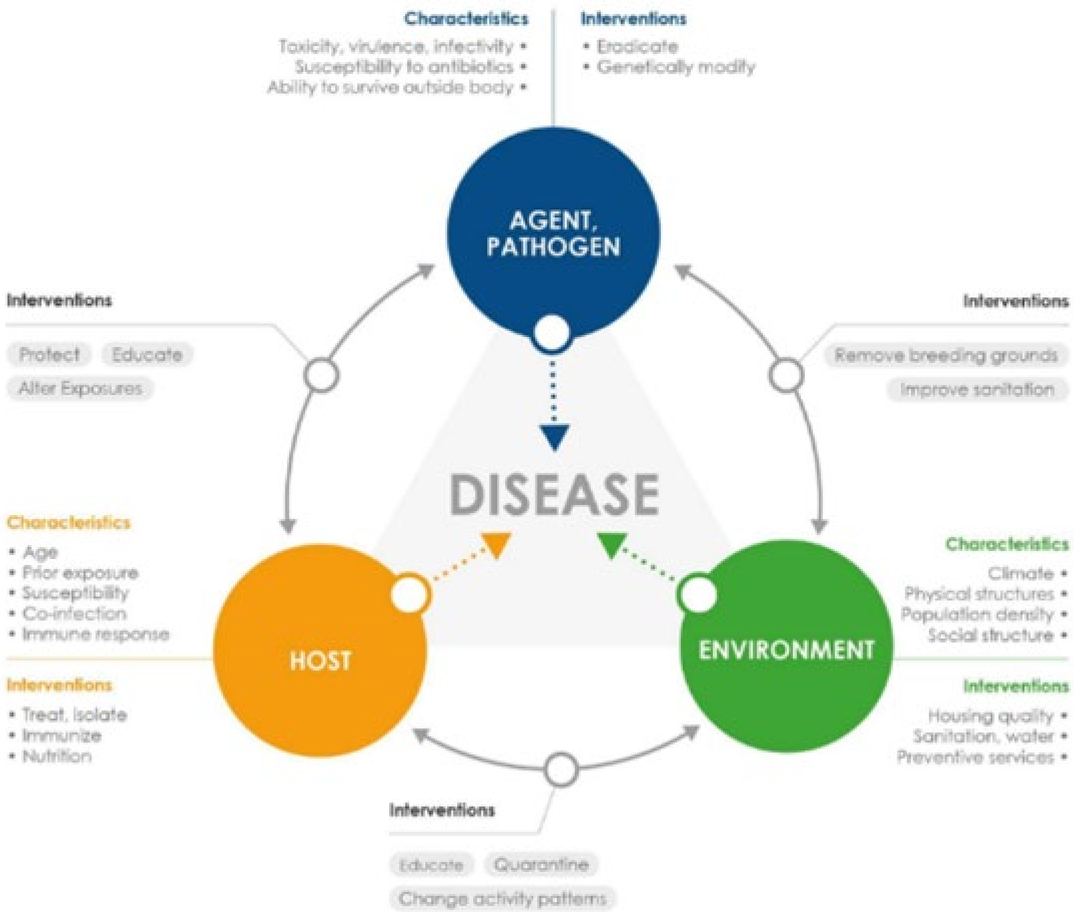


FIGURE 3-2 The complexity of transboundary diseases—understanding the epidemiological triad: host, microbe, and environment. Adapted from McDowell, 2013.

Transboundary Disease Outbreaks: Patterns and Implications

Transboundary disease outbreaks are characterized by highly transmissible infectious diseases capable of rapid spread to new geographical areas (Gongal et al., 2022). Originating in one country, these diseases can cross borders and impact the livelihoods of populations in other countries (Gongal et al., 2022). The focus of the infectious disease 'transboundary community' has been on animal disease emergence, spread, and the resulting economic consequences. Journals such as *Transboundary and Emerging Diseases* are part of a growing wave of publications addressing the diagnosis, prevention, and management of infectious diseases that pose economic threats to animals and humans worldwide. They reflect the increasing recognition of the necessity to approach these issues on a larger, more collective scale, alongside journals dedicated to One Health, ecosystem health, and planetary health.

Integrating Transboundary Approaches into the One Health Framework

Transboundary approaches are essential in addressing the complex challenges posed by infectious diseases and play a significant role in disease risk reduction. The One Health framework embodies the principles of transboundary approaches, by recognizing the nexus between human, animal, and environmental health while promoting integrated efforts to tackle health challenges at the interface. By integrating transboundary approaches within the One Health paradigm, we can foster collaboration, cooperation, and innovative solutions in disease risk reduction. This integration enables us to adopt a multiscale way of thinking and develop holistic strategies to prevent and control transboundary diseases, ultimately protecting the health and well-being of human populations (dos S. Ribeiro et al., 2019).

EXISTING CASES OF TRANSBOUNDARY COLLABORATION TO PREVENT SPILLOVER

Transboundary Partnerships

Understanding the risk, prevention, and control of emerging diseases presents a complex and dynamic challenge, often characterized by numerous boundaries—both physical and conceptual (Madhav et al., 2017). Collaborative approaches to address transboundary disease issues are frequently advocated, yet translating these concepts into effective practice remains a formidable task for health and policy professionals. In the realm of global health, the past two decades have witnessed the emergence of transboundary collaboration, often synonymous with the term 'One Health' (Asokan, 2015; FAO et al., 2008). However, it is important to acknowledge that other commonly used terms and approaches exist, including planetary health, ecosystem approaches to health, participatory epidemiology, socio-biological methods/models, mixed methods, team science, systems approach, and more, and also contribute to this vital field.

Ideally, the implementation of such a paradigm would have been initiated by a theory of change, followed by partnership development, training, and subsequent implementation and evaluation. In reality, the process has developed in reverse in most places. However, theories of change, implementation roadmaps, and evaluation strategies for One Health have been developed. (Hueston et al. (2013) developed one of the initial 'theories of change' during a Rockefeller Bellagio retreat in 2010, drawing upon themes and lessons synthesized from over 50 demonstration projects worldwide. More recently, the One Health High-Level Expert Panel (sponsored by the World Health Organization) published a comprehensive plan (OHHLEP, 2022a). One of the most user-friendly implementation roadmaps was published by the World Bank (Berthe et al., 2018). The European Network for Evaluation of One Health conducted a series of workshops and published case examples on comprehensive programmatic evaluation. Additionally, several large-scale and regional One Health workforce partnerships for training and implementation plans exist (Table 3-1).

The intent behind this section is to delve into the existing transboundary partnerships that are actively engaged in the prevention of zoonotic spillover. These partnerships represent real-world models of collaboration, offering valuable insights into how we can collectively address the pressing challenge of zoonotic disease transmission. By examining their achievements and approaches, we can gain a deeper understanding of how to strengthen global health systems and enhance our collective capacity to respond effectively to transboundary disease challenges.

TABLE 3-1 Key Transboundary Partnerships in Zoonotic Spillover Prevention

Organization Name	Description
One Health Joint Plan of Action (2022-2026)	Effective collaboration among FAO, UNEP, WHO, and WOAH has significantly reduced the risks of zoonotic epidemics through a unified approach, emphasizing prevention, early detection, and response.
Southeast Asia One Health University Network (SEAOHUN)	Regional collaboration among 92 universities in Southeast Asia not only trains a new generation of One Health professionals but also promotes interdisciplinary cooperation critical for preventing and mitigating zoonotic spillover.
Association of Southeast Asian Nations (ASEAN)	ASEAN's commitment to One Health and its implementation plan for the agricultural–human interface demonstrates the power of regional health collaboration in effectively preventing, detecting, and responding to animal health emergencies.
The Food and Agriculture Organization-Emergency Centre for Transboundary Animal Diseases (FAO-ECTAD)	FAO-ECTAD's integrated approach, focusing on capacity building, has enhanced diagnostic capabilities, responded to outbreaks, and strengthened animal health systems across over 37 countries, illustrating the importance of transboundary partnerships in building resilience.
Preventing ZOonotic Disease Emergence (PREZODE)	PREZODE's international initiative to understand zoonotic disease risks and implement innovative methods showcases the value of ecosystem-level actions and community engagement in preventing and mitigating emerging zoonotic diseases.
Emerging Pandemic Threats (EPT) Program	EPT, a USAID program, emphasizes regional cooperation and cross-border information sharing, highlighting the importance of collective global health systems for early detection and response to pandemic threats, such as COVID-19.

One Health Joint Plan of Action (2022-2026)

The importance of collaborative partnerships in addressing transboundary disease issues cannot be overstated. The One Health Quadripartite, which joins the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), the World Health Organization (WHO), and the World Organization for Animal Health (WOAH), serves as an excellent example of such partnership (FAO, n.d.-c.). The One Health Quadripartite has recognized the need for unified action and has endorsed the new One Health definition provided by the One Health High-Level Expert Panel (OHHLEP), as well as the definition of spillover prevention. In line with their commitment, they established the One Health Joint Plan of Action (2022-2026) and will release their implementation guidelines. Among the six action tracks, track 2, aptly named `Reducing the Risks from Emerging and Re-emerging Zoonotic Epidemics and Pandemics', aims to minimize the local and global impacts of such outbreaks. This involves understanding how spillovers emerge, implementing upstream prevention measures, and strengthening One Health surveillance, early warning, and response systems (FAO et al., 2022).

The One Health Joint Plan of Action benefits from the support of various activities carried out by FAO and WOAH. For instance, FAO's Field Epidemiology Training on Wildlife, Environment, Biodiversity, and Ecosystems enhances the capacity of those working in the environmental and natural resource management realm to effectively collaborate with animal experts and human professionals (FAO et al., 2022). This training aligns with national baselines and institutional settings, providing crucial support for One Health policies, legislation, and interventions. The training is formulated based on the assessment by the Environment Sector Country Mapping and Needs Assessment Tool to align with national baseline and institutional settings.

One member of the quadripartite partnership, WOAH, previously known as OIE, serves as the international organization tasked with creating standards, guidelines, and recommendations for animal health and zoonoses (WOAH, 2023). They have published several guidelines and training manuals, such as the *Training Manual on Wildlife Diseases and Surveillance.* WOAH's Global Programme for Capacity Building focuses on strengthening wild animal health capacity, and their establishment of subregional wildlife health networks, including Southeast Asia, exemplifies their dedication to fostering regional collaborations. WOAH's regional activities are summarized at the Wildlife Health Networking site.

The One Health Joint Plan of Action, created through a participatory process, serves as a prime example of how transboundary partnerships can effectively counter and mitigate the risk of zoonotic spillover and transboundary disease outbreaks. This initiative has not only fostered cooperation, communication, capacity building, and coordination to address health concerns among the human-animal-planet interface, but it has also yielded concrete results. The goal of the alignment of the efforts of the FAO, the UNEP, the WHO, and the WOAH, the One Health Quadripartite is the reduction of the risks of emerging and re-emerging zoonotic epidemics and pandemics (FAO et al., 2022).

The key takeaway from this initiative is that through collaboration, shared knowledge, and a holistic approach that considers the interconnectedness of humans, animals, and the environment, we have a powerful tool to prevent and control zoonotic diseases (FAO et al., 2022). As we work to develop a comprehensive guide for zoonotic disease prevention, we should emphasize the importance of international partnerships such as the One Health Quadripartite in sharing effective strategies for safeguarding public health.

Southeast Asia One Health University Network (SEAOHUN)

In Southeast Asia, several noteworthy examples of transboundary One Health efforts have emerged. One such early network operating in the region is the Southeast Asia One Health University Network (SEAOHUN) (Gongal, 2013). Established in late 2011, SEAOHUN brings together 92 universities across eight Southeast Asian countries, namely Myanmar, Cambodia, Indonesia, Laos, Malaysia, the Philippines, Thailand, and Vietnam. Its primary objective is to train a new generation of One Health professionals. SEAOHUN plays an active role in collaborating with various partners, including the USAID Strategies to Prevent (STOP) Spillover project (late 2020 to present) and a myriad of other partners on both individual country initiatives and regional endeavours. By fostering partnerships, SEAOHUN aims to strengthen capacity-building efforts and promote collaborative research and education in the field of One Health.

Through its extensive network of universities and engagement with diverse stakeholders, SEAOHUN serves as a vital platform for fostering collaboration, sharing knowledge, and implementing coordinated actions to effectively address zoonotic spillover and transboundary disease outbreaks in Southeast Asia. The success of the partnership between SEAOHUN and various organizations underscores the potential for transboundary cooperation and underscores the vital role of regional networks in tackling shared challenges. By harnessing the combined expertise and resources of universities across Southeast Asia, SEAOHUN is not only training a new generation of One Health professionals but also facilitating interdisciplinary collaboration that is essential for preventing and mitigating zoonotic diseases.

The key takeaway from SEAOHUN's efforts is that regional networks and partnerships, such as SEAOHUN, have the potential to drive meaningful progress in preventing and controlling zoonotic diseases.

Association of Southeast Asian Nations (ASEAN)

The Association of Southeast Asian Nations (ASEAN) has pledged to implement One Health initiatives to prevent future pandemics in the coming years (VNA, 2023). The recent ASEAN Leaders Declaration featured a strong commitment to One Health, aiming to foster stronger regional health collaboration among member countries. In 2022, ASEAN created and ratified an implementation plan titled 'ASEAN Strategy for Exotic, Emerging, Re-emerging Diseases and Animal Health Emergencies' that specifically addresses the agricultural–human interface. This strategy envisions the ASEAN region effectively preventing, detecting, and responding to animal health emergencies through a collective responsibility for animal health security (ASEAN, 2021).

The strategy focuses on enhancing the ASEAN Animal Health Emergency Preparedness (AHEP) and response capacity by strengthening core public health systems, increasing regional connectivity and coordination, and investing in ongoing performance improvement. It focuses on nine essential animal health functional areas necessary for AHEP, including risk mitigation and response operations (ASEAN, 2021).

Furthermore, this document is designed to harmonize with other national and international frameworks and initiatives within the region and globally such as ACCAHZ, AVEG, AIGA, ALDF, GAHP, GFTADS, GHSA, and APHCA, to foster collaboration on zoonoses using the One Health approach (ASEAN, 2021) (Table 3-2).

TABLE 3-2 Regional and Global Zoonotic Disease Frameworks

Abbreviation	Title	Function
ACCAHZ	ASEAN Coordinating Centre for Animal Health and Zoonosis	The inception of ACCAHZ dates back to 2012, aims to effectively address the rising threat of the emergence and transmission of zoonotic diseases.
AVEG	ASEAN Ad-Hoc Veterinary Epidemiology Group	The AVEG has been recommended to integrate with the ACCAHZ. At present, AVEG is in the process of crafting preliminary capabilities and fostering networks across Southeast Asia.

Abbreviation	Title	Function
AIGA	Avian Influenza Group in ASEAN	The AIGA represents an expansion of one of the earliest animal health collectives within ASEAN, namely the HPAI Taskforce, which was founded back in 2004. A concept note has gained approval concerning the evaluation of the execution of the roadmap towards achieving an HPAI-Free ASEAN Community by 2020, along with future strategies for the prevention and control of Avian influenza in the ASEAN region.
ALDF	ASEAN Laboratory Directors' Forum	The ALDF is dedicated to the enhancement of Laboratory Capacity Building and Networking in Southeast Asia.
GAHP	Good Animal Husbandry Practices	ASEAN GAHP for Layers and Broilers is a standard for good animal husbandry practices for broiler and layer production in the ASEAN region. The standards in ASEAN GAHP mainly aim at preventing or minimizing food safety incidents.
GFTADS	Global Framework for the Progressive Control of Transboundary Animal Diseases	The GFTADS is a joint initiative from the FAO and WOAH that aims to initiate and support regional cooperation for the control of transboundary animal diseases.
GHSA	Global Health Security Agenda	The GHSA serves as a catalyst for progress towards the vision of attaining a world safe and secure from global health threats posed by infectious diseases.
APHCA	Animal Production and Health Commission for Asia and the Pacific	THE APHCA supports sustainable improvement in rural livestock agriculture and resource use through information sharing, disease control, enhanced organizational efficiency, the diversification of farm production, supply chain development and other initiatives.

ASEAN's commitment to One Health and its implementation plan for the agricultural–human interface exemplify the importance of transboundary partnerships in addressing zoonotic spillover. By embracing the One Health approach and fostering collaboration across borders, ASEAN is taking significant steps towards building a resilient and unified response to transboundary disease outbreaks within the region. At the human–wildlife interface, the ASEAN Senior Officials on Forestry adopted the ASEAN Strategy for Preventing Transmission of Zoonotic Diseases from Wildlife Trade in October 2022 (ASEAN, 2022).

The Food and Agriculture Organization-Emergency Centre for Transboundary Animal Diseases (FAO-ECTAD)

The Food and Agriculture Organization-Emergency Centre for Transboundary Animal Diseases (FAO-ECTAD) is another notable partnership committed to the principles of One Health

(FAO, n.d.-e.). The regional office of FAO-ECTAD embraces an integrated approach that emphasizes increased multidisciplinary and intersectoral cooperation, capacity building and development, and effective communication.

Established in 2005, FAO-ECTAD operates as part of the Food and Agriculture Organization of the United Nations and focuses on planning and delivering animal health emergency and development programs to more than 37 countries. Its primary goal is to prevent and mitigate the impact of animal diseases using a One Health approach.

In its pursuit of enhancing animal health collaboration within the framework of One Health, FAO-ECTAD places significant emphasis on strengthening the capacity of the animal sectors. Through targeted interventions and initiatives, FAO-ECTAD supports training programs that have reached nearly 6,000 professionals and has contributed to enhancing the diagnostic capabilities of 90 laboratories in 22 countries. Additionally, in 2021 alone, FAO-ECTAD played a crucial role in responding to over 400 outbreaks of priority diseases in 19 countries.

To ensure sustainability, FAO-ECTAD actively supports the review and formulation of enabling policies and legislation frameworks. It also assists in the formulation of contingency and response plans against priority animal diseases, national action plans on antimicrobial resistance, and other One Health-related policies and legislation.

The achievements of FAO-ECTAD illustrate the vital role that transboundary partnerships play in building capacity, fostering collaboration, and implementing comprehensive strategies to address zoonotic spillover effectively (Figure 3-3).

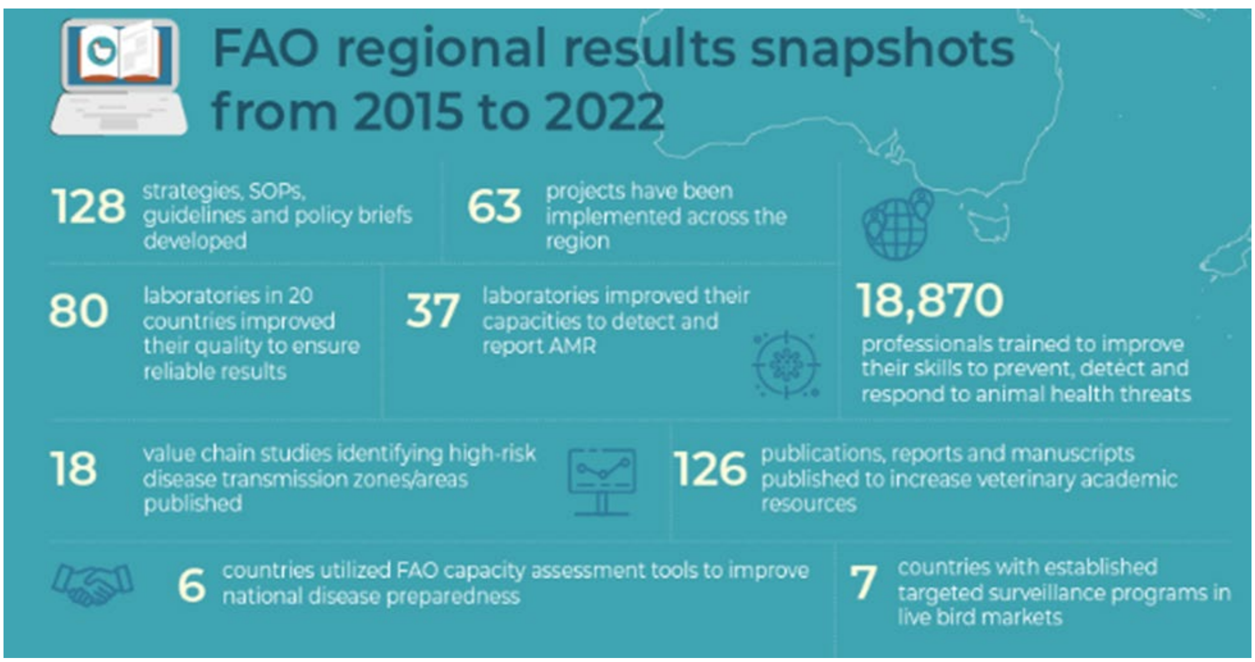


FIGURE 3-3 FAO regional results, 2015-2022. Source: Food and Agriculture Organization of the United Nations. Reproduced with permission.

Preventing Zoonotic Diseases Emergence (PREZODE)

PREZODE (Preventing ZOonotic Disease Emergence) is an international initiative launched in 2021 and created to understand the risks of emergence of zoonotic infectious diseases, to develop and deploy innovative methods to enhance prevention, early detection, and resilience, and to establish rapid response to the risks of emerging infectious diseases originating from animals (Debnath and Morand, 2023). The group is constructing a research framework to better comprehend the macro processes and drivers leading to zoonosis emergence amidst global changes. PREZODE facilitates the coordination of a large portfolio of regional, national, and international projects and programs pertaining to the emergence of zoonotic infectious diseases and implement innovative methods to enhance prevention and mitigate emergence risk (PREZODE, 2022).

For example, PREZODE has launched PREACTS (PREzode in ACTion in the Global South). This global project is divided into several regional programs such as PREACTS-AFRICAM, which is the first phase of PREZODE, involving four African countries (Cameroon, Guinea, Madagascar, and Senegal) and Cambodia. The second phase of PREZODE, which is ASAMCO, involves six countries: Lao PDR, Thailand, Democratic Republic of the Congo (DRC), Haiti, and Costa Rica. Working with national authorities, non-governmental organizations (NGOs), research institutions, and local communities and administrations, PREZODE has developed innovative actions to prevent and reduce the risk of emerging zoonotic diseases at the level of ecosystems and the human–wildlife interface.

Emerging Pandemic Threats (EPT)

The Global Health Security Program in the Emerging Threats Division Emerging Pandemic Threats (EPT) Division was pioneered by the United States Agency for International Development (USAID) in 2009, with the aim of detecting and responding to potential pandemic threats. The program focused on identifying and mitigating the risk of emerging and zoonotic infectious diseases. The EPT program sought to increase viral discovery, strengthen laboratory and surveillance systems in countries at high risk for outbreaks, and support training of health workers to detect and respond to outbreaks. It also worked with local governments and communities to sensitize the need for a One Health approach (USAID, 2014).

Working in over 100 countries, the EPT program placed a strong emphasis on the transboundary nature and threat of emerging diseases; promoting regional cooperation and collaboration by supporting the establishment of regional disease surveillance networks, facilitating information sharing across borders, and promoting joint response efforts to outbreaks. The theory of change was that by promoting regional cooperation and strengthening the capacity of partner countries, a collective more resilient global health system will emerge. These essential capacities and connectivities supported the early detection and timely response to the COVID-19 pandemic.

The current iteration of the EPT program (the third 5-year cycle) continues a transboundary approach, supporting a number of solutions-oriented programs. STOP Spillover is a 5-year project aimed at (1) Understanding the risk factors that contribute to viral spillover from animals to humans; (2) Implementing interventions at spillover points to prevent zoonotic disease; and (3) Assessing risk reduction practices and policies to prevent spillover and mitigate amplification and spread of disease (USAID, n.d.-a.). The One Health Workforce—Next Generation project continues support for the SEAOHUN network to continue developing One Health competencies among students so they are field-ready. They have performed activities such as simulations to enhance the capabilities of the current local workforce for various ministries to work together and respond to zoonotic diseases using the One Health approach.

Case Examples and Other Efforts

In the previous section, we explored examples of transboundary partnerships to prevent spillover and described the significance of One Health partnerships in tackling shared health challenges. We learned about various successful initiatives and organizations that have been working to enhance preparedness and response to transboundary disease outbreaks. In this section, we delve deeper into specific cases in Southeast Asia, where noteworthy instances of transboundary collaboration and communication have resulted in decreased likelihood or severity of disease outbreaks.

Case Example 3-1: The Cambodia-Vietnam avian influenza outbreak of 2021

In February and March of 2021, wild bird mortality events were detected by rangers and communities in three sites within protected wetlands of Cambodia, involving more than 1,700 Asian openbill storks, egrets, pond-herons, and cormorants. These areas have notable interfaces between wild water bird colonies and domestic duck flocks (Figure 3-4). An investigation was conducted by government and non-government partners from the animal health and environmental sectors. The cause was confirmed to be an outbreak of highly pathogenic avian influenza (HPAI) H5N1 in Cambodia and Vietnam; genetic sequencing identified the virus to be clade 2.3.2.1c. This clade is considered endemic in poultry in the region, and further analyses of sequencing data from Cambodia's dead Asian openbill storks showed genetic similarities to virus found in domestic poultry in Vietnam in 2019, suggesting a possible spillover and transboundary outbreak (Dane, 2021; EuroMeat News, 2024).

Following these reports, wildlife health experts in Vietnam began conducting active surveillance for avian influenza virus in two protected areas which were selected based on their diversified wild bird populations, including resident and migratory bird species, and their proximity with Cambodia. This parallel investigation in Vietnam led to the discovery of further wild bird mortalities (Dane, 2021; Euromeat News, 2024).

These significant wildlife health events in Cambodia and Vietnam demonstrate how a structured network of multisectoral stakeholders is critical to ensure good communication and a coordinated response during a transboundary outbreak. Subsequent HPAI cases in both poultry and humans in 2023, documented by WHO, were also preceded by wild bird mortalities (Charostad et al., 2023; EFSA et al., 2023). However, these precursor cases in the wild did not prompt proactive measures like those in 2021, underscoring the need for continued coordination, including at subnational levels in risk-prone areas. Based on these past experiences and similar response efforts in the countries since then, engaging on-the-ground personnel from the environmental sector is recommended. Mobilizing a country's existing wildlife health surveillance network, or laying the groundwork to establish one, is also key to rapid detection and response of mass mortality events in wild birds. By conducting transboundary communication between network stakeholders, these H5N1 outbreaks, and others since, were identified and investigated promptly.

FIGURE 3-4 Wild and domestic birds easily intermix in rural areas. Photo credit: Wild Conservation Society (WCS), Lao PDR.

Case Example 3-2: Collaborative efforts to detect African swine fever (ASF) in Southeast Asia: Laos, Cambodia, and Vietnam in 2019

African swine fever virus (ASFV) continues to devastate domestic pig populations following its introduction into Southeast Asia in 2019 and subsequent rapid spread across the region (Mighell and Ward, 2021). Although not zoonotic, ASFV has severe effects on animal welfare and human food and economic security. A recent example of the importance of cross-disciplinary collaborative actions was the discovery of ASF in wild pig populations following initial reports of the disease in domestic pigs in Laos, Cambodia, and Vietnam (Denstedt et al., 2021). Government and non-governmental stakeholders in each country, including livestock officers and forest rangers, conducted investigations in rural communities adjacent to wild boar habitat and experiencing mass mortality events in their domestic pigs at the time (Figure 3-5) (Denstedt et al., 2021). Risk factors for ASF spillover into wild boar were documented and, building on existing protocols from the livestock sector, mechanisms for reporting sick and dead wild boar were established. Active surveillance was conducted, including wild boar faecal sample collection by forest rangers on patrol. However, these methods were not effective or efficient in detecting ASF. Ultimately, operationalizing passive surveillance reporting systems for sick and dead wild boar, particularly systems involving rural communities, was the most effective strategy for detecting viruses in wild boar specimens. Laos was the first to detect ASF in free-ranging wild boar, and the experiences and methods pertaining to this investigation in Laos were shared with neighbouring networks in Cambodia and Vietnam. Both neighbouring countries detected cases of ASF in wild boar shortly thereafter.

Based on these experiences, it is recommended to engage communities early and often when ASF is suspected to be infecting animals inside wild boar habitats both from an efficiency standpoint and for cost-effectiveness. The efforts of these pilot networks, established under the WildHealthNet initiative, ultimately led to the first detection of ASFV in wild pigs in Southeast Asia and ushered in increased dialogue, monitoring, and surveillance efforts in other locations.

There are 11 endemic wild pig species found in Southeast Asia and the Pacific but little is known about the distribution and impact of ASFV on these populations (Luskin et al., 2021). Aside from the direct threat to wild pig population numbers, their decline may trigger cascading impacts for apex predators, plant communities, and the livelihoods of many communities living within proximity to wild pig habitat. Other mass mortality events in wild boar have since been detected anecdotally in other forests in these countries and others in the region. However, surveillance networks have not yet been established around every possible habitat, and therefore no formal reporting, investigations, or response were conducted when these events were detected. By establishing and scaling up cross-sector surveillance, policy instruments specific to wildlife health, and practical response systems, a clearer picture can be gained of the distribution and level of impact ASF is having on the region's wild pigs and what practical measures can be taken to reduce the ongoing risk of spillover and spillback (Luskin et al., 2021). The FAO, WOAH, and IUCN issued a joint communiqué recognizing the importance of wildlife health surveillance and a One Health approach to tackling ASF, calling on governments in the Asia Pacific region to develop stronger policies and take action (FAO et al., 2021).

FIGURE 3-5 Pigs raised on the perimeter of Nam Et – Phou Louey National Park, Lao PDR. Source: Emily Denstedt.

Case Example 3-3: Collaborative efforts to detect African swine fever (ASF) in Southeast Asia: Laos, Cambodia, and Vietnam in 2019

Malaria has been a long-standing health challenge in the Greater Mekong Subregion (GMS), which includes countries such as Myanmar, Cambodia, Laos, Thailand, Vietnam, and parts of China (Manzoni et al., 2024). The GMS is known for its high malaria transmission rates and the presence of drug-resistant malaria strains, particularly *Plasmodium falciparum* (Sattabongkot et al., 2022). In response to this regional health threat, the Mekong Malaria Elimination (MME) program was established in 2017, aimed to promote cross-border collaboration and communication among the GMS countries to accelerate malaria elimination efforts and contain the spread of drug-resistant malaria strains (WHO, n.d.-b.). The MME program closely collaborates with the WHO country offices, the WHO Global Malaria Programme, national malaria programmes, and partners (WHO, 2022d). The Malaria Elimination Database is a fundamental of the MME program. The regional platform uses 2010 data as its baseline and collects malaria data at the district and lower levels, such as subdistricts and health facilities, on a monthly basis. Access to this database enables countries in the Greater Mekong subregion to improve surveillance, boost monitoring and evaluation, analyse malaria distribution and trends, and share data via monthly epidemiological summaries and annual bulletins (WHO, 2022d).

Case Example 3-4: Foot and mouth disease on continental Southeast Asia

Foot and mouth disease (FMD) is a major animal health problem within Southeast Asia (SEA) (Blacksell et al., 2019). Although Indonesia and the Philippines have eradicated FMD, the virus still exists in other countries located across Southeast Asia. By gaining control and eliminating FMD across Southeast Asia, this would allow for greater market access in well-developed economies and decrease lost productivity in commercial or smallholder farming sites (Blacksell et al., 2019). While many countries have been able to successfully vaccinate their citizens against FMD, several obstacles have hindered the control of FMD in the region. Some of these include challenges with enforcing vaccination programmes, minimal knowledge on FMD amongst farmers, lack of timely reporting and response regarding FMD, weaknesses in national and international FMD control programmes, inadequate technical capacity and biosecurity at the country-level, and unmonitored movement of livestock and their products across boundaries. (Blacksell et al., 2019). In 1997, The South-East Asia Foot and Mouth Disease (SEAFMD) Campaign was created to control and eradicate FMD in the subregion, including Cambodia, Lao PDR, Malaysia, Myanmar, the Philippines, Thailand, Indonesia, and Vietnam (WOAH, 2021). In 2010, China, Singapore, and Brunei also joined the Campaign, which geographically expanded its influence. Consequently, SEAFMD changed its name to South-East Asia and China Foot and Mouth Disease (SEACFMD) Campaign. In 2016, Mongolia also joined as its 12th member. This Campaign is currently at Phase 6 (2021 to 2025). During this phase, the new Roadmap 2021-2025 will help countries incorporate their national FMD plan based on science and reflect on past achievements and lessons learnt from past phases (WOAH, 2021).

WILDLIFE TRADE AS A TRANSBOUNDARY SYSTEM IN SOUTHEAST ASIA AND THE ATTEMPTS TO UNDERSTAND AND REGULATE THE SYSTEM

Understanding Wildlife Trade as a Transboundary System

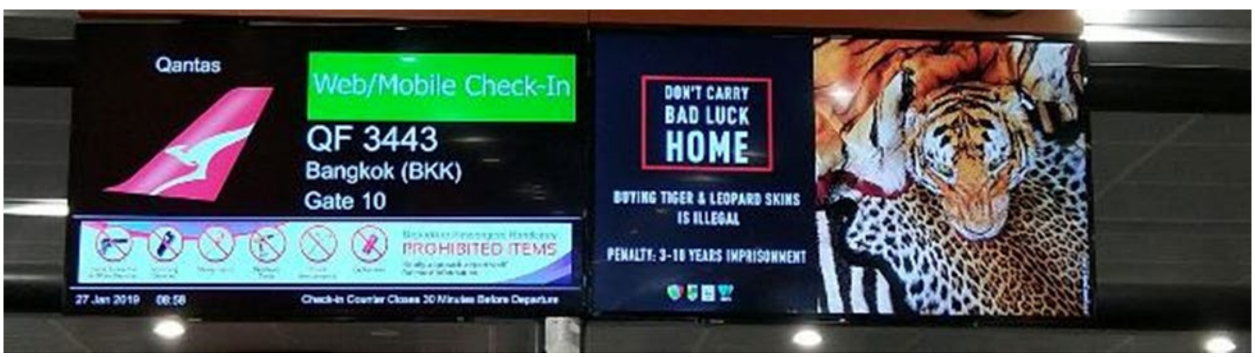


FIGURE 3-6 Public outreach messages at Yangon Airport, Myanmar, discouraging travellers from illegal trade and trafficking of wildlife products. Photo credit: K. Yoganand.

Wildlife trade is an interconnected system that operates across borders, making it a transboundary issue of significant concern (Figure 3-6) (Keskin et al., 2023). Southeast Asia, known for its exceptional biodiversity, harbours numerous endangered and threatened species of flora and fauna (Hughes, 2017). However, the region's widespread trade and consumption of wildlife increases the risk of zoonotic spillover and other negative consequences due to close contact facilitated by wildlife trade (Saba Villarroel et al., 2023). The trade, both legal and illegal, and formal and informal, poses substantial environmental impacts, drives species extinction, and threatens ecosystem services (Felbab-Brown, 2011). The increased contact through wildlife trade can lead to zoonotic spillover, where pathogens are transmitted from animals to humans. This risk increases as the length and complexity (i.e., number of human–animal interfaces) of the supply chain increase (WWF, n.d.-b.).

Legal trade

These are trade activities that comply with national and international laws and regulations. They involve obtaining the necessary permits, licenses, and documentation required from the governing authorities. Legal wildlife trade operates within the framework of established laws and regulations, ensuring that the trade activities are conducted in a lawful and regulated manner. The effectiveness of these operations depends on monitoring, compliance management, and, as with all aspects of regulated trade, effective law enforcement. However, sustainability is not considered in most wildlife trade laws, except in the case of the CITES regulated trade (CITES, 2014). Globally, much of wildlife trade is governed by national laws; they remain outside of CITES and do not consider sustainability in a methodical way.

An example is the legal export of 476,000 live long-tailed macaques (*Macaca fascicularis*) over 10 years (from 2010 to 2019) (Figure 3-7), predominantly by Southeast Asian countries such as Cambodia, Indonesia, Vietnam, China and Mauritius (Hansen et al., 2022). Most of them were imported by the U.S., Japan, China, France, and the U.K. (Keeling, 2023).

FIGURE 3-7 A long-tailed macaque mother and infant foraging along a road in Pahang state in peninsular Malaysia. Human travellers often feed the monkeys with human food and this creates an unnecessary interface and risky close contact between them. Photo credit: K. Yoganand.

Illegal trade

These are trade activities that violate national and international laws and regulations. Illegal wildlife trade operates outside the boundaries of formal regulations and often involves poaching, smuggling, and illegal sales of protected or endangered species. It is considered a serious threat to biodiversity and conservation efforts (WWF, n.d.-a.).

Elephant ivory

Examples include trafficking and illegal sales of elephant ivory, rhino horn, pangolin scales, and tiger bones (Figure 3-8) (TRAFFIC, n.d.). More than 63,000 kg of illegal elephant ivory seizures from 2003 to 2014 have implicated Malaysia as part of the trade route, with Malaysia itself seizing some 19,000 kg of ivory during this period (Koshy, 2020; TRAFFIC, n.d.).

FIGURE 3-8 Replica of illegal wildlife parts and products including rhino horns and a tiger skull on display at the Vientiane International Airport to educate travellers about the illegality of buying and carrying these products. Photo credit: K. Yoganand.

Bear bile

Sun bears and Asiatic black bears (Figure 3-9) are illegally captured from forests and held in captivity by traders to extract bile from their gallbladders (Hall, 2019).

FIGURE 3-9 An Asiatic black bear held in captivity in the Golden Triangle Special Economic Zone in Lao PDR. Illegal bear bile farms and restaurants offering bear paw soup on their menu were known to operate nearby. Photo credit: K. Yoganand.

Live macaques

In November 2022, the U.S. Department of Justice indicted several persons involved in illegally sourcing live long-tailed macaques from the protected areas of Cambodia, falsely labelling them as captive-bred and exporting more than 1,500 of them from Cambodia to the U.S. (Grimm, 2022).

Crocodile skins

In Malaysia, there is legal export of farmed crocodile skins to international markets (Figure 3-10). Malaysian crocodile farms that engage in this trade are required to obtain permits and licenses from relevant government agencies. This trade involves exporting crocodile skins from farms that adhere to Malaysian wildlife regulations and international agreements, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In a recent incident reported by *The Star* authorities in Sabah successfully thwarted an attempt to smuggle 220 crocodiles to a Malaysian crocodile farm from Indonesia (Vanar, 2019).

FIGURE 3-10 Some seized crocodiles were found at a swamp area in Kampung Pasir Putih in Tawau, Malaysia. Photo credit: Vanar, 2019.

Informal trade

These are trade activities that occur outside formal, regulated channels and may not always fully comply with regulations. Informal trade can take on various forms, including both legal but unregulated and unauthorized trade of wildlife species. This type of trade is often small-scale and localized, involving local communities or individuals trading to generate livelihood or household income. It can also include unregulated or unauthorized trade of wildlife species, leading to potential conservation and sustainability concerns (Wingard and Zahler, 2006; Wiseman, 2022).

Bamboo rats

In Lao PDR, small-scale farming of bamboo rats takes place in many households, typically in rural areas. Many species of rodents, such as bamboo rats (Figure 3-11), are traded for consumption or use in traditional medicine and to do so is not illegal and it requires no formal documentation nor is it regulated (Greatorex et al., 2016; Wingard and Zahler, 2006).

FIGURE 3-11 Rodents are commonly sold in local fresh markets along with fish, frogs, various insects, and vegetables in Lao PDR, such as at this organic market in Vientiane city. Photo credit: K. Yoganand.

Songbirds

In many countries in Southeast Asia and particularly in Indonesia, catching from the wild, keeping (sometimes breeding), and locally trading songbirds such as the magpie-robin, white-rumped shama (Figure 3-12), and orange-headed thrush is a well-known tradition. The songbirds are highly sought after for their melodious songs and are used in bird song competitions. However, in the island of Java, millions of households are involved in this trade (Marshall et al., 2020), resulting in severe declines and local extinctions of several bird species, a phenomenon known as the 'Asian songbird crisis' (Lee et al., 2016).

FIGURE 3-12 The white-rumped shama, a commonly traded songbird in southeast Asia. Photo credit: K. Yoganand.

Wildlife trade supply chains that move wildlife from source sites to large urban markets constitute evolutionary mixing vessels that mix viruses from different species, potentially generating novel pathogens through genetic processes such as reassortment and recombination. Trade of wild animals in markets, in particular live mammals and birds, creates environments where species (including humans) that normally would not frequently or ever come into contact with one another (nor do so in such high numbers) are in close and sometimes immediate proximity, sharing space and pathogens (Lin et al., 2021). Similarly, wildlife farms where large numbers of animals are raised close together and in frequent contact with people are also potent sites for emergent diseases (Espinosa et al., 2020).

In Asia, wild meat consumption as a dietary necessity is less prevalent than in other parts of the Global South and is consumed often as a luxury item or used in traditional medicine (Xing et al., 2020). Local communities in many countries in Asia also still hunt wild species as a source of food or income. Wildlife traded on a commercial scale to satisfy the significant urban demand for wildlife products, both within and far outside the region, continues to drive unsustainable take on already-depleted wildlife populations and habitat. This, in turn, deprives livelihoods and household incomes for local communities who rely on natural resources as important sources (People Not Poaching, 2022). Addressing the legal and illegal wildlife trade is crucial for preventing transboundary disease outbreaks (Rush et al., 2021). The illegal wildlife trade often involves the capture, transport, and sale of live animals, increasing the risk of disease transmission from animals to humans. Improving animal welfare, strengthening wildlife health monitoring, and encouraging sustainable use can help reduce the risk of disease outbreaks (CBD, 2022). In addition, strengthening law enforcement efforts to combat illegal wildlife trade and related crimes can help reduce the spread of zoonotic diseases (UNODC, 2020).

The rat trade in Cambodia demonstrates the transboundary nature of many types of wildlife trade. Indeed, wildlife trade, whether legal or illegal, formal or informal, operates across borders and poses significant risks, including zoonotic spillover and ecosystem threats. The rat trade in Cambodia intertwines local practices of hunting and consuming field rats with a cross-border supply chain that supports multiscale trade. This complex system highlights the potential consequences of close contact facilitated by wildlife trade, as it reveals a significant prevalence of confirmed cases of Coronavirus among rodents destined for human consumption (Huong et al., 2020). By examining the rat trade, we can gain insights into the interconnectedness of wildlife trade chains and their potential role in disease outbreaks, while also considering the diverse perspectives and trade-offs related to food security, species protection, and global sustainability.

The illegal trading of the critically endangered Sunda pangolin is another example of the transboundary nature of wildlife trade in Southeast Asia. The demand for pangolins and their body parts, driven by cultural and medicinal beliefs, has resulted in extensive illegal hunting and trade across the region (Archer et al., 2021). This trade not only drives the extinction of pangolin populations but also poses significant risks to public health. Pangolins carry viruses closely related to known human pathogens, including those associated with SARS-CoV-2 and MERS (Shi et al., 2022). The dynamic and unsupervised environment created by the illegal pangolin trade, including the illegal hunting and trapping, transportation in stressful conditions, unsafe handling during butchering and local market sales, provides opportunities for viral recombination, replication, and spillover (Gupta et al., 2022). With an estimated million pangolins illegally traded each year (Grein, n.d.), efforts to combat this trade have proven challenging, highlighting the need for a multifaceted approach that balances economic and livelihood concerns, species conservation, and transboundary cooperation.

Reviewing these case examples, we emphasize the broader issue of wildlife trade as a transboundary system and its implications for zoonotic disease outbreaks. The rat trade and the illegal trading of pangolins serve as specific examples that illustrate the interconnectedness of wildlife trade chains, the risks of close contact between different species and the potential consequences for public health. This reinforces the importance of understanding and regulating wildlife trade, minimizing trade in certain high-disease-risk taxa as a prevention strategy, and designing and enforcing biosecurity standards along the supply chain to counter zoonotic spillover disease outbreaks in Southeast Asia.

EXISTING REGULATORY EFFORTS ADDRESSING WILDLIFE TRADE IN SOUTHEAST ASIA: OVERVIEW OF POLICY CHANGES AND DEVELOPMENTS

Public policy is ‘a set of interrelated decisions taken by a political actor or group of actors concerning the selection of goals and the means of achieving them’ (Jenkins, 1978). The development, consultation to gain buy-in, and implementation require a substantial evidence base and governance structures to ensure implementation and accountability.

WHO CA+

Intergovernmental policies are complex and take years to develop. However, this should not stop the process. In recognition of the shortcomings of the international community to respond effectively to the COVID-19 pandemic in a timely manner, the World Health Assembly established an Intergovernmental Negotiating Body to establish a WHO convention, agreement, or other instrument on pandemic prevention, preparedness, and response (WHO CA+). Most notably, the agreement recognises that a One Health approach is needed to strengthen synergies with other existing legal or non-legal instruments to address drivers of pandemics, including increased risks at the human–animal–environment interface. The agreement also includes a commitment to strengthen surveillance systems and laboratory capacity to detect and minimize spillover events associated with zoonotic neglected tropical and vector-borne diseases from wildlife or domesticated animals (Prime Minister of Vietnam, 2020; WHO, 2023e).

Wildlife Directive in Vietnam following the Covid-19 Pandemic

Following the COVID-19 pandemic, Vietnam issued a directive (29/CT-TTg) including measures to restrict wildlife trade and consumption, banning the import of live wild animals and wildlife products (WWF, 2020). The directive aimed to restrict wildlife markets (Figure 3-13) and prohibit hunting activities that include the transport, slaughter, selling, buying, storing, and consumption of wildlife animals (Prime Minister of Vietnam, 2020; WWF, 2020).The Ministry of Agriculture and Rural Development (MARD) primarily led these efforts and coordinated with relevant agencies, while the Ministry of Public Security strengthened enforcements with other ministries, provincial and city authorities tasked with specific roles for implementation. A Pandemic Prevention Task Force composed of representatives of the Vietnam government, multilateral organizations (FAO, WHO, UNEP), NGOs, and several embassies also pushed to develop, strengthen, and enforce all legal measures required to phase out commercial trade and consumption of wild birds and mammals. This action represents an example of the government mobilizing dozens of normally siloed ministries and agencies to address spillover within the wildlife trade. The government mobilization was the institution of a One Health Partnership for Zoonoses (OHP), led by three ministries (MARD, Ministry of Health and Ministry of Natural Resources and Environment). This OHP has a current 5-year plan 2021-2025, and in 2021 established a Technical Working Group on Wildlife and Pandemic Prevention. Since then, Vietnam has reviewed the implementation through multisectoral, multistakeholder workshops and will be developing a National Action Plan to control the trading activities of wildlife flora and fauna species in the period of 2023-2030 (TRAFFIC, 2023).

FIGURE 3-13 Vendor and animals in wildlife market. Photo credit: WCS Viet Nam, 2020.

WCS's Counter Wildlife Trafficking:

The Wildlife Conservation Society's Counter Wildlife Trafficking program operates in 32 countries along major trafficking supply chains with locally led programs working in partnership with governments, in-house law enforcement, and criminal justice expertise. The focus of this effort is to end those elements of the commercial trade business with the highest risk, eliminating pathogens along the animal supply chain of certain species and products. The process includes a combination of ground-up initiatives such as combating illegal wildlife trade through the Wildlife Crimes Unit, a partnership between Indonesia and civil society, and advising governments on policies associated with deforestation or establishing new protected areas for wildlife. For example, the number of breeding waterbirds, e.g., the Oriental darter, in the flooded forest of Prek Toal on Cambodia's Tonle Sap (Figure 3-14) has increased significantly through the combined efforts of WCS, Cambodian Ministry of Environment, and local people (WCS, 2022).

FIGURE 3-14 Bird colonies commonly found in regions of Southeast Asia. Photo credit: Prek Toal Bird Sanctuary.

Adoption of Wildlife Health Surveillance into National Policy in Laos

The Lao PDR-Cambodia One Health Surveillance and Laboratory Network or LACANET (EU-funded) and WildHealthNet (US Defense Threat Reduction Agency-funded) (Figure 3-15) initiatives led by the Ministry of Agriculture and Forestry in Laos, together with WCS, formalized the Standard Operating Procedure for Wildlife Health Surveillance at the ministerial level in 2022. This network sets the operating standards for wildlife health surveillance to guide surveillance and management of disease information on wildlife and provides practical guidance on early case detection, risk assessment, and response to wildlife illness or death. The network successfully connects people who encounter wildlife, including villagers and staff at animal rescue centres, with scientists, decision-makers and stakeholders who can take action to analyse disease threats. A National Wildlife Health Surveillance Committee was created to establish central governance over these interactions (LACANET, 2016; WCS, n.d.-b.).

FIGURE 3-15 Wildlife Health Surveillance Standard Operating Procedure development in Lao PDR with government partners from animal health and environmental sectors. Photo credit: ©WCS Laos.

WildHealthNet

Wildlife health surveillance can be used for early detection of disease threats, including zoonoses and health threats directly impacting wildlife populations, although most efforts in the region have had limited scope and duration. WildHealthNet is an example of a cross-sectoral and transdisciplinary approach to build and implement effective, sustainable national wildlife health surveillance systems (Pruvot et al., 2023). This initiative in Cambodia, Laos, and Vietnam is building national wildlife health surveillance strategies from the ground up, implementing systems for reporting wildlife morbidity and mortality events detected in local wildlife trade markets, wildlife rescue centres, and protected areas where human–wildlife interfaces exist (Pruvot et al., 2023).

FIGURE 3-16 WildHealthNet initiatives leverage veterinary and wildlife health expertise to safeguard biodiversity in Southeast Asia. Photo credit: WildHealthNet.

The objective is to ensure early detection and response to events which may negatively impact the health of humans, livestock, and/or wildlife populations themselves. The approach brings together human, animal, and environmental health sectors that each hold part of a national One Health surveillance system solution (Figure 3-16). These sectors form a network that is supported by international frameworks, data management systems, capacity bridging, and technical training, to meet the challenge of providing locally relevant solutions that can be scaled globally. Different wildlife morbidity and mortality event reporting mechanisms were piloted to inform the development of national Standard Operating Procedures (SOPs) in Laos and Cambodia. Through these pilot networks, outbreaks of African swine fever in wild boar, Lumpy skin disease in endangered banteng, and highly pathogenic avian influenza (H5N1) outbreaks in wild bird colonies were discovered and investigated. In the case of Laos, WildHealthNet resulted in the drafting of an SOP for Wildlife Health Surveillance which was adopted into national policy and the official establishment of a National Wildlife Health Surveillance Committee in January 2023. The WildHealthNet approach, novel both in its scale and sustainability, has laid groundwork unique in the One Health field which allows for continued wildlife health surveillance on a national scale in Laos, Cambodia, and Vietnam today exist (Pruvot et al., 2023).

ADVOCATING FOR A TRANSBOUNDARY APPROACH TO WILDLIFE TRADE IN SOUTHEAST ASIA

The rapid expansion of wildlife trade in Southeast Asia has brought both economic and biodiversity conservation concerns (Felbab-Brown, 2011; Nijman, 2010). Outbreaks of zoonotic diseases, most notably the COVID-19 pandemic, have underscored the risks associated with wildlife trade and its severe impact on public health (Sheikh and O'Regan, 2021). This section explores the urgent need for collaborative efforts among countries to address these challenges collectively. Sharing knowledge, enhancing law enforcement, and integrating health professionals in wildlife management will safeguard public health, conserve biodiversity, and effectively counter the emergence of zoonotic diseases in the Southeast Asia region.

Strengthening Wildlife Trade Law Enforcement in the Context of COVID-19

China's response to the risks associated with wildlife trade in the wake of the COVID-19 pandemic has been marked by significant action. In February 2020, the Chinese government implemented a comprehensive ban on the trade and consumption of wild vertebrate animals, a crucial step to prevent the transmission of zoonotic diseases from wildlife to humans (Koh et al., 2021). By prohibiting the trade and consumption of wild animals, China aimed to reduce the likelihood of future outbreaks and safeguard public health (Koh et al., 2021).

According to CNN (Westcott and Deng, 2020), a government-sponsored report in 2017 by the Chinese Academy of Engineering reported that China's commitment to addressing wildlife trade extends to exerting control over wildlife farming, a lucrative industry estimated to be worth around $73 billion and employing over one million people. This action indicates that China recognizes the economic significance of the wildlife farming industry accompanied by willingness to prioritize public health and conservation over economic considerations.

Vietnam, a neighbouring Southeast Asian country, faces similar challenges in terms of wildlife trade (Luong, 2022). Like China, Vietnam has experienced the expansion of wildlife farming and trade, which has contributed to both economic growth and biodiversity conservation concerns (Pham et al., 2022; USAID, n.d.-b.). Taking a transboundary approach, countries in Southeast Asia, including China and Vietnam, could collaborate to strengthen wildlife trade law enforcement, enhance regulations, and implement stricter monitoring systems. Such collaboration would help mitigate the risks of zoonotic disease transmission and contribute to the conservation of endangered species in the region.

By sharing knowledge, resources, and best practices, China and Vietnam, along with other countries in Southeast Asia, can work together to develop comprehensive strategies that effectively address the complex issue of wildlife trade. Cooperation in law enforcement, developing regulations, and monitoring would help ensure that a ban on wildlife trade is effectively implemented and enforced, reducing the risk of future zoonotic disease outbreaks, and promoting both public health and biodiversity.

Enhancing Wildlife Trade Control and Monitoring for Public Health

Wildlife trade represents one of the most important, expanding, and uncontrollable interfaces for emerging disease spillover. Due to extreme complexity, it is one of the most complicated aspects of pandemic prevention to address (Hilderink and de Winter, 2021). To enhance wildlife trade control and monitoring for public health, the following recommendations are made.

Clarifying intervention opportunities based on knowledge, attitude, and practices

To effectively address the complex challenges associated with wildlife trade and its impact on public health, it is crucial to clarify intervention opportunities based on the knowledge, attitudes, and practices of various stakeholders (Vigilla-Montecillo et al., 2023). By understanding these factors, we can develop targeted strategies that align with different audiences and maximize the effectiveness of our interventions.

1. **Develop a unified theory of change** on how to address shared risks in wildlife conservation and public health with respect to wildlife trade. Many groups are working on this at many scales, but efforts are still relatively siloed.
2. **Develop and train best practices for engaging local communities in win-win solutions.** Species survival requires active engagement of local communities to promote conservation. One commonly identified gap in current disease prevention protocols is the continued low awareness about the connection between zoonotic diseases and wildlife conservation in rural and remote areas.
3. **Convene transboundary fora for shared wildlife trade governance**. Pathogen surveillance and legal protection and enforcement activities have been insufficient or ineffective; therefore, it is important to further develop legislation and policy to reduce disease risks from wildlife trade.
4. **Develop combined One Health surveillance and risk assessment models.** The examples above represent the beginning of a systems approach to pandemic preparedness. We must develop best practices for multispecies, One Health, monitoring programs and surveillance of emerging diseases. We must focus on how a systems approach can provide solutions to the complexity of this problem which consists of many 'boundaries' (geopolitical, disciplinary, interspecies, ecotones, socio-biological, etc.) at play currently in a dynamic way. Connecting risk-based models focused on the issue of emergence will help define and refine data needs for which monitoring, and surveillance systems can be optimized. These must contain biological risk factors but should be expanded to connect social dimensions as drivers of the interface that creates risk. Connecting biological disease transmission with individual- and policy-level decision analysis will help us move away from the reactive to a predictive and preventive approach.

Clarifying intervention opportunities based on stakeholders' attitudes, beliefs, and practices is essential for effective wildlife trade control and public health protection. By addressing the identified gaps, convening experts, developing unified approaches, and integrating diverse perspectives, we can foster sustainable practices and promote a harmonious coexistence between human populations, wildlife, and the environment.

Integration of health and wildlife professionals

The integration of health and wildlife professionals will facilitate not only teams capable of understanding and characterizing wildlife health threats to humans but will support development and implementation of One Health solutions aimed at safeguarding both animal and human health, while promoting the conservation of ecosystems. Traditionally, zoonotic diseases of wildlife origin have been underprioritized within regulatory frameworks worldwide. This fragmentation is akin to the challenges faced by neglected tropical diseases, with limited resources allocated to the interface issues between wildlife and humans. Wildlife-borne zoonotic diseases are frequently discovered in humans when they become ill or studied by animal health experts as part of veterinary or environmental health disciplines. The nature of their risk is often described as 'low probability, high consequence', meaning that while the likelihood of spillover and human-human transmission may be low, the potential consequences can be severe. Thus, there is a gap in funding and preparedness, as these diseases can be easily ignored or minimized in the present (Radin and

Eleftheriades, 2021). Recent global epidemic events such as SARS CoV-2, Ebola, Marburg, and others have raised awareness about the importance of addressing these issues worldwide. However, there is still a pressing need to foster more public health-wildlife partnership approaches in order to prepare for and prevent such outbreaks.

Experts in this field advocate for a holistic, transdisciplinary, systems approach known as 'ecohealth' or 'ecological approaches to health'. Ecohealth emphasizes the interconnectedness between humans and wild animals within the ecosystem context. It focuses on understanding how environment and ecological changes, including habitat destruction, pollution, and wildlife trade, can impact the health of wild animal populations and the risk of zoonotic disease transmission to humans. For example, Sethi et al. (2023) discuss the environmental correlates, including climate change, behind the rise in infectious diseases, and call for the need for infectious disease control and preparedness. For further insights of these integrated perspectives, refer to Module 1 on One Health, which explores the connections between ecohealth and environmental health approaches in greater detail.

CONCLUSION

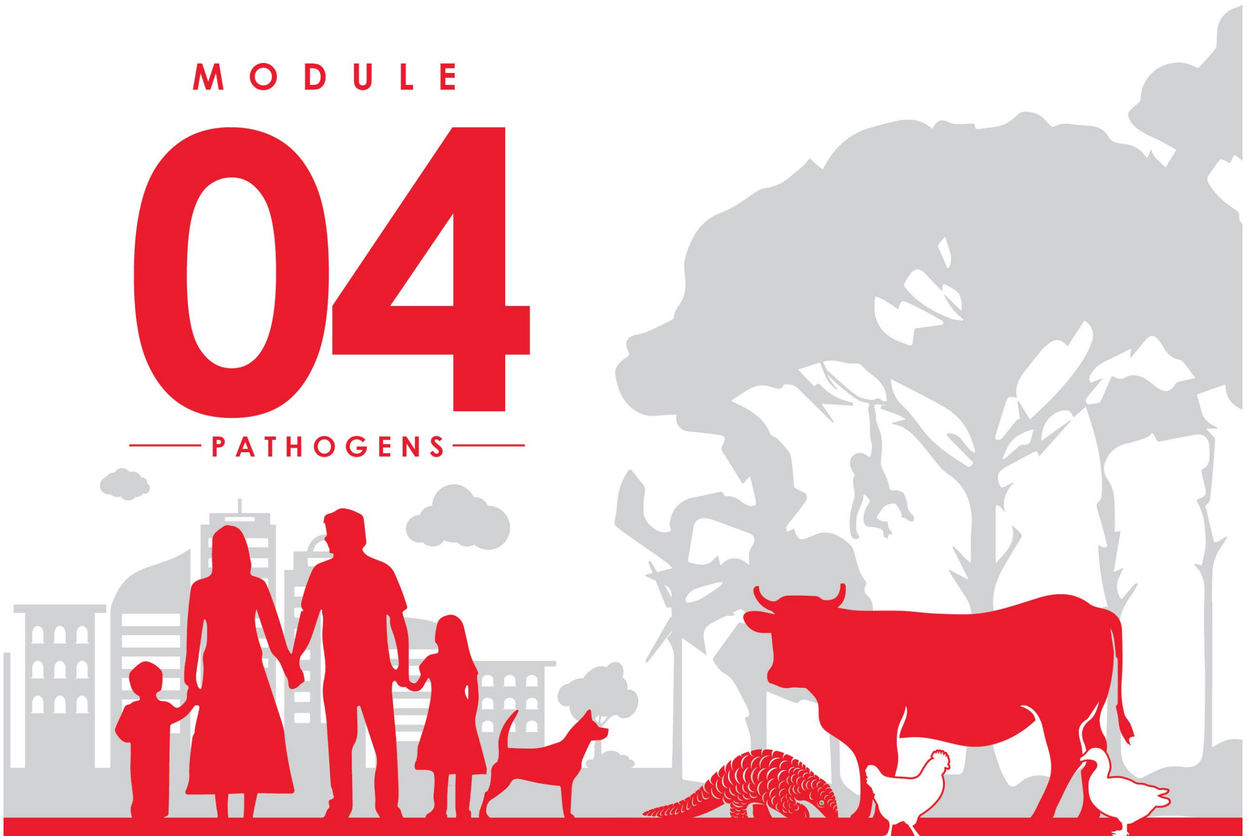
At the outset of this chapter, we posed that the application of the transboundary concept must be supported by the principles and practices of *One Health*—acknowledging the complexity of the epidemiological triad at multiple scales and interfaces, within a dynamic, chaotic world. We suggest that transboundary problems are not limited in scope by the traditional geographical use, but bridge across relevant domains including diversity of human culture, language, food (security and safety), politics, approaches to problems, needs, opinions, agendas, goals, desired outcomes, nature, and natural resources usage. This complexity automatically leads to a discussion of systems thinking. The goal of this discussion was to examine the idea of transboundary work and partnerships that match the complexity and scope of today's emerging diseases, including more focus on social systems, respect for cultural diversity and values, and a host of scientific disciplines. Our review of the current state of application of these principles reinforces (a) that progress is being made, and (b) the need to apply them more fully across scale—integrating local community and regional governance. We feel that focusing the next steps in the transboundary approach on the three objectives below will help fill existing gaps.

1. Continued harmonisation of methods across disciplines, countries, and regions to increase teamwork for prevention and response.
2. Continued fostering of more participatory wildlife monitoring and health surveillance.
3. Focus on fostering development and implementation of high-level standards for and community-based examples of wildlife trade risk assessment and management.

MODULE

04

PATHOGENS



How to Identify and Characterize Priority Pathogens to Guide Efforts to Address Zoonotic Disease Spillover

Co-Authors
Hung Nguyen-Viet, Linda Saif & Malik Peiris

How To Identify and Characterize Priority Pathogens and Animal Hosts to Guide Efforts to Address Zoonotic Disease Spillover

The goal of this module is to review and develop guidelines and tools to identify and prioritize zoonotic pathogens, especially those with pandemic potential and their animal hosts/reservoirs, in the context of SEA and the populations at highest risk. The prior (SARS) and ongoing human coronavirus epidemics/pandemics (MERS, COVID-19) and similar scenarios for influenza A virus will be used as examples related to these goals and to illustrate zoonoses, spillover and spillback of these pathogens among humans and animals. Case examples of the potential for new coronaviruses (CoVs) to emerge as WHO “Disease X” are presented. Finally biosafety and biosecurity measures and information sources related to work on high impact zoonotic pathogens are described.

BACKGROUND, INTRODUCTION AND HISTORICAL CONTEXT FOR EMERGENCE AND RE-EMERGENCE OF ZOONOTIC PATHOGENS

Due to an everchanging, globalized world, zoonotic spillovers and the rapid dissemination of pathogens are becoming increasingly inevitable. For centuries emerging infectious diseases (EID) have been spilling over as zoonoses from animals to humans with some spilling back from humans to animals (reverse zoonosis), creating the potential for secondary spillback to humans (see Box 4-1 for definitions of terms). However, the frequency of emerging/re-emerging zoonotic diseases has accelerated over the past 25 years (see Figure 4-1), with many EID causing severe illnesses, deaths and often pandemics. The increasing human population coupled with changes in climate, land use pattern, agricultural industry changes, international travel and commerce and increased human susceptibility to infections were identified as the top macro-level drivers of such rapid and sustained zoonotic spillover (Daszak et al., 2013; Karesh et al., 2012; Tajudeen et al., 2022). Underlying drivers of increased risk of EIDs that exacerbate the spillover/spillback also include microbial evolution; expanding human–animal–environmental interfaces; climate change; and human behavior (food consumption etc.) (Baker et al., 2022; Allen et al., 2017).

BOX 4-1
Glossary of Terms Referenced in this Review

Zoonosis

An infectious disease that is transmitted from animals to humans. e.g., influenza virus, ebolavirus, SARS coronaviruses.

Reverse zoonosis/spillback

An event in which a previously zoonotic pathogen that has undergone spillover into humans infects novel, nonhuman animals, e. g., transmission of SARS-CoV-2 from humans into mink or white-tailed deer.

Spillover

An event in which a species-specific pathogen establishes infection in a novel susceptible host, e. g., transmission of Nipah virus from bats into pigs.

Secondary spillover

An instance of spillover that occurs when a previously zoonotic pathogen that has undergone spillover into humans infects novel, susceptible animals that in turn infect naïve or previously-exposed humans, e. g., transmission of SARS-CoV-2 from humans into mink or white-tailed deer and then back into humans.

Adapted from Sparrer et al., 2023

Keusch and colleagues assessed major RNA virus outbreaks that have occurred since the 1960s. Studying these outbreaks allowed them to prevent opportunities for emergence and examine common features. Many of these include ancestral viral origins in bats, birds, and other mammals, along with intermediate hosts and animal reservoirs. The research team also identified pathways for community spread and zoonotic spillover that are responsible for local, regional, and international disease outbreaks (Figure 4-1) (Keusch et al., 2022). Notably most of the recent EID are caused by RNA viruses belonging to six major virus families as represented in Figure 4-1. The preponderance of RNA viruses among EIDs is attributed to the rapid evolution of RNA viral genomes via mutation, recombination and/or reassortment, and, for some RNA viruses (influenza A virus, coronavirus), a broad host range and highly efficient respiratory and enteric transmission in humans and animals. Figure 4-1 further illustrates multiple regions (identified by countries or regions listed in parentheses in the figure) for the origin or re-emergence of EID outbreaks based on the presence of the underlying drivers of EID.

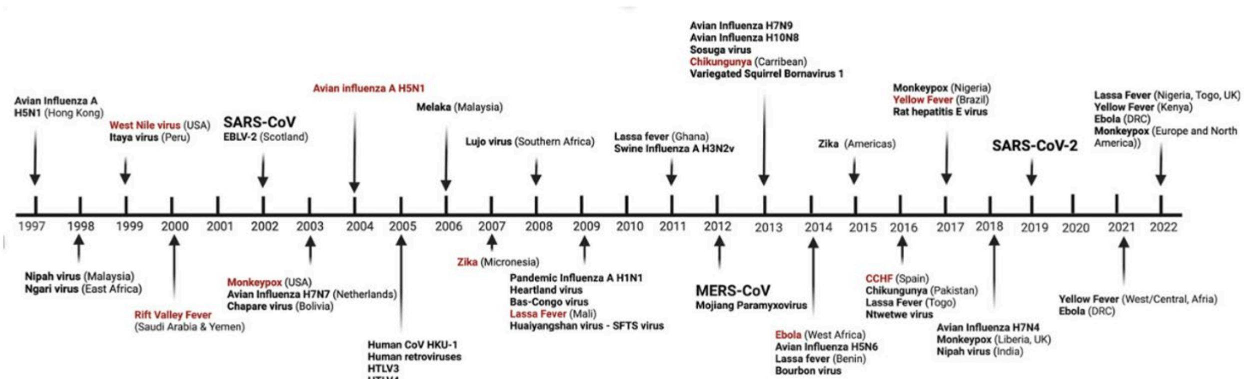


FIGURE 4-1 Historical context: emergence and repeated zoonotic spillovers to humans of select RNA/DNA viruses associated with outbreaks, epidemics, and pandemics, past 25 years. Based on Keusch et al. 2022.

PRIORITIZATION OF HIGH IMPACT ZOONOTIC PATHOGENS WITH PANDEMIC POTENTIAL

The US-Centers for Disease Control and Prevention defines high consequence pathogens as those causing "highly contagious or lethal viral, bacterial, fungal, prion, and related infections and diseases of unknown origin." The World Health Organization has a similar definition. Many agencies and institutes have established approaches and tools to prioritize high threat zoonotic pathogens and those with pandemic potential or have assembled lists of such pathogens (see Table 4-1, Primary Sources for Prioritization of Pathogens, at end of module). These resources are highlighted and summarized at the end of this Module. Notably RNA viruses are overrepresented, and several RNA virus families are common to multiple lists of high impact or pandemic potential zoonotic pathogens: *Orthomyxoviridae, Orthoparamyxoviridae, Flaviviridae, Coronaviridae, Arenaviridae, Filoviridae, and Rhabdoviridae.* These virus families include influenza A virus, Nipah virus, flaviviruses, coronaviruses, lassa virus, Ebola virus, Marburg virus, hemorrhagic fever viruses, rabies and others. Three additional tables (Tables 4-2, 4-3, 4-4) at the end of the module provide concise lists with valuable citations to round out this discussion of zoonotic and high-impact animal pathogens in the region.

Table 4-2 Zoonotic Pathogens in South-East Asia with Pandemic-Causing Potential

Table 4-3 Important Zoonotic Pathogens in South-East Asia

Table 4-4 High Impact Emerging/re-emerging Animal Pathogens in South-East Asia

COMMON CHARACTERISTICS OF PATHOGENS WITH PANDEMIC POTENTIAL

Reviewing pathogens that have served as the causative agents of past human pandemics reveals several common characteristics (see Box 4-2). Indeed, Casadevall has defined pathogenic potential as "proportional to the fraction of individuals who become symptomatic after infection with a defined inoculum and can include such attributes as mortality, communicability, and the time from infection to disease" (Casadevall, 2017). Adalja et al. extended this kind of analysis to define "pandemic potential" and identified seven characteristics to be considered essential components for pandemic potential (Box 4-2) (Adalja et al., 2019). They concluded that respiratory-borne RNA viruses are the most likely to cause global disease, in agreement with earlier work (Woolhouse et al., 2013). Augmenting these are considerations of direct virus-human host interactions as depicted in Figure 4-2. Experimental studies of animal viruses based on a four-part research framework to proactively identify animal viruses that may infect humans (Figure 4-2) has been proposed as an alternative monitoring strategy to that of merely sequencing viruses in nature to try to predict the next pandemic virus. This would measure viral properties that align with human infection, and pinpoint viruses that serve as the greatest risk for zoonosis and then study them further.

BOX 4-2
Seven characteristics of Human Pandemic or Epidemic situations for Zoonotic Pathogens

1. Efficient and sustained human-to-human (or animal-to-animal) transmissibility (consider zoonotic animal to human transmission as well)
2. A concerning or high case fatality rate and/or morbidity rate
3. The absence of effective or widely available public health countermeasures
4. An immunologically naïve host population (human or intermediate animal host)
5. Virulence factors enabling immune system evasion
6. Respiratory (or enteric or direct contact) mode of spread.
7. Ability to transmit during incubation periods and/or during mild or asymptomatic illnesses would further augment spread.

Adapted and modified from Adalja et al., 2019

To infect humans, an animal virus requires four biological properties: it must use the human ortholog of its cellular entry receptor and enter human cells; it must use human intracellular proteins to multiply itself and leave human cells; it must bypass human innate immune responses; and it must evade pre-existing human adaptive immunity (antibodies and T cells) (Warren and Sawyer, 2023). Data suggest that the overwhelming majority of animal viruses do not have all of these properties.

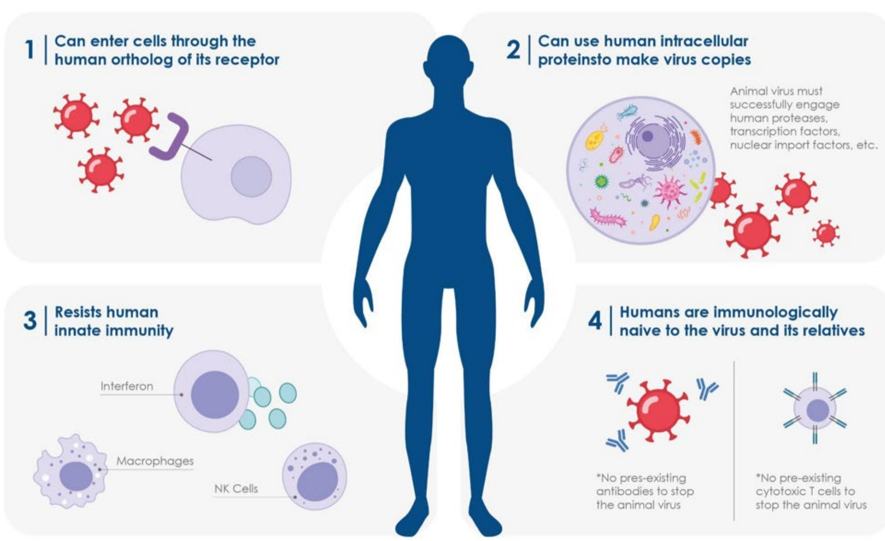


FIGURE 4-2 The four biological properties of an animal virus that can infect humans. Figure adapted from Warren and Sawyer, 2023.

WHO "Disease X" and Pandemic Preparedness

WHO has suggested that the next pandemic could be caused by "Disease X" – which is included in its list of top priority pathogens - and that it is a matter of "not *if* but *when*" a new zoonotic pathogen will spillover to humans to establish sustained human-to human transmission. (N.B. Some readers may encounter an alternative name "Pathogen X"—this guidance uses the WHO convention). It is reasonable to assume there are a large number of undiscovered viruses with unknown zoonotic and pathogenic potential. Scientists know currently of only ~250 viruses that infect people, which means >99.5% of the potential infectious viruses are unknown (Woolhouse et al., 2013).

The Coalition for Epidemic Preparedness Innovations, or CEPI, was established in 2017 to develop a rapid response program – striving to begin testing new vaccines within a month of the sequencing of a new pathogen. CEPI classified Disease X as a serious risk to global health security, for which the world needed to prepare:

> "If we can produce vaccines against Disease X in a matter of months instead of a year or more, we could revolutionize the world's ability to respond to epidemic and pandemic diseases. Disease X and other emerging infectious diseases pose an existential threat to humanity. But for the first time in history, with the right level of financial commitment and political will, we could credibly aim to eliminate the risk of epidemics and pandemics."
>
> Tom Mooney, Senior Communications & Advocacy Manager, CEPI

Host Reservoirs and Intermediate Hosts for Emerging/Reemerging Human and Porcine Coronaviruses

Keusch and colleagues compared major coronavirus outbreaks in people and swine over the past millennium and the projected reservoir and intermediate hosts (Keusch et al., 2022). As highlighted in Figure 4-4, coronaviruses have emerged in humans as zoonoses and in animals from several common reservoir hosts and intermediate hosts as depicted (see also Figure 4-1). Figure 4-3 illustrates evidence supporting the origin and source of emergence of many of these viruses in wildlife, including bats, other mammals, and avian species, often involving an intermediate animal host. The time of the initial spillover as determined by molecular clock analysis or the discovery of the virus by epidemiologic or virologic methods, presumed reservoir host, and the major intermediate hosts for human and swine CoVs are depicted. In Figure 4-3, black animal silhouettes indicate the likely reservoir (above) or intermediate host (below); PDCoV, porcine delta-coronavirus; SADS-CoV, swine acute diarrhea syndrome coronavirus; HCoV, Human coronavirus; PHEV, Porcine Hemagglutinating Encephalomyelitis virus; HKU-1, HKU-1 human coronavirus; Hu-PDCoV, Human-Porcine Delta coronavirus; Hu-CCoV, Human-Canine coronavirus.

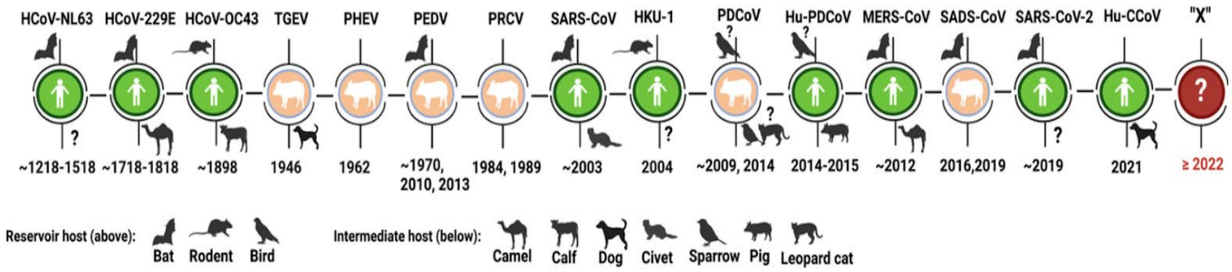


FIGURE 4-3. Timeline of the emergence of CoVs in people or swine over the past millennium (Keusch et al., 2022). Note: “X” denotes future unknown “Disease X”.

Case Examples for Different Potential Pandemic Threats for Emerging Coronaviruses

The following case examples illustrate newly recognized or ongoing potential pandemic threats for CoVs: “WHO Disease X”.

Case Example 4-1: SARS/SARS-CoV-2-related betaCoVs circulating in bats.

One prior pandemic (SARS) and two ongoing epidemic/pandemic events (MERS, COVID-19) caused by zoonotic coronaviruses have occurred in the last two decades (Figures 4-1, 4-3). Bat species are the ancestral hosts for all 3 of these human coronaviruses. The likely intermediate animal hosts are known for SARS-CoV (civet cats, raccoon dogs) and for MERS CoV (camels), but unknown for SARS-CoV-2 (suspect pangolins or raccoon dogs) (Huang et al., 2023; Crits-Christoph et al., 2023; Liu et al., 2023). A concern is that some SARS-related and SARS-CoV-2-related bat strains of the virus bind to human ACE2, suggesting a possibility of direct bat-to-human transmission (Ge et al., 2013; Temmam et al., 2022).

Case Example 4-2: Severe Acute Diarrhea Syndrome (SADS) alphaCoV in bats and pigs.

FIGURE 4-4. Bat farm in Cambodia. Photo credit: Vibol Hul

In 2016 and continuing in 2019, a new alphaCoV disease called Severe Acute Diarrhea Syndrome (SADS) emerged in swine in Southern China and killed approximately 50,000 baby pigs. By genetic analysis, the infection appeared to be directly transmitted from bats to pigs on the farms (Gong et al., 2017; Pan et al., 2017; Zhou et al., 2018). More concerning, the virus infects primary human lung and intestinal cells *in vitro*, suggesting a risk for human spillover (Edwards et al., 2020).

Case Example 4-3: Porcine deltaCoV in pigs, birds and humans.

Porcine deltaCoV was first detected in pigs in Hong Kong in 2012 (Woo et al., 2012) and genetic analysis showed it was most closely related to deltaCoVs in songbirds. In 2014, this virus caused an epidemic in pigs in the United States (Yang et al., 2014). It is a generalist virus with a broad host range, infecting avian species (Boley et al., 2020), swine (Jung et al., 2014), ruminants, human cell lines (Ji et al., 2020) and most recently, humans (Lednicky et al., 2021). There have been three confirmed infections of children who displayed mild febrile illness, in school clinics in Haiti (Lednicky et al., 2021). Two different lineages of porcine deltaCoV were isolated from the infected children.

FIGURE 4-5. Pigs in Chrey Thom, Cambodia. Photo credit: Vibol Hul

Case Example 4-4: A new canine alphaCoV (CaCoV) detected in humans

The new human canine alphaCoVs (designated HuPn-2018 and Z19) (Vlasova et al., 2022; Lednicky et al., 2021) have recombinant spike genes from dogs, cats and swine alphaCoVs and additional mutations within the backbone of a CaCoV IIb strain. The human CaCoV (HuPn-2018) was detected in children with pneumonia in Malaysia (Vlasova et al., 2022) and mild cases (Z19) occurred in mission workers back from Haiti (Lednicky et al., 2021). The temporally related (samples from 2017-2018), but geographically isolated viruses showed very high (99.4%) nucleotide identity between the two human CaCoV strains. The prevalence of related strains in humans or in dogs has not been evaluated.

The above CoVs are related to viruses that have already spilled over to humans and caused pandemics (SARS, SARS-CoV-2), or that may have potential for human infections based on in vitro experiments with human cells (SADS, PDCoV) or recent spillovers in humans (PDCoV, human-CaCoV) that could represent an early stage of adaptation to humans, prior to the possibility of sustained human-to-human transmission.

Spillovers, spillbacks, and secondary spillovers of SARS-CoV-2: analytical and *in vitro* predictors

Here we discuss spillover of zoonotic pathogens to humans (zoonosis), spillback from humans to animals (reverse zoonosis) and secondary spillovers from the new animal host to humans (see Box 4-1, Figures 4-7, 4-8) as exemplified by SARS-CoV-2. Prediction of transmission of SARS-CoV-2 from animals to humans was studied by Fischhoff and colleague using combined analytical and laboratory approaches (Fischhoff et al., 2021). Review of existing data and literature identified about 50 confirmed spillover/reverse secondary spillover events in about 50 mammals. In the study, three kinds of data were used to develop an algorithm for prediction of zoonotic transmission: 1) comparing amino acid sequences of ACE2 binding sites for viral attachment; 2) estimating binding strength at these sites using three dimensional structures; and 3) laboratory experiments. Machine learning models were trained on existing mammalian data and included geospatial and other species traits. The results expanded predictive capacity across more than 5000 species (of about 6500 total mammalian species worldwide) and identified a number of mammalian species in global hotspots that deserve specific attention (Figure 4-6). Many of the mammals identified as having potential zoonotic capacity were domesticated animals, e.g., pets, farmed or traded animals, validated in lab animal models, and many predictions were consistent with experimental evidence. The top 10% of animals demonstrating predicted SARS-CoV-2 zoonotic capacity were found in the tropics.

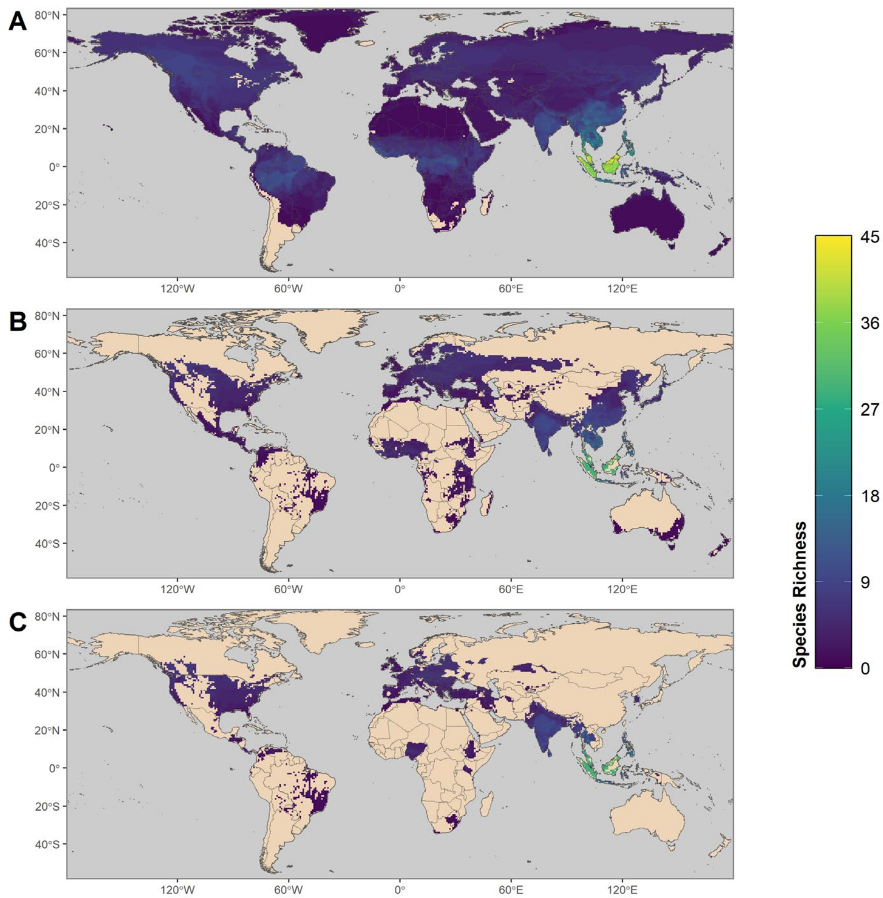


FIGURE 4-6 Three maps showing the global distribution of species with projected ability to transmit SARS-CoV-2. (A) shows global species richness of the top 10 percent of model-predicted zoonotic capacity. Ranges of this subset of species were filtered to those associated with human-dominated or human-altered habitats (B), depicts the subset of species that overlaps with areas of high human SARS-CoV-2 positive case counts (C) (as of 15 February 2021, there were more than 100,000 cases). Source: Fischhoff et al., 2021.

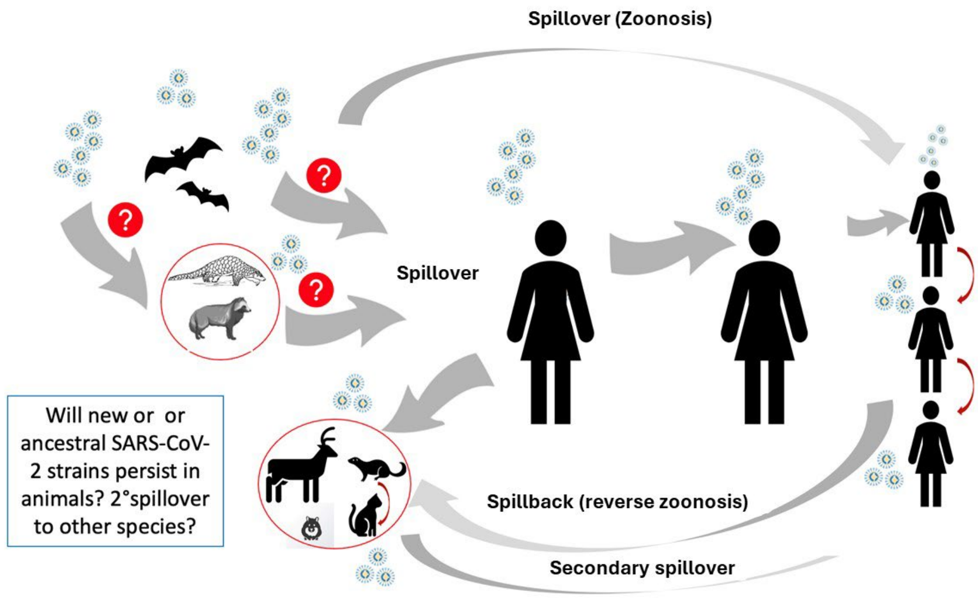


FIGURE 4-7 SARS-CoV-2 in animals: potential new host reservoirs for secondary spillovers to humans? Adapted from: Isabella Anna Eckerle (personal communication).

Although there are exceptions, such as HIV, one hallmark of zoonotic pathogens most likely to spillover and cause widespread disease in humans is a broad host range (Cleaveland et al., 2007). This characteristic is exemplified by various CoVs, as summarized, specifically for SARS-CoV-2 (Figures 4-7, 4-8) where continued spillover of SARS-CoV-2-related viruses from ancestral bat hosts (Temmam et al., 2022) or potentially from intermediate animal hosts is a concern (illustrated graphically in Figure 4-7). Also new animal hosts for SARS-CoV-2 could become established following spillover from humans into the new host (reverse zoonoses), thereby maintaining a virus reservoir and persistence, followed by secondary spillback from the new animal hosts into humans (discussed below) (Figures 4-7, 4-8).

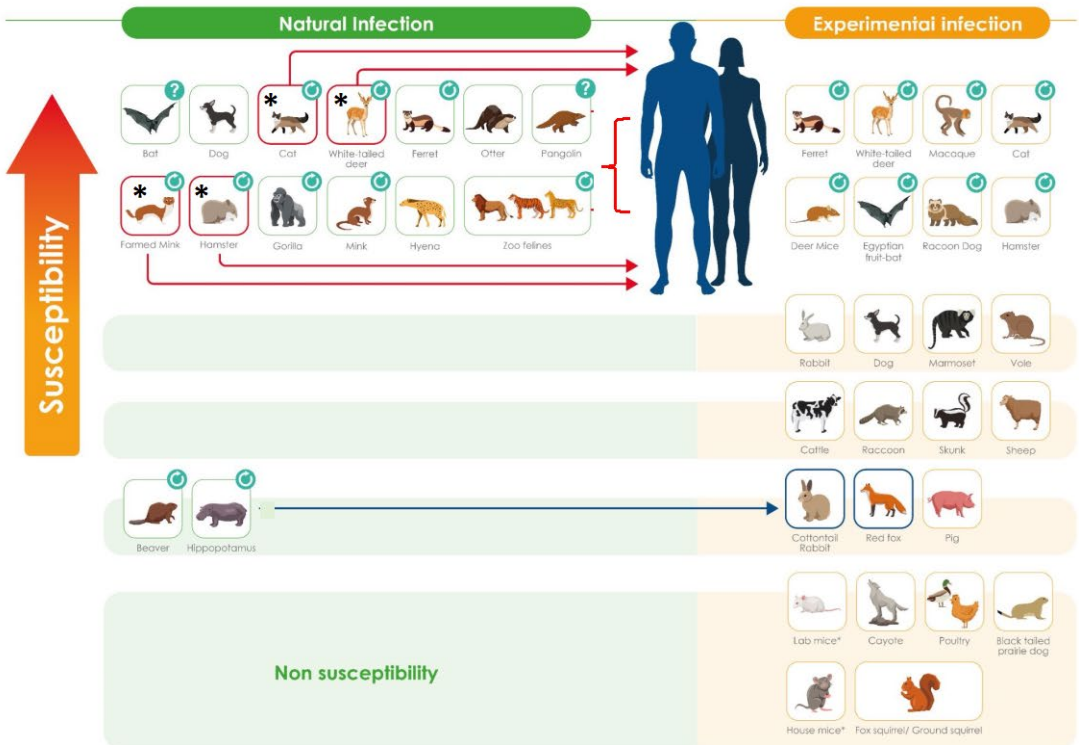


FIGURE 4-8 Infection and transmission of SARS-CoV-2 in animals and documented spillback from humans to animals and secondary spillover from animals to humans (animals denoted by*). Adapted from Keusch et al., 2022.

Case examples of spillback and secondary spillover of SARS-CoV-2

Some viruses spillback from humans into animals (reverse zoonosis) and establish additional animal reservoirs with virus persistence (Sparrer et al., 2023; Cox, 2021). Examples of SARS-CoV-2 spillback from humans into animals, followed by zoonotic secondary spillover back into humans, are summarized in Figures 4-7, 4-8 and include:

- Spillback from human caretakers to farmed mink, with secondary spillovers from mink to humans in Europe and North America (Munnink et al., 2021).
- Recent secondary spillovers from a cat to a veterinarian (Sila et al., 2022) in Bangkok, Thailand and from a zoo lion to caretakers in the US (Siegrist et al., 2023).
- Reports of multiple spillbacks from humans to white-tailed deer (Hale et al., 2022; Kuchipudi et al., 2022) with at least one report of secondary spillover from deer into a person (Pickering et al., 2022).
- A hamster outbreak in Hong Kong involving hamsters infected with human strains that then caused secondary spillback into humans (Yen et al., 2022).

Case examples of targeted animal reservoirs and intermediate or bridging host species to monitor for surveillance of zoonotic coronaviruses.

Table 4-5 lists possible target animals to monitor for CoV zoonoses based on historic (determined by molecular clock viral genetic analysis) or recent spillover of zoonotic CoVs to humans (reviewed in Keusch et al., 2022).

TABLE 4-5 Possible target animals to monitor for CoV zoonoses – see end of Module, p. 31

We are aware that felids and carnivores are infected by SARS and SARS-CoV-2. We know that ungulates including cattle and camelids were involved in the endemic human alphacoronavirus, 229E and the betacoronavirus OC43 zoonotic spillovers and the continuing spillover in the middle east of the betacoronavirus Middle East Respiratory Syndrome (MERS) (Keusch et al., 2022). SARS-CoV-2 is present in another ungulate species--white-tailed deer and also in other wildlife species (Table 4-5; Figures 4-7, 4-8).

Interspecies transmission, Spillovers and Spillbacks of influenza viruses

Case Example 4-5: Emerging Influenza A viruses

Influenza A pandemics arise when animal viruses, either whole, or in part, contribute animal viral hemagglutinins and/or neuraminidases or other gene segments to an existing human influenza A virus. Three influenza A pandemics occurred in the 20th Century (caused by H1N1, H2N2 and H3N2 virus subtypes) and one (H1N1 subtype) pandemic has occurred to date in the 21st Century. Pandemic-like respiratory disease outbreaks have been recorded throughout human history with 3-4 such pandemics occurring, most of these believed to be caused by influenza, but some of these may have been caused by coronaviruses or other respiratory viruses (Krammer et al., 2018).

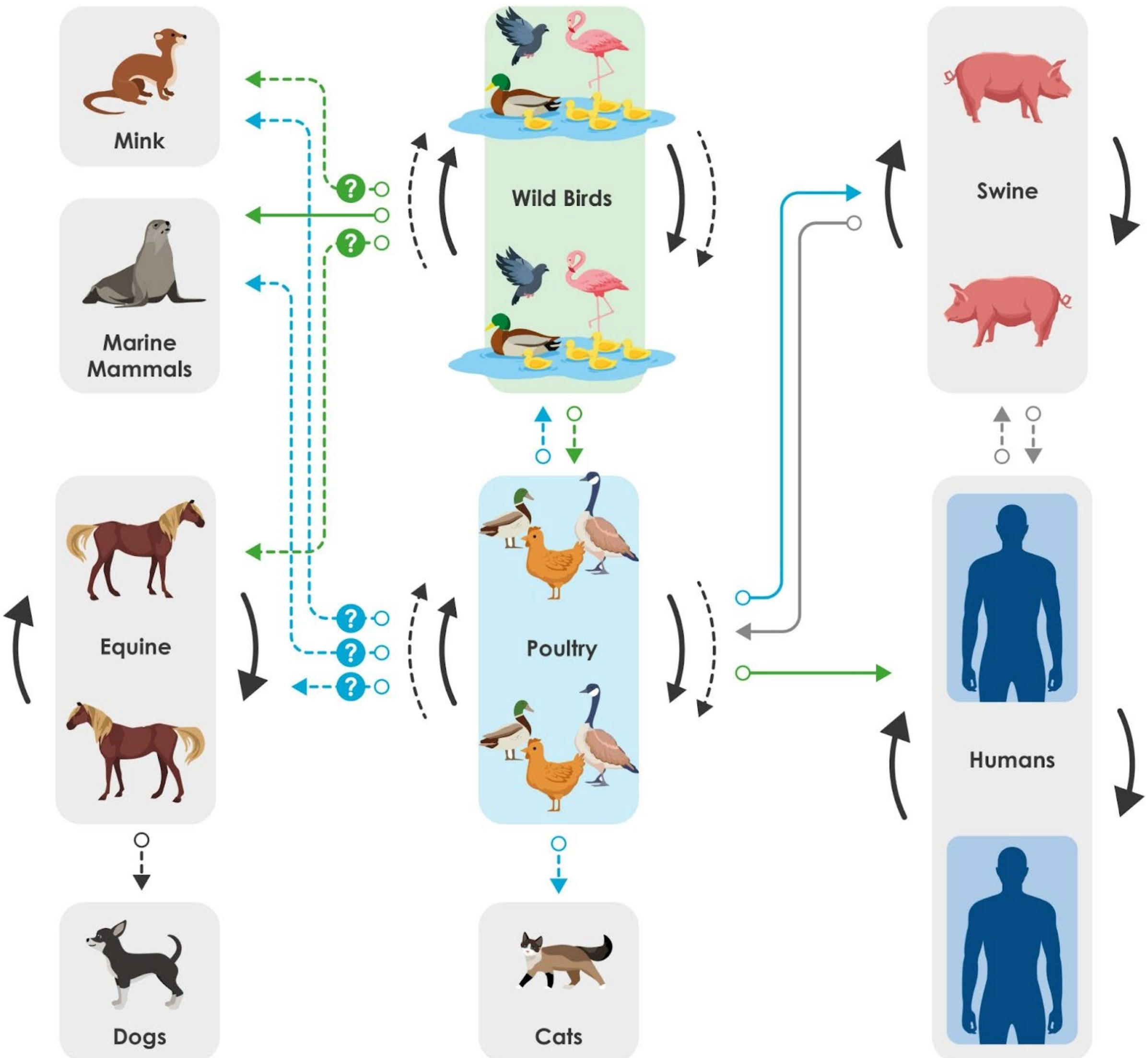


FIGURE 4-9 Influenza A viruses – Interspecies transmission, spillover and spillback. Dashed lines and "?" indicate potential interspecies transmission. Adapted from OSU background page and Kerstetter et al., 2021. Copyright © 2021 Kerstetter, Buckley, Bliss, and Coughlan.

In addition, zoonotic spillovers, sometimes associated with severe disease and death, but without sustained transmission have been reported repeatedly. Such zoonotic spillovers occurred repeatedly for avian H5N1 and H5N6 viruses (arising from the Guangdong 1996 H5 lineage) and also with H7N9, H7N7, H7N3, H9N2, H6N1 and H10N8, and others, in different geographic regions (Uyeki et al., 2019; Short et al., 2015). Viruses established in domestic poultry in Asia (e.g. H5N1, H5N6, H7N9) have been associated with hundreds of zoonotic infections. Zoonotic transmission has also been reported with swine viruses of H1 and H3 subtypes in North America and Asia (Short et al., 2015). One such spillover led to the influenza A H1N1 pandemic in 2009. Since swine are susceptible to many humans and some avian influenza viruses, they have been hypothesized to be a "mixing vessel" in the genesis of pandemic influenza.

Host reservoirs for Influenza A virus

Wild aquatic birds are the natural reservoir of influenza A viruses with a wide diversity of viral hemagglutinins (subtypes H1 – H16) and neuraminidases (N1 – 9) (CDC, 2022a; Venkatesh et al., 2018). Bats also harbor novel H17 and H18 subtype viruses (Tong et al., 2013), but so far these have not been associated with spillovers to other species. A few of the aquatic avian virus subtypes are established in terrestrial poultry (e.g. chickens). Avian viruses repeatedly spill over into other mammalian species including swine, horses, dogs, and aquatic mammals, sometimes adapting to sustained transmission establishing long-term lineages in these mammalian species (Figure 4-9). H1 and H3 subtypes are also established as long term lineages in swine, while H7 viruses circulate long term in horses, with further spillover into canine species (Figure 4-7) (Wille and Holmes, 2020; Lloren et al., 2017).

Spillover of Influenza A viruses to avian and mammalian species

Interspecies spillover of influenza A viruses from avian species to other avian and non-human mammalian species is not uncommon (see Figure 4-9). Terrestrial poultry such as chickens or quail harbor a more restricted range of influenza A subtypes (e.g. H5N1, H9N2, H7N9, H6N1 etc.) than seen in the natural reservoir, aquatic waterfowl. These spillovers are usually accompanied by reassortment with pre-existing viruses prevalent in chickens such as H9N2 as illustrated by the emergence of H5N1, H7N9, H10N8 and more recently H3N8 (Hemida et al., 2019). The establishment of these viruses in domestic poultry is more likely to lead to zoonotic transmission (e.g. H5N1, H7N9, H10N8, H3N8). Similarly, influenza A virus spillover from either aquatic or terrestrial poultry to other mammalian species including pigs, horses, aquatic mammals, dogs, and other species (see Figure 4-9) (Runstadler and Puryear, 2020). Recently, highly pathogenic avian influenza A (H5N1) has spilled over from wild birds to a range of terrestrial (e.g. mink, badger, bear, fox, pig, raccoon etc.) and aquatic (e.g. dolphin, otter, seal) mammalian species, with convincing evidence of transmission demonstrated between mink and seals (WHO, 2022a). These ongoing interspecies spillovers pose threats to both animal health (e.g., current poultry deaths caused by highly pathogenic avian influenza A(H5N1) or humans.

Spillover of avian influenza A viruses to humans

Spillover events of highly pathogenic avian influenza viruses to humans and other species are more likely to be detected because they may cause more overt and severe disease than that in the host. However, it is important to recognize that although past human pandemics were not caused by low pathogenic avian influenza viruses, where spillover may be less overt, it is important to also maintain active one health surveillance for spillover events of low pathogenic influenza to humans and between other species. The need for "one health" surveillance to monitor spillover events between species and to humans is an important aspect of ongoing risk assessment for pandemic threats. An example of such a network is the WHO Global Influenza Program-led Quadripartite surveillance and application of the Tool for Influenza Pandemic Risk Assessment (TIPRA) process (WHO, 2020a; Cox et al., 2014).

Spillback of influenza A viruses from humans to other mammalian species

Spillback of influenza A virus (reverse zoonosis) has been reported, most often from humans to swine. At least 12 instances of spillback of human influenza viruses establishing sustained transmission in swine have been reported, but this is likely to be a gross underestimate

(Trovão and Nelson, 2020). Swine influenza viruses derive some or all of their gene segments from humans or from avian species, subsequently leading to further reassortment of these viruses in swine. The 2009 H1N1 pandemic virus which emerged from swine, spilled back to swine as the pandemic virus spread globally (Mena et al., 2016). The 2009 H1N1 pandemic virus gene segments, reassorted with previous enzootic swine and many swine influenza A virus lineages in Asia, North America, and perhaps elsewhere, have one or more 2009 H1N1 pandemic virus genes within them. Also, some influenza viruses common in China have Eurasian Avian origin H1 gene segments (antigenically divergent from H1 viruses endemic in humans at present) with multiple human 2009 pandemic H1N1 gene segments within them (i.e. potentially well adapted to humans), posing significant pandemic threats (Sun et al., 2020).

Other zoonotic influenza viruses may also pose concerns.

Cattle are a leading reservoir for influenza D viruses (Collin et al., 2015; Ruiz et al., 2022). The recent finding of asymptomatic influenza D virus infections in dairy cattle workers suggests that influenza D virus is present in dairy cattle environments and can result in worker exposure (Leibler et al., 2023).

Surveillance

Employing a One Health surveillance effort with an early emphasis on the interface while targeting viruses or key viral families (i.e., influenza viruses, coronaviruses, enteroviruses, flaviviruses, hemorrhagic fever viruses, filoviruses, adenoviruses, paramyxoviruses, etc.) is imperative for early warning, preventing inter-species transmission, determining extent of viral spread and controlling pandemics. Zoonotic viruses must be detected rapidly to prevent their transmission to humans and to other species by monitoring the human-animal-environmental interface, the One Health connection (reviewed in Keusch et al., 2022). Prevention of initial spillover at local and regional levels to mitigate sustained human-to-human transmission and avert new epidemics or pandemics relies on effective surveillance programs that provide early and accurate warning. Surveillance methodology and applications in the fight to control or mitigate zoonotic spillover is examined in Module 5: How to design and conduct risk-based surveillance for zoonotic diseases at the human-animal Interface.

Laboratory Biosafety Infrastructure and Capacity

Laboratory biosafety in SEA encompasses the practices, guidelines, and regulations that ensure the safe handling, containment, and disposal of biological agents and materials within laboratories. While biosafety practices can vary between countries in SEA, there are overarching principles and initiatives aimed at promoting biosafety and biosecurity.

A number of web-based tracking studies have gathered information about existing and new biological containment laboratories. These studies also evaluate the biosafety and biosecurity oversight efforts to coordinate the function of these laboratories. In addition, attempts to assess public health or pandemic preparedness in individual countries also include data about labs and biosafety/biosecurity programs.

- WHO Health Emergency Dashboard
- WHO IHR State Party Self-Assessment Annual Reporting

- WHO JEE Biosafety and Biosecurity
- International Federation of Biosafety Organizations
- Global Biolabs, tracks maximum containment laboratories and their associated programs around the world.
- Global Health Security Index (2021) measures the capacities of 195 countries to prepare for epidemics and pandemics.

It is important to note that biosafety practices can vary across countries in SEA due to differences in resources, infrastructure, and regulatory frameworks. Each country's biosafety system is tailored to address its specific needs while aligning with international standards and best practices outlined by organizations such as the World Health Organization (WHO) and the World Organisation for Animal Health (WOAH). A number of key features are common to biosafety practices around the world. Below are some examples of specific national programs addressing these practices.

National Biosafety Guidelines and Regulations

Many countries in Asia have developed their own national biosafety guidelines and regulations that outline the requirements for laboratories working with biological agents. These guidelines typically cover areas such as facility design, personnel training, risk assessment, containment measures, waste management, and emergency response. Further discussion of laboratory capacity and training can be found in Module 7 "Strategies to overcome barriers, fill gaps and address systemic issues." Examples include:

Biosafety Training and Capacity Building

Several organizations and institutions in Asia provide biosafety training programs to laboratory personnel, researchers, and administrators. These programs focus on educating individuals about best practices, risk assessment, personal protective equipment (PPE) use, and proper handling and disposal of biological agents. Capacity-building efforts aim to enhance biosafety practices across laboratories in the region.

Laboratory Accreditation and Oversight

Some countries have established accreditation systems or regulatory bodies responsible for inspecting and overseeing laboratories to ensure compliance with biosafety guidelines. These bodies conduct assessments, provide recommendations, and issue certifications to laboratories that meet the required biosafety standards.

International Collaboration and Initiatives

Asia actively participates in international collaborations and initiatives aimed at promoting biosafety. For example, the Asia Pacific Biosafety Association (A-PBA) and the Association of Southeast Asian Nations (ASEAN) promote knowledge sharing, training programs, and harmonization of biosafety standards across the region.

Pathogen Security and Biosecurity

Biosafety efforts in Asia also encompass biosecurity measures to prevent the unauthorized access, theft, or intentional misuse of biological agents. Countries work on developing policies, procedures, and training to ensure the secure handling, transport, and storage of pathogens and maintain laboratory security.

Recommendations

- Use various agencies (ASEAN, CDC, WHO, etc) described criteria, tools and approaches to prioritize the high impact zoonotic pathogens specific to each country in SE Asia and to promote biosafety and biosecurity.
- Identify the target animal species to monitor for zoonotic pathogen spillover at the human-animal-environmental interface based on their susceptibility to the priority pathogens and the associated risk assessments (see Module 5, How to design and conduct risk-based surveillance for zoonotic diseases at the human-animal Interface).
- Prepare for pandemics of unknown emerging zoonotic diseases (WHO disease X) by use of agnostic detection methods (NGS, etc) and development or sourcing of broadly reactive pan-virus family vaccines and antiviral therapeutics.

Conclusions

The frequency of emerging/re-emerging zoonotic diseases has been accelerating in the past 26 years. A majority of these are RNA viruses that have emerged from wildlife reservoirs via direct spillover or through intermediate animal hosts. Prioritization of high impact zoonotic pathogens, especially those with pandemic potential, but also high impact animal pathogens in SEA, is critical to focus resources and the workforce. Sources for approaches and tools and several criteria used to prioritize high threat zoonotic pathogens and the potential animal hosts are provided. Moreover, the WHO scenario of "not *if* but *when"* a new zoonotic pathogen, "Disease X" will infect humans and cause the next pandemic requires novel agnostic approaches to zoonotic disease detection and monitoring and development of broadly reactive pan-virus family vaccines and antivirals.

We further use coronaviruses, including SARS-CoV-2, and influenza A viruses as case examples to illustrate the range of susceptible reservoir and intermediate animal hosts and to highlight targeted animal species to monitor for zoonotic transmission of these viruses to humans. Importantly in the context of One Health, we also emphasize the often-overlooked spillback of these viruses from humans into new animal hosts, which could maintain the virus in a new host reservoir community in which the virus could persist, evolve and spillback into humans, necessitating prevention and control, not only in humans, but also in the susceptible animal hosts.

TABLE 4-1. Primary sources for prioritization of high impact zoonotic and animal pathogens:

Source	**Title**	**Description**
ASEAN	ASEAN Strategy for Exotic, Emerging, Re-emerging Diseases and Animal Health Emergencies	*This strategic framework reflects all hazards related to biological threats approach adopted by the region and incorporates the lessons learnt from actual events, focusing on nine essential animal health functional areas necessary for AHEP, risk mitigation and response operations.*
CDC	Zoonotic Disease Prioritization Tool (ZDPT)	*Guidance with different lists for each country that goes through the process*
FAO	The Emergency Prevention System for Animal Health (EMPRES-AH); Enhancing the prevention and control of high-impact animal and zoonotic diseases through biosecurity and One Health	*This document describes the EMPRESAH Strategic Plan for 2023–2026, which provides a renewed approach for integrating biosecurity and One Health to support members in managing threats to animal health through enhanced early warning and progressive biosecurity management pathways. The Plan also supports the FAO Strategic Framework (2022–2031) and sustainable livestock transformation for progress towards the SDGs.*
WHO	WHO R&D Blueprint for Epidemics: Updating the WHO list of pathogens with epidemic and PHEIC potential (expected 2023)	*This document focuses on identifying prototype virus family members applicable to other potential threat viruses in the same family. The goal for prioritization is to review transmission, virulence (fatality, sequela rates) and availability of countermeasures for entire classes of viruses as well as the future Disease X threat.*

TABLE 4-2 Zoonotic Pathogens in South-East Asia with Pandemic-Causing Potential

Pathogen	**Source Reservoir**	**Intermediate host**	**Risk factors**	**Spillover causes**	**Location**	**Current Standing**	**Best practices for prevention:**
Henipavirus Nipah Virus (NiV)	Flying foxes or fruit Bats (Eaton et al., 2006)	Domestic animals (e.g., pigs, horses, dogs, cats, etc.) (Islam et al., 2023)	Food-borne (raw date palm sap, foraged fruits, bat bushmeat (Pteropus bats) close contact infected pigs, fruit bats, humans (Openshaw et al., 2017; Simons et al., 2014; Montgomery et al., 2008)	Habitat loss; climate change; food shortages in bats; water contamination; rapid urbanization; ecotourism (McKee et al., 2021)	Emerged as a large outbreak among pig farmers in Malaysia in 1998 (Chua, 2000 Nipah virus: a recently emergent deadly paramyxovirus) Singapore; Paton et al., 1999 Cambodia (Cappelle et al., 2020) Philippines (Alam, 2022 Nipah virus, an emerging zoonotic disease causing fatal encephalitis)	Malaysian government banned open farming of the pig industry; pig farms need to be in an enclosed environment.	Raising awareness among clinicians of signs, symptoms, and risk factors for NiV; contact tracing and quarantining of infected individuals; adhere to personal protective equipment (PPE)
Hendra Virus	Flying foxes or fruit Bats (Calisher et al., 2006). Flying fox species density; a spatial risk factor for Hendra virus infection in horses in eastern Australia	Domestic animals, mainly horses	Husbandry, management practices with Flying fox-horse interactions.	Infected commensal rodents (brown or Oriental House rats), cold, dry weather (Martin et al., 2018) Bat food shortages	Cambodia, China, Indonesia, Malaysia, Singapore, and Thailand (Quarleri, 2022 Henipaviruses: an expanding global public health concern)	Endemic, with yearly outbreaks, especially in major cities. Treatments have become standardized across health institutions, so fatalities are low.	Property attributes, husbandry and management practices that reduce flying fox-horse interactions; Vaccine treatments for horses available for use under permit by veterinarians
Influenza	Wild birds and poultry (Nabil et al., 2020)	Mammals including swine, cats, dogs, tigers, and leopards	Poultry trading, live poultry markets, cock fights, general poultry contamin	Wild birds, multiple poultry species in live	Cambodia, China, Indonesia, Japan, Lao PDR, Thailand, and Vietnam (Riedel, 2006)	(see text)	Vaccine-preventable in poultry with controversial control strategies including vaccination of

Pathogen	**Source Reservoir**	**Intermediate host**	**Risk factors**	**Spillover causes**	**Location**	**Current Standing**	**Best practices for prevention:**
Avian Influenza (H5N1) "G4" swine influenza Eura sian (EA) avian-like H1N1	 Pigs	(Amonsin et al., 2008) (Keawcharoen et al., 2004) (WHO, 2023b) (Wang and Palese, 2009)	ation (Hulse-Post et al., 2005; Leung et al., 2007)	markets (Nabil et al., 2020)	China (Sun et al., 2020)		domestic dogs and / or wildlife. Vaccines and anti-viral for humans; TIPRA
Coronavirus Sarbecoviruses SARS CoV SARS-CoV-2	 Rhinolopus bats (Alkhovsky et al., 2022)	 Civet cats, Racoon dogs (Freuling et al., 2020) Unknown (Pangolins? Zhao et al., 2020) Racoon dogs? Mallapaty, 2023)	Live wildlife markets (Naguib et al., 2021) Live wildlife markets (Aguierre et al., 2020).	Wildlife trade and consumption Unknown-wildlife trade and consumption? (Jiang and Wang, 2022)	Emerged in China, 2002-spread throughout SEA—29 countries (Huang, 2004; Lam et al., 2003) Emerged in China 2019 (Maxmen, 2022) Global Pandemic	Disappeared in 2004 but SARS CoVs still in bats Ongoing	Quarantine, contact tracing, adhere to wearing personal protective equipment (PPE) Early: Quarantine, contact tracing, adhere to wearing personal protective equipment (PPE) New vaccines, antivirals and monoclonal antibody treatments
Reston Ebola	Pigs, Macaque (Demetria et al., 2018)		Hunting of "bush meat", or direct contact with fruit bats (Baudel et al., 2019)	Infrastructure problems, low public awareness	Singapore Philippines (laboratory 2015) (Demetira et al., 2018)		

Pathogen	**Source Reservoir**	**Intermediate host**	**Risk factors**	**Spillover causes**	**Location**	**Current Standing**	**Best practices for prevention:**
Flaviviruses (e.g. West Nile, Dengue, Yellow Fever)	Bats, arthropods (Boys et al., 2020)					Ongoing outbreaks	Early detection; control vectors; vaccines and anti-virals
Filoviruses (e.g. Ebola, Marburg)	Bats, rodents, arthropods (potential) (Olival and Hayman, 2014)	Hominids	Direct contact with infected host (Smiley-Evans et al., 2018)		Central Africa; projection models into SEA (Peterson et al., 2004 Ecologic and geographic distribution of filovirus disease)	Ongoing outbreaks	Early detection; quarantine; PPE
Poxviruses (Mpox)					Multiple continents (Zhai et al., 2022)		
Paramyxovirus (measles virus, mumps virus, parainfluenza virus, respiratory syncytial virus (RSV)	Bats, rodents for emerging species (Thibault et al., 2017)						

TABLE 4-3 Important Zoonotic Pathogens in South-East Asia

Pathogen	**Source/reservoirs**	**Intermediate host**	**Risk factors**	**Spillover causes**	**Location**	**Current Standing**	**Best practices for prevention:**
Bacteria							
Anthrax *Bacillus anthracis*	Animal (ungulates) Soil (stable environmental reservoir) (Carlson et al., 2019b)	Unknown	Inhalation of spores (CDC, 2018)	Farming Consumption of infected meat (Ndolo et al., 2022; Wang et al., 2024)	Myanmar Cambodia Lao PDRs Indonesia Philippines Vietnam (WHO, 2008)	Sporadic	Understanding the enzootic reservoir of B anthracis on farmlands
Melioidosis *Burkholderia pseudomallei*	Soil (Pongmala et al., 2022) Contaminated water (CDC, 2023c) Various mammals, reptiles (Kelser, 2016)	N/A	Diabetes (Chowdhury et al., 2022)	Inhalation, consumption or of inhalation of contaminated dust or water droplets, ingestion of contaminated water, and direct contact with contaminated water or soil, particularly through cuts or abrasions (Virginia Department of Health, 2018)	Thailand (Hinjoy et al., 2018); (Bulterys et al., 2018) Malaysia (Butlerys et al., 2018); (Kingsley et al., 2016)		Understanding the geodistribution of Bulkholderia
Group B Streptococcus *Streptococcus algalactiae*	Fish (Chau et al., 2017)			Consumption of under cooked contaminated fish (Singapore Food Agency, 2022)	Singapore (Schar et al., 2023) (Rajendram et al., 2016)		Consume well cooked fish

Pathogen	**Source/reservoirs**	**Intermediate host**	**Risk factors**	**Spillover causes**	**Location**	**Current Standing**	**Best practices for prevention:**
Group D Streptococcus *Streptococcus suis*	Pig (Kerdsin et al., 2023)			Consumption of undercooked pork (Praphasiri et al., 2015)	Vietnam, Thailand (Kerdsin et al., 2022)		Consume well cooked pork
Leptospira	Rodents Association of rodent-borne Leptospira spp. with urban environments in Malaysian Borneo (Blasdell et al., 2019)	Cats, dogs, horses (Azócar-Aedo, 2023)		Consuming infected urine contaminated food, water (CDC, 2015)	Throughout SEA (Douchet et al., 2022)		Improve hygiene, manage the population of rodents.
Coxiella burnetii	Water buffalo, cattle, goat and sheep Chicken (Celina and Cerny, 2022; Sethi et al., 1978)			Inhalation of infectious aerosol or airborne dust, ingestion of milk or milk product from infected animals (CDC, 2019b)	Philippines (Galay et al., 2020) Thailand (Doung-ngern et al., 2017)		Pasteurize milk and dairy products
Parasites							
Schistosomiasis	Animals (Mammals) (Gordon et al., 2019)	Snails (Sokolow et al., 2016)	Anemia, stunted growth, cognitive impairment, fatigue, infertility, liver fibrosis and bladder cancer (Sokolow et al., 2016)	Contact with intermediate host snails shed (Sokolow et al., 2015)	China, Philippines, Indonesia, Cambodia, Lao PDRs (Ross et al., 2013)		Avoid wading in fresh water or drinking unboiled water in area where schistosomiasis is endemic.

Pathogen	**Source/reservoirs**	**Intermediate host**	**Risk factors**	**Spillover causes**	**Location**	**Current Standing**	**Best practices for prevention:**
Leishmaniasis Leishmania parasite	Humans, animals (mammals) (Reithinger et al., 2016)	Sand fly, (Cecílio et al., 2022)	Fever, anemia and leukopenia (Ready, 2014)	Transmitted by the bite of an infected sand fly vector (WHO, 2023a)	India, Thailand (Krayter et al., 2015)		Vector control. Avoid sandfly bites in areas where Leishmania is endemic
Plasmodium knowlesi	Long-tailed macaques (Jeyaprakasam et al., 2020)			Transmitted by the bite of vector mosquitoes (Fornace et al., 2023)	Malaysia Indonesia Singapore Thailand Vietnam (Shearer et al., 2016) Thailand Lao PDRs (Jongwutiwes et al., 2004; Iwagami et al., 2018)		Vector control
Viruses							
Hantavirus	Rodents (Hamdan et al., 2017) Bats (Zana et al., 2019)		Haemorrhagic fever with renal syndrome (Hamdan et al., 2017)	Inhalation of aerosolised infectious particles (ECDC, n.d.)	Malaysia Indonesia (Lukman et al., 2019)	Lack of surveillance data. Seropositivity was reported in 2001.	Rodent control

Pathogen	**Source/reservoirs**	**Intermediate host**	**Risk factors**	**Spillover causes**	**Location**	**Current Standing**	**Best practices for prevention:**
Japanese encephalitis	Pigs Waterbirds such as egrets (SHIC, 2018)	Culex mosquitoes (CDC, 2022c)		Mosquito bites (Mulvey et al., 2021)	Japan, Thailand, Philippines, Indonesia (Kuwata et al., 2020)		Vector control
Herpes B virus	Macaques (Hilliard, 2011)			Bite and scratches from macaques, contaminated needle, contamination of wounds with macaque saliva (Weigler, 1992)	China (Zhang et al., 2022)		Avoid physical contact with macaques.
Hepatitis E	Pigs, rabbits, bats (Wang et al., 2023b) Rodents (Reuter et al., 2020)		Severe liver disease (Zhang et al., 2017)	Consuming contaminated drinking water, uncooked or raw animal meat (CDC, 2020)	Cambodia, Lao PDRs, Indonesia, Singapore, Thailand, Vietnam, Malaysia (Raji et al., 2017) China (Ren et al., 2017)		

Pathogen	**Source/reservoirs**	**Intermediate host**	**Risk factors**	**Spillover causes**	**Location**	**Current Standing**	**Best practices for prevention:**
Rabies Rhabdovirus	Wildlife Dogs (Ahmed et al., 2015) Cats and bats (Gautret et al., 2015)			Bite and scratch from infected animals (CDC, 2019a)	Lao PDRs (Ahmed et al., 2015) Thailand (Thanapongtharm et al., 2021)	Ongoing	Vaccination of dogs and cats, dog /cat population control
Pteropine orthoreovirus	Frugivorous bats (Egawa et al., 2017)	Cynomolgus macaques (Tan et al., 2019)		Close contact with bats and excrete/inhalation of aerosol (Tan et al., 2019)	Phillipines China Indonesia Malaysia (Egawa et al., 2017; Tee et al., 2023)		Unknown Avoid contact with bats and excreta
Bovine Spongiform Encephalopathy (BSE)	Pigs, sheep (Hedman et al., 2016; Marin et al., 2021)			Consuming contaminated meat or meat product (Concepcion and Padlan, 2003)	Multiple countries (Kumagai et al., 2019)		Test ungulates for prion diseases and slaughter positives

TABLE 4-4. High Impact Emerging/re-emerging Animal Pathogens in South-East Asia

Pathogen	Source / Reservoir Host	Intermediate Host	Risk factors	Causes of Spillover:	Location	Current Standing	Best practices for prevention:
African Swine Fever asfivirus	Bushpigs and warthogs (Oura et al., 1998)	All suidae are susceptible (Oberin et al., 2022)	Contaminated swine carcasses, swine products & wastes (Taylor et al., 2020)	Poor biosecurity and hygiene, Swine/pork trade (Nantima et al., 2015; Matsumoto et al., 2021)	Multiple countries (Gallardo et al., 2015)	Stable	Cases have decreased due to good sanitation practices in humans working with swine (i.e. masks and hand washing) but continued outbreaks and re-emergences occur Biosecurity, quarantine and culling, control transport pigs/swine products
Foot and mouth disease (FMD) Aphthovirus	Ruminants such as cattle, sheep, and goats (WOAH, n.d.-b.)	Pigs (Iowa State University College of Veterinary Medicine, n.d.)	Recovered or vaccinated animals subsequently exposed to FMDV may become carriers and subclinically infected animals are contagious. (Gortázar et al., 2022)	Wildlife reservoir (Rahman et al., 2020b)	Multiple countries (USDA, 2021)		Quarantines, culling of positive animals/herds, vaccines
Canine Distemper Morbillivirus	Canidae (dogs are the main reservoir) (Kapil and Yeary, 2011)	Mustelidae, Procyonidae, Hyaenidae, Ursidae, Viveridae (Kapil and Yeary, 2011)	Wildlife spillover/spillback (Beineke et al., 2015)	Increase in dog population worldwide and widespread urbanisation (Kapil and Yeary, 2011)	Multiple countries (Duque-Valencia et al., 2019)		Vaccination
New Castle Disease Virus NDV disease Paramyxovirus	Avian species Hypervirulent strains are maintained in chickens; avirulent strains have been found in urban and migratory birds such	Poultry is susceptible (Dimitrov, 2023)	Possible spillover from migratory birds to poultry (Brown and Bevins, 2017)	Increase in poultry farming (Puro and Sen, 2022)	Multiple countries (WOAH, n.d.-c.)		Vaccination

Pathogen	Source / Reservoir Host	Intermediate Host	Risk factors	Causes of Spillover:	Location	Current Standing	Best practices for prevention:
	as pigeons and fowls. (Snoeck et al., 2013)						
Lumpy skin disease Capri poxvirus	Ruminants especially cattle (Boss spp.) and buffaloes (Bubalus spp.) (Ratyotha et al., 2022)	Giraffe, impala eland wildebeest bulls, and springboks (Ratyotha et al., 2022)	Blood sucking athropods such as stable flies (Stomoxys calcitrans), mosquitoes (Aedes aegypti), and hard ticks (Rhipicephalus and Amblyomma species), house fly (Musca domestica) (Sprygin et al., 2019)		Myanmar, Vietnam and Thailand (Ratyotha et al., 2022)		Vaccination and enhanced biosecurity; vector control (Dubey et al., 2023)
Peste des Petits Ruminants Virus (PPRV) Morbillivirus	Small ruminants such as sheep and goats. Wild ruminants such as ibex and gazelle. (SowjanyaKumari et al., 2021; Asil et al., 2019)	Cattle, Large ruminants such as water buffalo, pigs (Rahman et al., 2020a)	Close contact with infected animals via inhalation of infectious nuclei; biting midges (Culicoides imicola) (Rahman et al., 2020a)		Africa, China (Mantip et al., 2019; Wang et al., 2009)		

TABLE 4-5 Possible target animals to monitor for CoV zoonoses

Animal	**Hosts/viruses**	**References**
Bats	SARS-r CoVs; SARS-CoV-2; MERS CoV, endemic human CoVs	(Delaune et al., 2021)
Felids	SARS, SARS-CoV-2	(Ferasin et al., 2021; Giraldo-Ramirez et al., 2021; Siegrist et al., 2023)
Pangolins	SARS-CoV-2 targeted surveillance and specimen testing of pangolins trafficked through and confiscated in Vietnam	(Nga et al., 2022; Peng et al., 2021; Huang et al., 2023)
Carnivores	SARS spillover from civet cats and raccoon dogs in wet markets to humans; detection of a new canine alphaCoV in humans, HuPn-2018 and Z19	(Vlasova et al., 2020; Lednicky et al., 2021)
Ungulates-	Cattle (endemic human CoV OC43), camelids (endemic human CoV 229E, MERS CoV-ongoing), cervids (SARS-CoV-2-spillover from humans into white-tailed deer and spillback from deer into humans	(Pickering et al., 2022; Palmer et al., 2021; Chandler et al., 2021; Hale et al., 2022; Caserta et al., 2023)
Rodents	Endemic human CoV HKU1, OC43; SARS-CoV-2, hamsters	(Wang et al., 2023a)
Swine (PDCoV, SADS)		PDCoV (Zhang et al., 2016; Li et al., 2022; Lednicky et al., 2021; Saif et al., 2019)
Birds (DCoV)		(Vlasova et al., 2020)

TABLE 4-6 SEA region biosafety organizations and resources

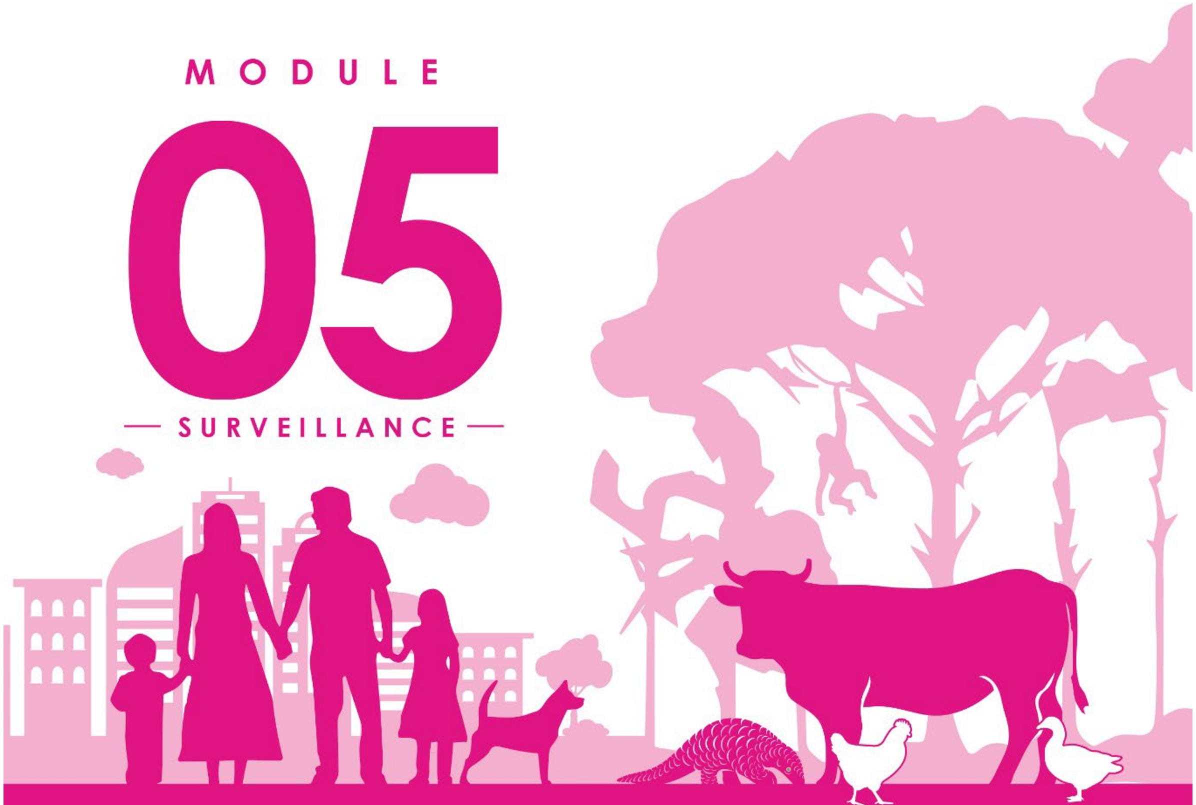
Country	Title	Link
Burma (Myanmar)	National Health Laboratory, Myanmar	10.1371/journal.pone.0273380
Cambodia	National Institute of Public Health; Institut Pasteur du Camboge	http://hismohcambodia.org/public/fileupload/EMP%20of%20NIPH%20 Lab%20FINAL.pdf; https://pasteur-network.org/en/members/asian-region/institut-pasteur-du-cambodge/
China	National Security Commission; Wuhan National Biosafety Laboratory; Biosafety Lvel 4 training; Biosafety Law of the People's Republic of China, October 17, 2020	https://lssf.cas.cn/en/facilities-view.jsp?id=ff8080814ff56599014ff59e677e003d; https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6478205/; http://www.npc.gov.cn/npc/c30834/202010/bb3bee512285 4893a69acf4005a66059.shtml
Indonesia	Indonesia Biosafety Clearing House; Indonesian Biorisk Association	https://indonesiabch.menlhk.go.id/ https://internationalbiosafety.org/ifba_members/indonesian-biorisk-association/
Lao PDR	Institut Pasteur du Laos	https://www.pasteur.la/project-carried-on-in-the-lab/project-03/ biosafety-lab/
Malaysia	Malaysian Biosafety and Biosecurity Association	https://mbba.my/ https://internationalbiosafety.org/ifba_members/malaysian-biosafety-biosecurity-association/
The Philippines	Biorisk Association of the Philippines; National Training Center for Biosafety and Biosecurity	https://internationalbiosafety.org/ifba_members/biorisk-association-of-philippines/ https://nih.upm.edu.ph/institute/national-training-center-biosafety-and-biosecurity
Singapore	Biorisk Association of Singapore; Ministry of Health Biosaftey	https://internationalbiosafety.org/ifba_members/biorisk-association-of singapore/https://www.moh.gov.sg/biosafety/useful-info/useful-info-and-guidelines

Country	Title	Link
Thailand	Biosafety Association of Thailand; BIOTEC Biosafety Program	http://biosafetythailand.org https://www.biotec.or.th/home/en/biosafety-program-en/
Viet Nam	Viet Nam Field Epidemiology Training Program	https://www.tephinet.org/training-programs/vietnam-field -epidemiology-training-program

MODULE

05

— SURVEILLANCE —



How to Design and Conduct Risk-Based Surveillance at the Human-Animal Interface

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How to Design and Conduct Risk-Based Surveillance at the Human–Animal Interface

INTRODUCTION

In 2018, the FAO-WHO-WOAH Tripartite (the Tripartite) called for the development or improvement of coordinated One Health surveillance systems within member countries and regional networks (FAO, WOAH, and WHO, 2019). Surveillance systems, whether they are risk-based or not, are defined as ongoing efforts, whether active or passive, aiming at detecting cases of disease (Thacker and Berkelman, 1988). Risk-based surveillance takes advantage of information about known or suspected high-risk targets to narrow surveillance efforts, often as a way to optimize use of limited resources (Bordier et al., 2020). This approach naturally aligns with One Health systems that target both human and animal populations, and ideally employ environmental monitoring as well (Berezowski et al., 2023). However, sector-specific resources and authorities remain as major gaps in achieving effective coordination among human, animal, and environmental monitoring and response activities (Sharan et al., 2023). This module aims to provide guidance on the design and execution of risk-based surveillance at the interface of human–animal–environmental health, where the risk of spillover is known or suspected to be higher.

RISK-BASED ONE HEALTH SURVEILLANCE APPROACHES

To carry out risk-based One Health surveillance, One Health authorities (typically ministries of health, agriculture and animal health, natural resources, and the environment) interact with community partners, One Health researchers, their networks, and policymakers to conduct activities in an iterative way (WHO, 2017b). In the context of early detection and rapid response, regional and local surveillance programs are critical to identify initial cases of spillover, document potential human-to-human transmission, and inform efforts to intervene to avert outbreaks, emerging epidemics, and pandemics (Berthe et al., 2022; Tufts University Consortium, 2022). At national and international levels, triangulation of data from disparate sources, including human, animal, and environmental domains, and considering the potential for transboundary movement of disease, aids in understanding the scope of the event, transmission pathways, and potential intervention points (Figure 5-1). Within surveillance systems, disease reporting and laboratory networks may rely on established mandatory reporting requirements at multiple levels of governance or institutional structure (Nsubuga et al., 2006), whereas syndromic surveillance may use emerging technologies, such as text data mining and intelligence (AI) based systems (Box 5-1) (Zeng et al., 2021). Sampling programs may be part of established initiatives, such as occupational health surveillance (Lele, 2018), or may rely on clinical populations and research initiatives for some or all of the data. In this, the data integration and decision-making may be based on One Health approaches, although the individual surveillance systems may not be.

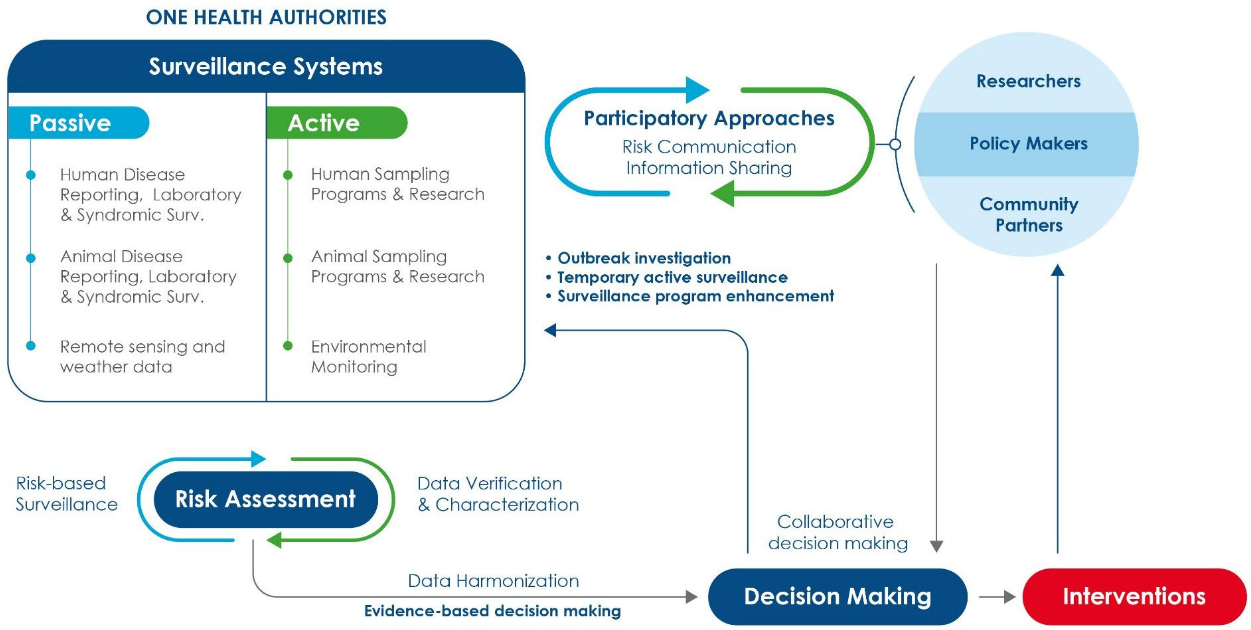

FIGURE 5-1 Interactions among partner groups and iterative activities for One Health surveillance, risk assessment, and decision-making using participatory approaches.

Risk-based approaches often aid in the prioritization of targets for surveillance or intervention and may be based on traditional risk assessment processes used widely on a global scale for public health efforts. When these are targeted to One Health approaches and context, activities typically involve identification of higher-risk human and animal populations and geographic regions or high-risk microenvironments (e.g., live animal markets). Ultimately, information from surveillance systems often guides risk assessment and decision-making, e.g., restrictions on trade or transport of animals or their products or the initiation of infection control, enhanced biosecurity or quarantine measures in response to an ongoing outbreak (Thacker and Berkelman, 1988). For example, during the 12 years of avian influenza surveillance from 1999 to 2011 in Hong Kong, the authorities implemented a series of interventions to control outbreaks of the H5N1 influenza virus in live poultry markets and poultry farms (Leung et al., 2012). These included (1) implementation of a monthly rest day, (2) a mandate that all poultry in live poultry markets be sold or slaughtered at the end of each day, (3) a requirement that poultry stalls be cleaned and disinfected and (4) that stalls must be left free of live poultry for 1 day before restocking, (5) prohibiting the sales of live quail, and (6) a complete ban on holding live poultry overnight in 2008. These have been shown effective in reducing viral amplification and persistence in live poultry markets while also mitigating the risk of avian influenza transmission to humans (Leung et al., 2012).

Known zoonotic pathogens can be regularly monitored with animal surveillance and functioning veterinary service systems. The World Organization for Animal Health (WOAH) publishes Performance of Veterinary Services (PVS) standards that are widely used to track national veterinary capacity and surveillance (WOAH, 2019; WOAH, 2023). However, the PVS primarily addresses domestic animal health standards. Notably, wildlife are most likely to harbour a new zoonotic pathogen with pandemic potential that can either directly spillover into people or pass through an intermediary domestic animal host (Module 3; Jones et al., 2008). It is likely that emerging pathogens will evade detection until they cause noticeable illness or mortality in humans or animals identified through surveillance activities. WOAH also has published a National Wildlife Health Surveillance framework (WOAH, 2022), but the use of such surveillance systems remains the exception rather than the rule (Machalaba et al., 2021). For example, surveillance of Lao PDR's wildlife trade only recently detected a high prevalence of leptospirosis (20%) in all traded animals as well as rickettsial species responsible for murine typhus, revealing a 'substantial risk for exposure through handling and consumption of wild animal meat' (Nawtaisong et al., 2022; Phongmany et al., 2006).

Participatory approaches, in which community members are engaged in the design and conduct of surveillance systems, can enhance quality of reporting and accelerate detection and response efforts (Mariner et al., 2011). Ideally, community-based participatory approaches to surveillance and response efforts are built on and oriented to what communities identify as priorities, and the efforts typically are conducted by community members (Palmer and Duclos, 2023). However, specific activities may fall along a spectrum of community engagement and participation, from community-led efforts to those led by national authorities or researchers who work with communities to incorporate their needs into surveillance and mitigation efforts. Participatory and public-based surveillance of small livestock holdings can greatly expand the number of engaged observers within a national, regional, or local framework. For example, there is a mobile-phone-based Participatory One Health Digital Disease Detection (PODD) project in Thailand, and a similar project in Africa: Enhancing Community-Based Disease Outbreak Detection and Response in East and Southern Africa (DODRES). Other examples are wildlife health surveillance networks, such as the WildHealthNet initiative (Pruvot et al., 2023) and the Wildlife Conservation Society's SMART FOR HEALTH. When communities themselves define high-risk priority interfaces, they are more likely to engage in implementation of interventions to reduce or mitigate the risks.

DESIGNING ONE HEALTH SURVEILLANCE AT THE HUMAN-ANIMAL INTERFACE

One Health surveillance efforts that address high-risk human-animal-environmental pathogen interfaces and their potential for use in monitoring programs aid in spillover detection and response (Bordier et al., 2020). Surveillance efforts can take numerous forms and be either passive or active (Figure 5-1) (Nsubuga et al., 2006). Passive collection of human or animal health data relies on reporting disease from human and animal healthcare providers, local health departments, local animal health ministries, and similar groups (Murray and Cohen, 2017). Disease reporting therefore may be less timely or depend on the provision of a diagnosis (Jajosky and Groseclose, 2004). Other passive systems include clinical, reference and public health laboratories and networks that compile and report information about pathogen detection and other pathogen characteristics, and given sufficient resources, include pathogen genomic sequencing and analysis to identify key virulence factors (e.g., the polybasic cleavage site in the hemagglutinin of avian influenza viruses). Such efforts aid in the detection of novel variants, and guide investigation of outbreaks using genomic epidemiology supported by meta-data, ideally including host and geotemporal data (Nsubuga et al., 2006). Remote sensing and other sources of weather data also may be important to inform prediction of outbreak events based on risk factors related to temperature, rainfall, sea surface temperature and wind patterns (e.g., vector-borne diseases or cholera) (Kuhn et al., 2005). Finally, syndromic surveillance relies on reporting at the population level (e.g., via intelligence (AI) systems) (Box 5-1) of clusters of cases based on symptoms rather than disease diagnosis (Groseclose and Buckeridge, 2017). Surveillance for influenza-like illness is an example of this, where healthcare systems may monitor the number of people with respiratory symptoms as their primary presenting complaint, where pharmacy systems track purchase of common over-the-counter medications used to alleviate respiratory symptoms, or where AI algorithms track online queries related to respiratory illness. Syndromic surveillance at the individual host level (e.g., presentations of foetal demise, encephalitis, or haemorrhagic fever) often are reportable and provide early warning of emerging infectious diseases (Henning, 2004).

In contrast, active collection of surveillance data and/or samples relies on trained personnel, often at regional or national levels in ministries of health or agriculture, who administer surveys, collect samples and aggregate data, or perform other information-seeking activities (Murray and Cohen, 2017). This may be augmented by targeted programmatic or research activities by non-profit organizations or academic partners, e.g., via the Southeast Asia One Health University Network (SEAOHUN). Active surveillance often provides more timely results better targeted to higher-risk populations but also has higher resource costs in personnel, materials, and other supplies (Nsubuga et al., 2006). These efforts also may require more substantial investments in One Health workforce expertise, although it is important to note that expertise is essential for a wide range of surveillance efforts. Further, investment in programs that use active sampling approaches, such as collection of environmental DNA (eDNA) for non-targeted sequencing, or targeted sequencing of pathogens, can inform passive approaches (Rishan et al., 2023). There are numerous approaches to surveillance (Table 5-1) which may be used alone or in combination depending on the goal of the surveillance activity.

Syndromic Surveillance

Risk-based monitoring for severe respiratory and neurologic syndromes or foetal demise in humans and animals relies on accurate and comprehensive knowledge of key risk factors, including occupational or other behavioural risk factors and pathogen epidemiology (Sosin and DeThomasis, 2004). Syndromic surveillance allows for earlier detection of clusters of similar disease in time or geographic region, and therefore can be particularly important for novel diseases because these may be threat-agnostic, i.e., the hazard does not need to be known in advance (Henning, 2004). Syndromic surveillance can be limited by lack of human health or veterinary care-seeking or access, non-specific (e.g., fever) clinical or subclinical presentations, or lack of reporting mechanisms (Elliot et al., 2020).

TABLE 5-1. Approaches to surveillance activities

Surveillance Approach	Description	Role in Risk-Based Approaches
Syndromic surveillance	Use of symptom data to identify clusters of disease in time or space	Identify populations or areas of higher risk
Laboratory surveillance	Use of laboratory reporting data or specimens to identify clusters or diagnose outbreaks	Identify related strains across time and space to inform response and outbreak investigation
Seroepidemiological studies	Use of biospecimen repositories (serum samples) for novel targets	Inform knowledge of risk factors
Environmental surveillance	Active sampling of environmental media for pathogens	Environmental locations informed by risk analysis
Event-based surveillance	Use of information outside of normal reporting systems to identify disease clusters	Identify populations or areas of higher risk

Laboratory Surveillance

When samples from humans or animals are collected through routine health assessments, i.e., a test ordered by a physician, laboratory detection of pathogens can be used to identify unexpected clusters of pathogens (Nsubuga et al., 2006). When bacteria are cultured or viruses detected as part of these efforts, further characterization of the pathogen (antimicrobial susceptibility, genomic sequencing) can aid in identification of related strains of the pathogen, and this can help to enhance case identification for outbreak investigations that are more likely related in terms of transmission events. This approach requires laboratory standardisation in diagnostic testing, lab accreditation and quality control programs, and access to reference laboratories for confirmation. This also requires the robust maintenance of laboratory biosafety and biosecurity standards (Taylor et al., 2017).

Seroepidemiological Studies

In addition to activities that target sampling of humans or animals and use of the biospecimens for microbiological and immunological assays to detect known or emerging diseases or host responses to them (Murphy, 2008), some activities can use established repositories such as blood donation banks or military archives to identify prevalence of prior exposure (Cariappa et al., 2004; Zhang et al., 2020). These benefit by being more population-based and feasible to access, assuming the repositories have been established and maintained in a way that allows such use. Access to standardised protocols and reagents is also an important enabling factor. However, biorepositories for animal specimens are limited and national laboratories may not have resources for longer-term storage of samples (Module 4), which offers an opportunity for resource investment. Another consideration is the use of salivary antibody testing in lieu of blood antibody testing for high-risk human populations (such as animal or abattoir workers) who are averse to blood draw for serological testing, if salivary antibody tests are available (Pisanic et al., 2020; Thomas et al., 2023). Given that few salivary biospecimen repositories exist, this may require active surveillance and *de novo* sample collection.

Environmental Surveillance

Environmental surveillance may include wastewater (including litter, manure, and effluent from markets), bioaerosol and surface sampling, as has been done for influenza virus of swine origin in swine production facilities (Anderson et al., 2017; Prost et al., 2019) or for *Chlamydophila psitacci* (bioaerosols) in slaughterhouses (Dickx et al., 2010). Locations of high concentrations of animals in the human food chain (and thus associated with exposure) include animal production facilities, wet markets, slaughterhouses, and abattoirs (Al-Gheethi et al., 2021; Clark, 2022; Lin et al., 2021). High-throughput DNA sequencing can be used to identify animal species (Suminda et al., 2022) kept in live animal markets and whether they are illegal species, which can inform enforcement efforts. For example, one study demonstrated that airborne eDNA used to monitor and confirm animal species was sufficiently sensitive to detect dead animals fed to zoo animals as well as rodents (Lynggaard et al., 2022). Additionally, environmental surveillance should include monitoring anthropogenic changes related to land use and deforestation, as these actions may put animals under stress and impact viral ecology and spillover through altered proximity dynamics.

Event-Based Surveillance

In contrast to classic surveillance activities in which collection occurs routinely and action may be based on defined criteria, such as thresholds for number or rates for cases, event-based surveillance captures information through less formal channels and outside standard reporting systems. An early warning system can be established from event-based surveillance, identifying unusual health events or trends in human and animal health, which can serve as signs of disease emergence. For example, this could take place through media reports or community groups and may be verified through formalized processes; the World Health Organization has published guidance for establishment of these systems (WHO, 2014). For example, Lao PDR has adopted an event-based surveillance system and has a standard operating procedure (SOPs) with four components: community engagement, health facility-based surveillance, hotline, and media monitoring; the WHO is providing technical support. These activities (i.e., considering the network, actors within the system, their role, etc.) inform policy development. Affordable monitoring of targeted specific species, especially those identified as reservoirs and intermediate hosts, can be implemented as a crucial component of wildlife disease surveillance, especially in the context of constraints on diagnostic capacities (Kelly et.al, 2021). A remaining challenge is that this requires ample time for development of government support, and there are additional challenges of sustainability.

BOX 5-1
Artificial Intelligence and One Health

Artificial intelligence (AI) plays an increasingly crucial role in One Health, which focuses on the intersection of human, animal, and environmental health (Ezanno et al., 2021). AI methods can help organize the vast amounts of data that are central to the One Health approach by detecting outbreaks, predicting disease spread patterns, contributing to drug discovery, and optimizing resource allocation for interventions across different species and ecosystems (Malik et al., 2021; Seifman, 2023; Qureshi et al., 2021). AI methods can integrate large amounts of data from different sources and synthesize information across multiple systems, helping scientists understand zoonotic diseases and identify potential interventions (Pillai et al., 2022). For example:

1. Machine Learning algorithms analyse large datasets to identify patterns and predict disease outbreaks, track environmental changes, and assess the effectiveness of interventions.
2. Deep Learning techniques assist in image and sequence data analysis for medical imaging, tracking wildlife movements, and analysing genomic sequences.
3. Natural Language Processing enables the extraction of valuable insights from textual data, such as medical records, One Health-related reports, scientific literature, and social media posts.
4. Network Analysis methods can efficiently and accurately model complex interactions among hosts, pathogens, vectors, and environmental factors to help develop disease transmission pathways, identify key nodes for targeted interventions, and predict disease spread patterns within and across populations.
5. Predictive Analytics, such as Bayesian networks and decision trees, can forecast disease outbreaks, assess the impact of climate change on disease distribution, and optimize resource allocation for disease control measures.
6. Robotics and other autonomous systems are used for surveillance, sample collection, and monitoring environmental parameters in remote or hazardous areas, facilitating data collection in challenging environments (forests, oceans, and disaster zones) to support early warning systems and ecosystem health monitoring.

One Health approaches are based on data, and AI methodologies offer efficient and creative ways to harness data for good. However, AIs are accompanied by concerns with bias, access, cost etc. The concepts of "FAIR(ER)" (Findable, Accessible, Interoperable, Reusable, Ethical and Revisable) are essential to address deep-seated inequities that characterize so many global arenas. Calvin Wai-Loon Ho published a call for a One Digital Health Framework (Ho, 2022) that argues for:

"a dedicated global ODH framework that also augments current ABS provisions in the CBD and NP as an ABS+ Framework. In essence, this ODH framework should apply to both human and non-human biological materials and related data, put into effect the FAIRER principles (more aligned with global justice under the SDGs) through arrangements like federated data systems, and shift toward multilateralism."

RISK-BASED APPROACHES

Regardless of the approach used for surveillance, selection of surveillance targets (human populations, animal populations, environmental sites) can rely on risk assessment and target interfaces established or suspected to be of higher risk to maximize use of limited resources, i.e., identify targets for surveillance or intervention that have a higher benefit-to-cost ratio. Risk-based approaches also can inform interventions, such as restriction of the live trade of high-risk reservoir host species in urban markets where alternative protein sources are available (Module 2). Wildlife meat products still may carry pathogens (Espinosa et al., 2020), but any unobserved processes of pathogen amplification or viral recombination and evolution are reduced. In this, there are dual needs for coordination—first to interpolate data and biosurveillance strategies, e.g., through identification of common targets (Box 5-2), and second to integrate surveillance with response and control efforts (Nsubuga et al., 2006; Zinsstag et al., 2020).

Approaches to risk-based surveillance in animal populations benefit from consideration of infection dynamics within any given host population (Stark et al., 2006). For example, reservoir animal hosts often carry infectious agents without showing many or any symptoms of disease and may not shed the infectious agent (virus, etc.) routinely, which limits the utility of methods that rely on pathogen detection or isolation (Module 4) unless sampling occurs during periods of high shedding (e.g., during stressor events). Similarly, risk-based environmental strategies need to consider the detection method (PCR, pathogen isolation, etc.) and the stability of that target over time given the organic matrix of the waste or wastewater, since agents may die, and genetic material may degrade given environmental conditions and time. On the other hand, certain host genera or species (i.e., kinds of animals), such as bats, rodents, and birds (Table 4-5; Module 4), are in a higher-risk category for potential to carry established and novel zoonotic agents, including those with pandemic potential.

Box 5-2
Avian influenza example

Although laboratory-confirmed cases of highly pathogenic avian influenza viruses have been associated with high mortality in humans (59%), true infection rates are unknown in the absence of sound seroepidemiological studies (Butler, 2012). Prior studies have identified seroprevalence ranging from 0 to 3.2% depending on exposure, HPAI viral subtype, and clade. One longitudinal study in southern China, however, revealed 54.2% live poultry market workers were seropositive with antibodies to H7N9 virus, suggesting that this workforce is at higher risk and may be a useful target for active surveillance activities (Wang et al., 2014). Incidence of infection among poultry workers varies, with incidence density higher for H5N1 clade 2.3.4 (3.8/1,000 person-months) compared to other H5N1 clades (0.3/1,000 person-months for clade 2.3.2.1 and H7N9 viruses (1.6/1,000 person-months) in one study from Beijing, China (Yang et al., 2016).

The use of new risk assessment tools to predict virus emergence or identify areas of higher risk for spillover events can guide selection of target populations (Salerno et al., 2017; Vora et al., 2023). Classic risk assessment techniques adapted from assessment of environmental toxins include problem formulation, hazard identification, exposure assessment, risk characterization, risk management, and risk communication, ideally within a participatory approach framework (NRC, 2009). These may be important to consider because of their widespread use for other public health activities at regional, national, and international levels, including decision-making that involves large industries. The International Union for Conservation of Nature (IUCN)-WOAH *Guidelines for Wildlife Disease Risk Analysis* (2014) is one more recently developed disease risk assessment tool based on classic risk assessment processes adapted for and intended to inform animal value chain decision-making around movement of wildlife and wildlife products. A tool that focuses on the pathogen rather than on the target population is the Influenza Risk Assessment Tool (IRAT) developed by the U.S. CDC (Cox et al., 2014); this is a 10-element assessment conducted by influenza experts that helps to prioritize virus strains in terms of their pandemic potential.

The Tripartite has produced three operational tools to help support One Health risk-based surveillance activities: the Multisectoral Coordination Mechanism Operational Tool (MCM OT) the Joint Risk Assessment OT (JRA OT), and the Surveillance and Information Sharing OT (SIS OT). Specifically, the MCM OT offers a process to establish and strengthen governmental multisectoral coordination to manage zoonotic diseases and other health events at the human–animal–environmental interface; the JRA OT is an expert-based process to conduct One Health risk assessment; and the SIS OT provides a process to help support coordinated surveillance activities and information sharing, for example, the Tripartite Zoonoses Guide. Other tools include the Strategic Tool for Assessing Risks (STAR).

Recommendations On how to Conduct Risk-Based Surveillance at the Human–Animal Interface

Recommendation A: Use aids developed for risk-based approaches to prioritize resources and target high-priority areas and populations

Whether risk assessment is used in the selection of target human or target animal populations (Box 5-3) or environmental sites or not, there are strengths and limitations to different approaches (Table 5-2). Common considerations include whether a population is well enumerated or otherwise defined—specifically whether there are lists of known people or identified locations with known numbers and types of animals—and whether or not a population is accessible—specifically whether employers or community leaders will allow engagement or whether animal owners will allow access for surveillance purposes (Box 5-4). Another key consideration for the animal populations is not just whether they are identified at the group level (e.g., a herd of cattle linked to the geographic location of a farm) but also whether they are identified at the individual level (e.g., animal identification tattoos, tags, or other devices for domestic animals). National or regional requirements for individual animal identification—or requirements tied to global trade or compliance with International Health Regulations—may aid in enumeration efforts and improve traceback in the event of an outbreak.

TABLE 5-2. Strengths and limitations of different populations of humans or animals used as surveillance targets— as identified by risk-based approaches for active and passive surveillance activities

Population	Strengths	Limitations
Humans		
Occupational cohorts—animal (e.g., livestock producers, other food industry workers, wildlife traders/hunters, fisheries/forestry workers, veterinarians/allied professionals)	• May be enumerated/well-defined • Have known animal exposures	• Accessibility may be inconsistent (e.g., supervisor permissions, risks of retribution from employers for participation)
Occupational cohorts—human (e.g., physicians/allied professionals, military)	• May be enumerated • May have existing occupational surveillance programs	• Accessibility may be mixed (e.g., military agreement/security, opportunity costs to participate)
Age-based cohorts	• Birth cohorts or babies may be enumerated and tracked through other programs	• Enumeration requires national census or other database
Cohorts based on comorbidities (e.g., immunosuppression)	• May be enumerated (via health records, if available)	• Vulnerable populations (rural or lacking healthcare coverage) may not be included
Animals		
Domestic livestock/aquaculture	• May be enumerated	• Accessibility may be mixed (e.g., owner/producer permissions)
Domestic working animals	• May be enumerated	• Accessibility may be mixed (e.g., owner/producer permissions)
Domestic pet animals		• Often not enumerated
Captive wildlife	• May be enumerated	• Accessibility may be mixed
Farmed wildlife	• May be enumerated	• Accessibility may be mixed (e.g., owner/producer permissions)
Free-ranging wildlife	• Higher-risk population	• Often not enumerated
Mosquito or other vector pools	• Target vector population • Integrates risk across human and animal host targets	• Often not enumerated

Box 5-3
Rabies example

Although mammals generally are susceptible to rabies virus and able to transmit it into human populations, surveillance of human rabies cases identified that 99% of human rabies cases come from the bite of an infected dog, particularly in Asia and Africa (WHO, 2018a). This has guided the global efforts of the Tripartite and the Global Alliance for Rabies Control to reduce human cases—the 'Zero by 30' strategic plan—largely through dog vaccination campaigns (WHO, 2018b). This is an example of a risk-based approach used to identify a target animal population and focus resources strategically as well as to simplify approaches to improve feasibility.

Box 5-4
Indonesia Surveilans Triangulasi example

A surveillance program known as 'Surveilans Triangulasi' was jointly organized by Directorate General of Livestock and Animal Health, Indonesia Agriculture Ministry, in collaboration with USAID and FAO, has been operating since 2015 (FAO, 2023; Muflihanah, 2017; Muflihanah, 2021). The program was initiated in Kabupaten Maros, Sulawesi Selatan Indonesia. This archipelagic region, marked by its abundant biodiversity, wildlife, and a dense population of domestic animals such as cattle, buffaloes, goats, pigs, and horses in backyard farms, also features bats in both their natural habitats as well as within residential areas. Some local tribes consume bats as a local delicacy and believe in their medicinal value. Ponelo Island has fruit varieties that attract bats, and locals allow their livestock to graze freely in the farms, where they consume leftover fruits dropped by bats. This situation increases the risk of disease spillover (FAO, 2023; Muflihanah, 2017; Muflihanah, 2021).

The program is a collaborative effort involving various sectors, including veterinary services, agencies such as FAO and PREDICT, and local communities in Ponelo Island. During the program, passive surveillance measures were undertaken, and engagement with local communities aimed to foster an understanding of interactions between wild and domestic animals, and humans based on the One Health concept (FAO, 2023). This approach promotes a balance in the human ecosystem and safe coexistence and addresses the threat of emerging zoonotic diseases. Outputs of this program includes the establishment of disease surveillance systems and the implementation of enhanced biosecurity measures. As a result, heightened surveillance of wild birds and poultry has led to a reduction in the frequency of major outbreaks, ultimately increasing farmers' profits from livestock sales.

Data Harmonisation and Interpolation

When surveillance efforts are not well coordinated across domains, animal disease data and meta-data for samples may not be the same (i.e., harmonized) (Kuchipudi et al., 2023; Bellet et al., 2012). Furthermore, data are collected and stored in ways that limit analysis because the data cannot be combined or compared (i.e, interpolated). Ultimately, this threatens not just the speed with which emergent outbreaks or new strains of infectious agents can be identified but challenges the ability of surveillance systems to detect smaller outbreaks or outbreaks that do not occur on a regional level. Conversely, systems that allow for comparison of data along the animal value chain and in human risk cohorts, such as animal workers or other vulnerable community populations, can allow for identification of outbreaks (Box 5-5). Ideally, these systems are built on routine surveillance functions but are able to adapt to emerging infectious disease threats using an All Hazards Preparedness model, in which capabilities are strengthened to detect and respond to both routine threats and emerging risks. The Viral Emergence Research Initiative, founded in 2019 at George Washington University in the US (VERENA), and the associated Pathogen Harmonized Observatory (PHAROS) are developing frameworks based on molecular mechanisms to explain viral dynamics at a planetary scale.

Box 5-5
Group B Streptococcus example

In 2015, Singapore faced an unprecedented outbreak of Group B *Streptococcus* (GBS) linked to consuming raw freshwater fish (Kalimuddin et al., 2017). It has been shown that eating *yusheng*, Chinese-style raw fish dish typically made with freshwater fish like Asian bighead carp (*Hypophthalmichthys nobilis*) or snakehead fish (*Channa* spp.) are major risk factors (Chau et al., 2017). In fact, prior to the 2015 outbreak, GBS was not considered as a foodborne pathogen (Muthanna et al., 2023). Updated policies and guidelines concerning the sale of ready-to-eat raw fish dishes using raw freshwater fish, including a public advisory issued in July 2015, significantly reduced the number of cases (Tan et al., 2016). Following the outbreak, genomic evaluation of GBS isolates collected through routine clinical surveillance and various project activities found that freshwater fish in Singapore continue to carry GBS ST283, leading to a suspicion that fish in regional aquaculture operations may be colonized (Chen, 2019). It was subsequently determined that GBS ST283 is widespread in Southeast Asia and may have been responsible for human disease for over 25 years, with potential expanding intercontinental dispersal and human–fish host switching (Schar et al., 2023). This example also highlights the role of genome sequencing of pathogens and use of surveillance technologies to identify cross-species transmission and uncover novel routes of exposure, which can directly inform interventions.

Recommendation B: Ensure data collection is coordinated and interoperable across human, animal, and environmental domains

Data should be collected and managed in a way that permits analysis across domains, including consideration of coordinated targets (coordinated according to type of sample, pathogen target, and relevance for potential human–animal transmission events). Data must be standardised at a global scale, follow best practices, and be fed directly into AI-enabled databases capable of tracking the evolution of the agents of interest and flagging potential spillover events. Existing genome databases such as GISAID, NCBI, Nextstrain etc., can be improved and built on for this purpose. Ideally, systems should allow for the integration of metadata, including from Geographic Information System (GIS), weather, and land-use data based on spatial interpolation with case data to improve risk assessment, given the influence of spatial, temporal, and weather factors on disease emergence and transmission. An example is the PHAROS open-access wildlife disease database that requires spatiotemporal metadata for submissions.

Improved interoperability of One Health data is foundational to faster and more complete assessment of outbreaks from spillover or intentional release events. In the long term, improvements to data completeness and dataset interoperability are critical for development of automated processes for data reporting, interpolation, and assessment, with the potential for further automation of analysis through machine learning or other intelligence approaches (Box 5-1). In this, especially for some of the latter approaches, deposition of data into the public domain is important; while funded research may have publication mandates, the same may not be true of governmental or non-governmental program activities.

SURVEILLANCE TECHNOLOGIES

Surveillance technologies include digital and laboratory resources for the detection and monitoring of pathogens and human or animal disease (Kostkova et al., 2021). With technological approaches, there often is a trade-off between more complex but more precise, accurate, sensitive, and specific assays and these performance characteristics of simpler, more accessible testing. For example, low-cost point-of-care (POC) diagnostics may be more readily available and provide faster results but have challenges with limits of detection, false positives, and/or false negatives (Wang et al., 2016). Additionally, results may not be reported in a systematic manner. In addition, POC tests are more readily available for human compared to animal populations, particularly for livestock or wild animal populations (Velayudhan and Naikare, 2022). Further, serological, or molecular assays do not yield infectious pathogens for full identification or phenotypic characterization. Depending on the context, point-of-use tests or other technologies that are user-friendly, i.e., not requiring laboratory equipment to run, may have advantages that outweigh the disadvantages, particularly in resource-limited or rural settings with limited access to regional or national laboratory networks (Heidt et al., 2020).

Where viruses from specific families are sought, molecular detection has frequently focused on well-conserved regions of the viral genome. Assays using pan-CoV primers optimized for coronavirus polymerase targets aim to detect viruses across *Alpha-, Beta-, Gamma-* and *Delta-coronaviruses.* For filoviruses, a panel of assays with both agnostic targets aimed to encompass the viral family (*L* or *NP* genes) and specific to certain genera (*NP* gene of *Ebolavirus*) and viruses (EBOV) have been developed and implemented (Koehler et al., 2014). Similarly, an *L* gene target has been used for broad detection of paramyxoviruses (Tong et al., 2008; Jin et al., 2021). Assay sensitivity is enhanced using a nested approach (Hanlon and Nadin-Davis, 2013), but may be limited for cryptic (including animal) viruses underrepresented in genomic databases, impeding optimal primer and probe design.

Next-generation sequencing has become progressively more accessible and versatile for pathogen discovery and characterization as well as for hypothesis generation around viral evolution and ecology (Gupta and Verma, 2019). There are three broad approaches that are progressively more agnostic, including amplicon-based sequencing of known targets such as SARS-CoV-2, bait-capture assays targeting broader viral families, and metagenomics, which is an unenriched and non-specific approach (Rehn et al., 2021). Critically, viral genomics and metagenomics can be leveraged to generate novel insights into viral ecology and drivers of spillover by transforming data into knowledge using key metadata and appropriate analytical approaches (Roux et al., 2021).

Recommendation C: Repurpose or maintain existing diagnostic capacity for future emerging zoonotic future threats

The COVID-19 pandemic caught many countries off guard in early 2020 (Hiscott et al., 2020; Singh et al., 2021) despite earlier reports of the discovery of SARS-CoV-2 in China in December 2019 (CDC, 2023a) and the earlier emergence of SARS-CoV in China in 2002-2003. Many countries adopted the wait-and-see strategy, expecting the epidemic to spike and wane off

(Wise, 2021). When local SARS-CoV-2 infections were reported, numerous diagnostic laboratories were unequipped and unprepared (Lippi et al., 2023; Tang et al., 2023) despite the procurement of real-time PCR equipment during the 2009 H1N1 influenza pandemic.

Since the World Health Organization (WHO) declared that COVID-19 is no longer a global health emergency (Fadel and Aizenman, 2023), diagnostic capacity has gradually declined due to fiduciary and workforce reprioritization. For example, in Malaysia, SARS-CoV-2 diagnostic laboratories are being repurposed for human papillomavirus screening program which is nested within the Action Plan Towards the Elimination of Cervical Cancer in Malaysia 2021-2030 (Malaysia Ministry of Health, 2021) and other real-time molecular assays for syndromic surveillance. Onsite health screening posts, such as airports or immigration checkpoints, along with their standardised procedures should be maintained, as an essential component of global mitigation measures (CDC, 2022b). Further, maintenance of standardised procedures and attention to quality control should be maintained between health crises. This may result in the maintenance of technological investments and the training of the future workforce as an ongoing preparation for the next pandemic.

Recommendation D: Strengthen interpandemic surveillance including broad virologic assays

Building on the existing technologies in the diagnostic laboratories, syndromic surveillance should be adopted and intensified, and advanced technologies such as next-generation sequencing (NGS) strategically applied. Many pathogens endemic to humans are zoonotic in origin (Rahman et al., 2020), and surveillance is the key to further understanding the natural and intermediate hosts (Pepin et al., 2010).

Unlike many bacteria and fungi that are more readily cultivable and/or have robust barcoding protocols (Lebonah et al., 2014; Xu, 2016), viruses lack a single consensus barcoding region. However, family-wide consensus primers are often available. Despite the availability of next-generation sequencing (NGS) technologies that boast the potential of whole genome sequencing (Qin, 2019), the majority of NGS platforms remain costly to acquire and effectively implement (Schwarze et al., 2020). While NGS capabilities are often available in-country through medical, animal health, or research institutions, the public containment strategy learned during the COVID-19 pandemic made centralized diagnostics and outsourcing a challenge, especially in countries with lands separated by sea.

The development of multiplexed virus discovery kits using family-wide consensus primers would allow rapid detection of novel and emerging viruses, enabling a preliminary warning system in anticipation of further characterization.

Compatibility of reportable data

Monitoring the trajectories of outbreaks and pandemics is important to position resources for rapid deployment and to enhance surveillance in at-risk populations (Qasmieh et al., 2023; WHO, 2022b). For novel pathogens, this may require rapid investment in new tests for pathogen detection. Other than laboratory-based diagnostic tools, rapid tests or point-of-care testing platforms must be developed such that in-country capability is available to develop and validate new tests quickly with upscaling capability for mass screening. The ideal criteria for these tests must be:

1. Economical
2. Stable at ambient temperature
3. Have reasonably high sensitivity and specificity
4. Usable without a corresponding analyser/reader (standalone)

For example, the use of national mobile applications such as MySejahtera (Malaysia), TraceTogether (Singapore), Mor Prom (Thailand), etc. allows real-time information to be made available to the population, including vaccination status and contact tracing while allowing individuals to upload essential data about their COVID-19 status. Such applications should ideally be repurposed and maintained for future public health emergencies. Although some emerging high-tech diagnostic technologies, such as biosensors, isothermal amplification, aptamers, etc. are promising, more research should be done to allow rapid development, validation, and scalable implementation. Further, better integration of data on livestock, domesticated pets, and wildlife with development or deployment of surveillance technologies and monitoring by field workers across different animal services or governmental agencies, or by community volunteers, is needed in Southeast Asia to alert local authorities, although some examples exist, such as the Participatory Surveillance App by the Thailand PODD, which is an example for event-based surveillance opportunities.

Further Recommendations for One Health Surveillance

Current surveillance systems to detect emerging pathogens and/or outbreaks among animal populations require better integration of animal and environmental surveillance data with human disease surveillance efforts.

Recommendation E: Conduct value chain analyses and exposure assessment to identify high-risk populations

Using approaches that include engagement of experienced stakeholders at the local level, conduct national and regional value chain analysis and exposure assessment in terms of occupational and consumer exposure to identify how people are in direct or indirect contact with animals and animal products, whether these are domestic or wild animal populations. This can include:

- Determining locations of farms, other production facilities, and processing facilities, identifying the species they serve, and categorizing these (qualitatively or quantitatively) in terms of likely risk.
- Identifying obvious screening points (e.g., transboundary, processing) for active surveillance activities.
- Facilitating the adoption of integrated biosecurity approaches to enhance disease detection and management within the value chain.

CONCLUSION

Regardless of the kinds of surveillance activities that are used to collect, interpolate, analyse and act on data across human, animal, and environmental health domains, these data are intended to inform decision-making and, ultimately, interventions or other programmatic activities to address the challenge of zoonotic disease spillover. In this, attention to sustainability of these programs, including the expertise within the One Health workforce at local, regional, and global scales, is a key consideration. This includes One Health-oriented training in laboratory and data-based approaches (qualitative and quantitative) to inform and conduct risk assessment, training in implementation of evidence-based intervention strategies, and guidance in effective communication strategies (which likely will differ according to audience and context). Further, given that surveillance inputs and intervention or other implementation outputs from these systems rely on strong community engagement, attention to local value systems, cultural norms, and unintended consequences of such outputs is essential for such activities to be successful (Module 7). Strong bidirectional communication systems (between public health authorities and communities or other partner groups) can improve situational awareness and enhance engagement around control measures. Indeed, understanding of the externalities and other consequences of changes along the animal value chain (Module 6) may help to uncover potential barriers to implementation and allow for more engaged action, with a goal of participatory approaches to community implementation. Finally, integration of surveillance and response systems, including engagement of decision-makers and coordination across human, animal, and environmental sectors, is needed for surveillance activities to inform public health measures to mitigate risks.

MODULE

06

— STAKEHOLDERS —

Strategies to Engage Diverse Stakeholders Across the Live Animal Value Chain to Address Risk

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STRATEGIES TO ENGAGE DIVERSE STAKEHOLDERS ACROSS THE LIVE ANIMAL VALUE CHAIN TO ADDRESS RISK

INTRODUCTION

Zoonotic disease transmission is a pressing global public health concern, with far-reaching implications for nations around the world. In low- and middle-income countries, the risk of zoonotic disease transmission is exacerbated by factors such as extensive farming activities, unregulated trading and slaughtering practices, and limited access to veterinary services, among others (Karesh et al., 2012). By incorporating a comprehensive array of perspectives, values, and interests, alongside evidence-based scientific insights, decision-makers can craft robust strategies for effectively addressing the emergence or resurgence of zoonotic diseases with pandemic potential, thereby reducing transmission from animals to humans. This module is dedicated to the elaborate process of identifying and engaging with all relevant stakeholders (Refer Module 1; Box 1-1 for a discussion on the term 'stakeholder'), from individuals and local communities to broader populations, who play pivotal roles in creating, assessing, and managing risks across value chains related to both domestic and wild animals. Humans come into contact with various animals through various avenues including live animal markets, domestic animals, and intensive wildlife farming or hunting. The central focus of this module lies at the juncture where humans and animals interact within shared environments, particularly highlighting critical points of contact facilitating transmission of zoonotic diseases. The module explores various stages of the animal and animal products value chain offering a set of culturally tailored, collaborative, and interdisciplinary efforts and recommendations to combat zoonotic disease spillover. The module broadly recommends collaboration with a more diverse set of stakeholders, some not traditionally engaged, to ensure greater transparency, coordination, and ultimate success in global public health efforts. The collaborative approach advocated within this module offers a holistic and inclusive perspective on zoonotic disease management, ultimately benefiting populations throughout Southeast Asia and beyond.

THE ANIMAL AND ANIMAL PRODUCTS VALUE CHAIN WITHIN SOUTHEAST ASIA: STRUCTURE AND COMPONENTS

In this section, we review the different steps in the value chain for food products derived from live domestic animals, with a particular focus on animal welfare standards and exposure of humans to zoonotic pathogens. Value chains related to animal-derived products exhibit a remarkable level of complexity and dynamism. They evolve in response to a myriad of factors, including seasonality, economic fluctuations, political shifts, and public health imperatives. Ultimately, these chains are shaped by consumer preferences and behaviours, which in turn dictate the spectrum of commodities available, production methodologies, processing techniques, and the overarching trends within the marketplace.

There are multiple opportunities for human-animal contact at each step along the value chain, such as, for example, in natural habitats, on farms, and during transport, marketing, and ultimately consumption. These chains of economic activities allow for intensive exposure and therefore increase the risk of potential pathogen spillover. By presenting region-specific or case-specific value chain examples, this module aims to provide a practical understanding of the factors that may impact animal welfare and zoonotic disease risk within a particular local context.

Figure 6-1 showcases an example map of the value chain for a farm-based poultry food system, providing a comprehensive overview of the different stages, actors, and activities involved in the production of a commodity until it reaches the consumer. Along this value chain, the risk of zoonosis varies depending on the farm size and the time and space between steps. Figure 6-2 illustrates the diverse points of contact and modes of zoonotic disease transmission across different stages of the value chain. For example, at the slaughter stage, handlers may encounter direct contact with infected animals or animal products, as well as potential airborne and surface-contamination transmission of zoonotic diseases (Klous et al., 2016).

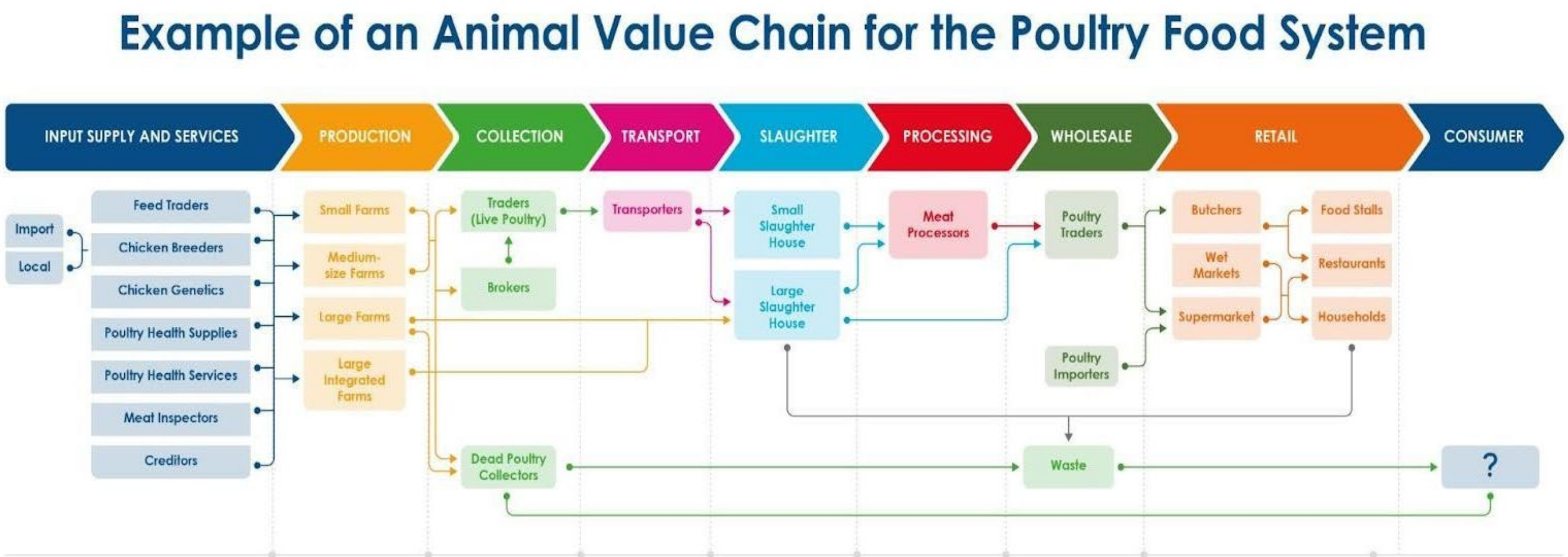

FIGURE 6-1 Example of value chain for a poultry food system.

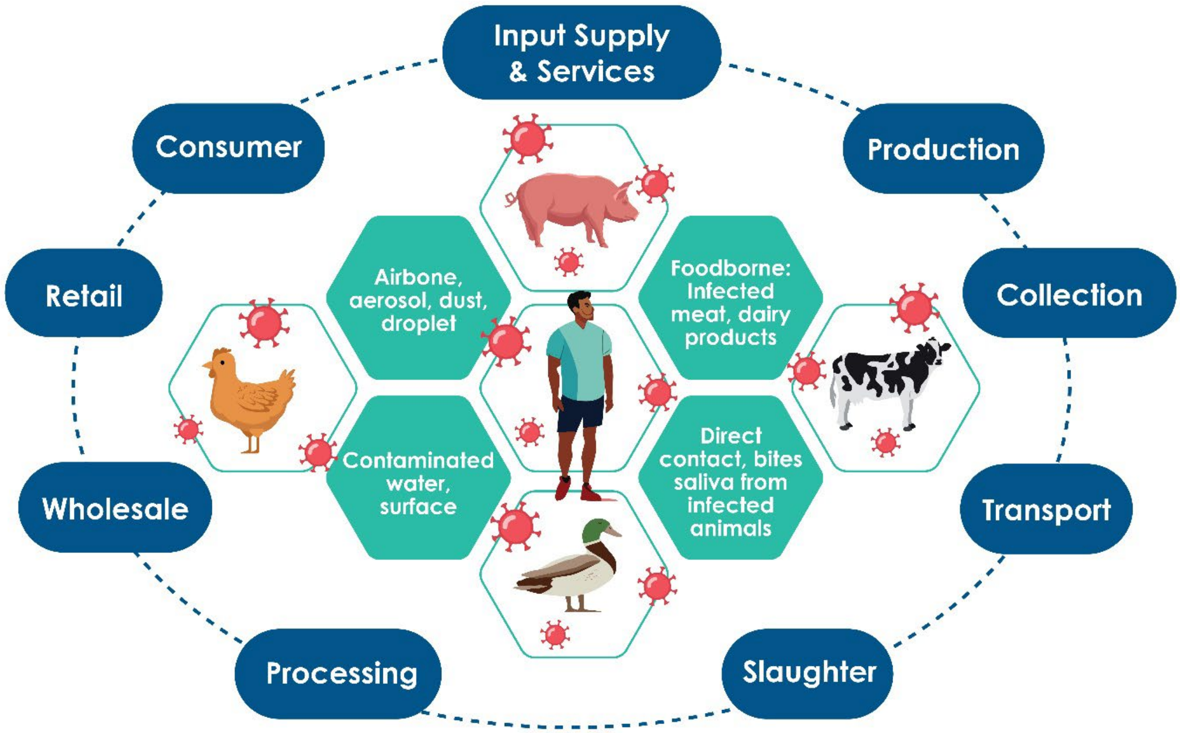

FIGURE 6-2 The animal value chain presents numerous critical points for zoonotic disease transmission pathways such as airborne, contamination, and foodborne transmission. From input to consumer, the sequence of processes along a value chain associated with livestock-derived commodities is typically structured into the groups of activities described below.

Input Supply and Services

This group of activities includes suppliers or service providers to provision essential resources such as animal feed, veterinary and health services, inspectors and creditors, extension services, and other goods or service inputs necessary to support the livestock production chain (Jaffee et al., 2010). These resources are crucial for ensuring the health, growth, and overall well-being of the animals. In many Southeast Asian countries, input suppliers and service providers may be private, state-provided, or industry-provided. Private suppliers are for-profit businesses selling these inputs, while state provision of inputs or services often involves a form of subsidies through national and local agricultural or veterinary offices. Industry-provided inputs are relevant where companies have contracted farmers to raise animals that are exclusively sold to them as contracting companies.

Production

Livestock production involves a range of actors depending on farm size and production outputs. They are typically grouped in at least three categories, i.e., smallholders, who are characterized as small-scale farmers managing areas varying from less than 1 to 10 hectares, and medium- and large-scale farmers (Dawe, 2015). Each country sets its own standards on the scale classification of farmers, with various regulatory measures in place for each scale of production. Integrated farming (multi-dimensional farming that combines various sustainable agricultural practices to efficiently use resources while minimizes polluting inputs) also comes into play, incorporating multiple sustainable aspects of production, including breeding, raising, fattening, and potentially even processing of products derived from the animals, in a single business operation, utilizing modern technologies as well as traditional methods (Rose et al., 2019).

Collection

Once animals have reached slaughter age (in certain cases, the animals succumb to diseases), relevant actors, including traders, brokers, and dead-animal collectors, collect them for further processing. They gather animals from smallholders, medium- and large-scale farms, and integrated farms. This step in the value chain often involves negotiations and financial transactions associated with acquiring the animals, which will then be distributed to the next step in the value chain.

Transport

Transporters are responsible for moving the collected animals safely, while ensuring animal welfare, from their original locations to slaughterhouses or live animal markets, but other destinations may also be relevant, such as farms for fattening of the animals. The transporters may be the same individuals as the collectors. Depending on the specific context and geographical factors, modes of transportation to move animals or animal products vary. This may involve animal-drawn or motorized carts such as bikes, or even more well-built trucks.

Slaughter

Small and large slaughterhouses are facilities where animals are processed for meat extraction. The establishments should adhere to hygiene and food safety standards to ensure the quality and safety of the meat. In some countries, each town has designated slaughterhouses managed or regulated by local governments. In specific instances, slaughtering takes place in backyards or households, particularly during socio-cultural events. This riskier practice can impact both animal and human welfare, potentially elevating the risk of zoonotic diseases transmission.

Processing

Meat processors transform raw meat obtained from slaughterhouses into various processed products such as packaged cuts, sausages, and other value-added items. Processing enhances value of the meat and offers a wider range of items to consumers.

Wholesale

Processed meat products are distributed to various poultry traders and importers. They are involved in the distribution of meat to retailers, restaurants, and other consumers. Additionally, waste management entities handle byproducts and waste generated during processing and distribution stages.

Retail and Consumers

Finally, processed meat products ultimately reach retail outlets such as wet markets, supermarkets, food stalls, restaurants, and households for home consumption (Zhong et al., 2020).

As described above, the animal and animal products value chains involve sequential steps from source to consumer, with each actor typically benefitting financially. These steps involve a different and diverse set of actors and procedures. To illustrate this, Box 6-1 highlights a case example in Nueva Ecija, Philippines that exemplifies the timing, places, and actors involved in the initial steps of the value chain in a large-scale livestock facility. Animal production from small, medium, and larger farms along the value chain is well documented (OECD/FAO, 2017), and actors can be identified and effectively engaged given the right communication and collaborative tools (Module 8). The compilation and analysis of this information can lead to the successful implementation of regulatory or management tools to decrease the risks of zoonotic disease transmission. However, the complexity of the animal value chain varies, with input pathways, trading processes, selling practices, and actors involved depending on social, economic, religious, and seasonal drivers. The latter is particularly true for wild animal trade or smaller farms, which are sensitive to extreme climate events (Talukder et al., 2021) and global health crises, such as pandemics.

BOX 6-1
Contract Farmers and Growers Discussing Effective Integrated Livestock Systems in Nueva Ecija, Philippines

Southeast Asia is home to large-scale livestock production (Lee and Hansen, 2019). This particular case example in Central Luzon, Philippines, sheds light on a large-scale animal value chain and potential points for disease transmission. This case revolves around chicken contract farming of approximately 2.6-2.8 million heads per year. Private companies engage with poultry producers for exclusivity of their farming products (e.g., live chickens, eggs) during the production phase of the value chain. These companies hire experienced farm managers from selected farms who have received professional paid training. In these large-scale businesses, one to two farm managers oversee the buildings, with each building equipped with a leadman and a couple of handlers. Each person typically works in 8-hour rotating shifts for continuous monitoring.

Veterinary services are offered at low cost or for free by the private company that engages the contract growers. Animal health screenings are performed on a weekly or biweekly basis and begin with wellness checks by the handlers. During this process, the handler wears disinfected slippers prior to entering the work building and wears disposable shoe covers indoors. Hand disinfectants (e.g., isopropyl alcohol) are also part of the routine hygiene requirements. While hygiene measures are generally well followed, strict compliance is not always guaranteed. In this case example, workers were sometimes seen without personal protective equipment (PPE) (as related by interviewee).

During screenings, the handlers look for physical symptoms such as “halak” (coughing), bulging eyes, and loose or wet faeces; review feed intake; and look for unusual mortality rates. When non-sick animal carcasses are discovered, the dead chickens are separated and placed in chest freezers and disposed of in mortality pits outside the farm. However, if an unusual symptom is observed, the handler must inform the leadman immediately, and the contracting private company calls a veterinarian. Because these events also represent occupational hazards, sick animals are either culled or separated into an intensive care unit pen, and workers assigned in the infected buildings are isolated. In case of a disease outbreak, the grower first buries dead animals at the farm. Additionally, the grower power-sprays the delivery trucks prior to entering and leaving the farm, and directs the transporters, vets, and animal handlers to shower and change clothes. Fly control measures are also implemented such as cyromazine or green-labelled pesticides during the growth period, and non-green labelled pesticides during non-growth periods. Some farmers belong to federations or a group of contract growers with industry-standard practices. These groups sometimes notify farmers of an outbreak in the area or neighbouring provinces, alerting them to heighten their biosecurity measures. Social media groups or pages for chicken growers also exist and serve as extension service spaces, sharing information and posting for fly control techniques, hiring workers, and other product promotions.

Broilers grow in only one building, for a duration that usually lasts anywhere from 26 to 32 days; they then leave the building, going directly to slaughter or the market. The contracting company provides all poultry feed. Growers routinely check unfiltered water for pH levels. Poultry production usually generates two types of wastes: carcasses (that are disposed of in mortality pits) and animal manure (oftentimes a mix of chicken manure, carbonized rice husk (CRH) used as litter beds, and pesticides to prevent flies) that is used as fertilizer by neighbouring farms. Between batches of chicks, buildings are emptied for about 14-21 days. During this interval, the building's floors are layered with organic material such as manure and CRH as a litter bed and sit for roughly 4-5 days. For the next 7 days, the building is then cleaned, and the equipment is disinfected before the start of the next production cycle

Given pathways of disease transmission along the animal value chain, it also is important to consider where each step may have further inputs (opportunities for disease introduction) and outputs (further pathways for disease transmission) (Rushton, 2011). Inputs can include introduction of disease agents through feed sources, from higher-risk activities such as the use of live animals to feed other animals, to transmission of disease agents on animal byproducts or even plant-based feeds, e.g., African swine fever (ASF) and porcine epidemic diarrhea virus (PEDV) (Niederwerder, 2021). Outputs include animal wastes (litter, manure) and dead animals which may harbour live disease agents, sometimes for extended periods of time. Even effluent (wastewaters) from markets can be critical pathways for disease agents to be spread back into the environment onto land, including crop fields, and through surface runoff or direct discharge into surface waters (Davis et al., 2011). This can enhance indirect contact with wild animal populations that interface with contaminated land and water.

Importantly, from a risk assessment and management perspective, the behaviours of the actors along the value chain also influence the transmission risks of zoonotic infections associated with various commodities at any stage along the process (Win et al., 2023). This module highlights such examples in the sections below. For example, a small-scale poultry farmer raises chickens in a backyard business to sell to a trader or transporter, who then sells to a meat stall owner at a local wet market. Subsequently, the market worker slaughters the animals and sells the meat to consumers. For risk mitigation, risk assessments of current behaviours can provide valuable insights into the contributions of behaviours to the overall origin of risk factors. It is also crucial to emphasize the multifaceted and dynamic nature of the live animal trade, including legal and illegal wildlife trade and subsistence hunting, and the diverse places and settings involved, such as large-scale agricultural operations, backyard farmers, abattoirs, or wet markets (Challender et al., 2015). Each of these places involves actors that bring distinct behaviours, which collectively shape the risk landscape.

GENERAL STAKEHOLDER MAPPING ACTIVITIES AND ENGAGEMENT IN BEST PRACTICES

In the preceding section, we provided a comprehensive overview of a regional animal value chain, shedding light on various stakeholders associated with it. In Module 8, we describe how to account for several layers of the social environment (e.g., public policies and regulations, community relationships, organizational culture, interpersonal exchange, and individual factors) to guarantee that actions and decisions are appropriately formulated (Module 8; Figure 8-1). This section emphasizes the significance of identifying influential actors within this chain who possess the capacity to impact the risks associated with commodities carrying zoonotic disease potential. This distinction sets the stage for more precise, targeted, and effective risk management strategies. Stakeholders can be categorized by their respective sectors, relationships, and levels of decision-making. Effective collaboration, open communication, and coordination among these stakeholders are instrumental in mitigating the consequences of an outbreak and preventing its spread. To illustrate, a detailed, but not exhaustive, list of relevant stakeholders involved at local, national, and international levels within Southeast Asian value chains can be found in Box 6-2. Box 6-3 offers an example of stakeholder collaboration from Cambodia, highlighting the critical role of engaging with diverse stakeholders to effectively respond to an avian influenza outbreak.

BOX 6-2
Examples of actors in the animal and animal product value chain by sectors and levels of decision

Local level:

- Hunters and butchers
- Landowners and farmers
- Medical and veterinary practitioners
- Law enforcement officers
- Border patrol agents
- Indigenous and local communities, including tribal and religious leaders and community representatives (e.g., monks, influencers, etc.).

Private and nonprofit non-governmental organizations (NGOs):

- Wildlife rescue organization
- Meat processing industry
- Food transportation and distribution
- Petting zoos and educational programs
- Animal interest groups, rescue centres, and biodiversity conservation organizations, including national chapters (Fauna and Flora International, World Wildlife Fund, Wildlife Conservation Society, National Academy of Sciences, CITES National Focal Point)
- Industry (e.g., logging, tourism, farming, and aquaculture)

State and federal level:

- Wildlife trade regulators
- State agencies (e.g., Department of Forestry)
- Government departments (e.g., Department of Health, Environment and Natural Resources, Agriculture)
- Accompanying organizations (e.g., Bureau of Animal Industry)
- Countries' leaders and prime ministers

Regional/international levels:

- International agencies (e.g., World Health Organization, the Food and Agriculture Organization, World Organisation for Animal Health)
- Regional consortia (e.g., Southeast Asia One Health University)

BOX 6-3
Responding to avian influenza outbreak, key stakeholders and strategies in Cambodia

A localized outbreak could have far-reaching consequences, potentially leading to a global pandemic, depending on the virulence and transmissibility of the disease. Cambodia's forests, wetlands, and other natural habitats are home to a wide variety of animal species, contributing to the country's reputation for rich biodiversity (USAID-Cambodia, 2011). Human activities, such as the unmonitored wildlife trade and the loss of ecosystems, have increased the stress on these species and contributed to the emergence of zoonotic disease (Esposito et al., 2023).

In 2023, two individuals in Cambodia were infected with avian influenza A (H5N1) virus. A joint animal-human health investigation is underway to identify the source and mode of transmission of the virus, with support from the in-country Centers for Disease Control (CCDC). Additionally, the investigation is led by the rapid response team, as well as the Cambodian Ministry of Health and other global public health professionals (CDC, 2023b).

However, in 2024, new H5N1 cases resulting in fatality were reported, revealing that the patient was exposed to sick or dead poultry before the onset of their illness (CDC, 2024). While efforts have been made to control the disease, continued vigilance and action are necessary to prevent future outbreaks and ensure food security. The key stakeholders to engage in response to an outbreak in Cambodia would include:

Government agencies: This includes the Ministry of Health, Ministry of Agriculture, Forestry and Fisheries, Ministry of Environment, and other relevant departments. They would coordinate the overall response and provide guidance and support to affected areas.

- Healthcare professionals: Examples are doctors, nurses, and other healthcare workers who would be responsible for treating patients and providing guidance to the public.
- Local communities: Examples are community leaders, religious figures, and other influential individuals who are crucial for effective communication and awareness-raising efforts within local communities.
- International organizations entities: The World Health Organization (WHO), the Food and Agriculture Organization (FAO), and other international organizations would provide technical assistance and support to the government of Cambodia.
- Donor agencies can provide financial and technical assistance to support the response efforts.
- The private sector can contribute by providing financial support, resources, and expertise to help address the outbreak.
- The media plays a critical role in communicating important information to the public and raising awareness about the outbreak.

Stakeholders can also be identified through formal mapping activities, which is a visual process of identifying all the stakeholders of a product, project, or idea on a map (Bernstein et al., 2020). In this case, mapping is informed by data and input gathered through value chain analysis, as well as focus group discussions and other activities suitable for compiling a comprehensive list of all interested parties. The overall complexity of stakeholder environments suggests that formal stakeholder mapping is essential to the effort of spillover prevention and outbreak response.

An approach to mapping the roles of actors in zoonotic risk at a particular step of the value chain can be described by considering their influence and interest through an X-Y chart (Box 6-4). Stakeholder mapping helps illustrate the interrelationships between different stakeholders, aiding to inform decisions regarding their involvement in developing and implementing risk management strategies. Specifically, this X-Y chart enables mapping the power and interests of specific individuals or groups of individuals involved. This approach helps answer critical questions such as who should be prioritized for engagement (Module 8 for practical discussions on actor engagement). It is highly likely that for each future scenario that leads to the increased risks of spillover, every country will have a different composition of stakeholders and different networks of influence created between these stakeholders. These dynamics may also vary between regions, even within countries, and evolve over time. Therefore, conducting stakeholder mapping is a critical prerequisite in the development of effective risk management strategies.

Establishing Trusted Networks in a Fragmented System

The risk of zoonotic disease emergence is influenced by activities and processes shaped by actors from the human, animal, and environmental health sectors (Gilbert et al., 2014). Once interested and influential actors and leaders have been identified using the stakeholder mapping activity highlighted above, establishing trusted partnerships and consistent and efficient communication channels becomes critical. These partnerships should be forged between key actors and decision-makers across sectors and disciplines, involving different governmental and research levels, medical professionals, private organizations, commercial entities, farming communities, and the public. Increasing cross-sectoral collaborations to improve national and local zoonotic disease management in Southeast Asia could benefit all countries at all levels in the region (Binot et al., 2015).

BOX 6-4

Stakeholder mapping at the retail step of the value chain using power-interest grids (X-Y chart)

Conventional retailers, such as traditional merchants in markets in Indonesia, play a significant role in shaping the cultural and economic landscape of Southeast Asia (Aliyah et al., 2016). However, they often grapple with issues such as substandard sanitation, poor infrastructure, and labour inequity. The intricate web of relationships among various stakeholders or stakeholder categories adds complexity to the situation, as each party brings its own unique challenges, making it difficult to establish effective coordination among them. To nurture a secure and thriving environment for traditional traders in Indonesia, a thorough stakeholder analysis of the traditional markets business ecosystem in Indonesia has been conducted (Prabowo et al., 2017). The X-Y chart (Figure 6-3; top) categorizes various stakeholders based on their influence and interest in the traditional market (Figure 6-3; bottom). This categorization informs our understanding of each stakeholder's needed level of participation in the future development of a resilient traditional market business.

FIGURE 6-3 Power-interest grid for stakeholders of traditional markets in Indonesia. Image adapted and enhanced for resolution from Prabowo et al., (2017) (top). Image of a retailer in a traditional market in Indonesia. Photo credit: Rafal Cichawa (bottom).

The challenge in creating trusted networks of different actors along the value chain lies in identifying effective mechanisms for bringing together relevant individuals or groups who need to be involved in emerging zoonoses management dialogues (Binot et al., 2015). In many countries around the world, different sectors are not accustomed to working together. Most countries in Southeast Asia are currently promoting the integrated One Health approach for the governance of pandemic risk within social-ecological systems (WHO, 2023d). However, government bodies remain fragmented in terms of their roles and responsibilities. For example, one department focuses on human health, another on production or companion animal health, and a separate one on forestry health, which includes wild animal health as well. Additionally, environmental health may fall under the jurisdiction of yet another government department. Given the interconnectedness of factors driving pandemic risk within this complex system, close coordination among these bodies is essential to achieve effective risk mitigation.

The impact of inaccurate information via social media should not be underestimated, particularly in terms of how interventions can influence public perception (Angawi and Albugmi, 2022; Liu, 2022; Zhou et al., 2023). Furthermore, the prevailing lack of trust and established relationships between farmers and government authorities often leads farmers to perceive disease control and prevention measures as threats to their livelihoods (Pao et al., 2022). Establishing trust with stakeholders in the value chain becomes imperative, as this trust can significantly enhance the effectiveness of outreach initiatives aimed at bridging knowledge gaps.

Different models have been implemented to foster such cooperation and develop truly integrated risk mitigation strategies using the One Health approach. For example, Bangladesh has established the One Health Secretariat, which acts as a coordinating body for managing risk governance for zoonotic infectious disease risks (CDC, USAID and FAO., 2017). The implementation of the One Health approach alongside operational tools enables the active participation of various stakeholders, integrating information and expertise from diverse perspectives to collaboratively evaluate and mitigate risks and threats posed by zoonotic diseases at the human–animal–environment interface (Binot et al., 2015). Three operational tools outlined in the Tripartite Zoonoses Guide (TZG) that promote cross-sector coordination are:

1. Joint Risk Assessment Operational Tool (JRA OT) provides countries with a qualitative methodology for assessing the risks associated with selected prior diseases. The guide identifies relevant risk factors that can form the foundation for risk-based surveillance and highlights opportunities for cross-sector collaboration to mitigate disease risk, including management, operational, and technical guidance that can be easily tailored to within-country situations.
2. Multisectoral Coordination Mechanism Operational Tool (MCM OT) provides countries with a stepwise approach to establishing or strengthening their multisectoral One Health coordination mechanism. This tool is adaptable for use in countries that currently lack any such mechanism or in those countries with an existing One Health task force. The tool directs the user in a very practical way through the process of bringing stakeholders together in a workshop and developing a One Health action plan, including its subsequent impact evaluation. The tool provides an Excel spreadsheet that can be used to assist in the process.
3. Surveillance and Information Sharing Operational Tool (SIS OT) provides countries with a tailored list of resources that can be implemented to improve intersectoral surveillance and information sharing. These tools contribute to building the country's capacity and strengthening the national system, ultimately resulting in the development of an action plan aligned with existing resources.

The diversity of socio-ecological systems in Southeast Asia countries poses a challenge to effective utilization of stakeholder mapping and operational tools (Ginige et al., 2018). Therefore, regional-level efforts must be initiated to address the challenge of implementing and sustaining collaborative efforts between member states, especially those sharing borders and engaging in trade. Box 6-5 describes several local, national, and regional initiatives and partnerships to enhance resilience against zoonotic diseases in Southeast Asia.

BOX 6-5
Overview of ASEAN and other multisectoral partnerships

The ASEAN Leaders's Declaration on One Health Initiative, made during the 42nd ASEAN Summit in May 2023 in Labuan Bajo, Indonesia, emphasizes the significance of collaborative efforts across sectors in adopting a One Health approach. The declaration underscores the importance of engaging stakeholders and raising community awareness to enhance prevention, preparedness, and response (PPR) activities while building national and regional capacities to address future threats and sustainably maintain the human-animal-environment.

Local ongoing initiatives such as Akademi Sains Malaysia (ASM) Special Interest Group (SIG) on Zoonosis, international organizations (Nature for Health, PREZODE, USAID EPT Projects such as RESPOND), and representatives from other various sectors, including the commercial and economic sectors such as the food industry, are collectively valuable in assessing policies, challenges, and strategies to enhance resilience against zoonotic diseases in ASEAN.

World Zoonoses Day, celebrated on July 6, serves as a platform for bringing together leaders and the public to enhance awareness about zoonotic diseases (WHO, 2021). Leaders of ASEAN Member States have embraced it by incorporating it into local languages, such as 'Hari Zoonosis Sedunia' in Malaysia and Indonesia.

The interconnectedness between organizations such as FAORAP, TRAFFIC etc., with local and regional authorities, helps engage with local communities to raise awareness of zoonotic diseases and encourage the reporting of unusual animal or human health events. For example, to address African swine fever (ASF) outbreaks, FAORAP initiative on educational videos (e.g., Be a Champion Farmer, Just Like Farmer Su) plays a critical role in inspiring smallholders to adopt better biosecurity measures, ultimately safeguarding the economies of small-scale farms by preventing massive pig losses.

Additionally, one way to develop risk communication strategies is to identify partners with the expertise, interest, and capacity to work collaboratively and determine the most effective ways to engage them (WHO, 2017a). Communication and engagement strategies should also take into consideration stakeholders in geographically challenging areas that are difficult to reach. Module 8 of this guidebook provides examples of how partners around a common set of issues can take part in participatory activities to collaboratively address them. Biosafety practices in Southeast Asia differ from country to country, influenced by variations in resources, infrastructure, and regulatory frameworks. Each nation customizes its biosafety protocols to meet its unique requirements while also adhering to international standards and best practices set by organizations like the World Health Organization (WHO) and the World Organisation for Animal Health (WOAH). Effective engagement with groups or individuals who may not be aware of biosafety issues at each step of the animal value chain but are influenced by top-down approaches for animal farming, handling, and consumption requires the use of targeted approaches or assistance aimed at facilitating their participation in the decision-making process. These voices are essential for co-producing solutions and successful implementation on the ground.

Tailoring social and behavioural change interventions to various stakeholders

The utilization of targeted participatory methods to enhance the knowledge, attitudes, and practices of stakeholders focuses on addressing the unique needs of each group. Participatory approaches actively engage stakeholders using tools such as straightforward diagrams pertinent to value chains and risk pathways to track the spread of infectious pathogens (Module 8). This effort ensures a comprehensive understanding of the dynamics involved in disease transmission and containment across the value chain. Other ways for social and behavioural change include prioritizing human development in remote areas, particularly among smallholders, cultural or tribal leaders, and the stateless community at bordering countries. An essential prerequisite for such stakeholder engagement is that it must be based on mutual trust (Harrison et al., 2019). It will take time to develop the required trust relationship, and once it has been lost, it takes time to re-establish. It is very rarely possible to develop a new trust relationship during an outbreak (Gambetta and Morisi, 2022).

Engagement initiatives should be designed to empower a diverse range of stakeholders, regardless of their power or interest in the issue. Often, meaningfully engaging various actors participating in value chains relevant to the emergence of pandemic risks falls short of conveying the impact of their actions and the significance of specific interventions. This deficiency frequently arises from the presentation of knowledge to stakeholders, often lost in complex technical jargon, without due consideration for adapting the information to the local context. Younger generations, such as schoolchildren and individuals lacking formal education, cannot fully comprehend the intricacies of zoonotic diseases, threats, and risks due to the highly technical nature of the available materials. It is, therefore, essential to integrate the concept of One Health into school-level education (Haxton et al., 2015), covering vital aspects such as the food system, food security, health and diseases, environment health, as well as biodiversity and ecosystem (Angelos et al., 2017). This initiative seeks to instil awareness in the younger generation of standard food safety and hygiene practices (One Health Commission, 2018).

Effective communication entails explaining the potential risks faced by individuals involved in farming and/or consuming animals that may be infected with zoonotic diseases and engaging them in plain and straightforward language. Such examples were featured in a recent report on wildlife animal trade and consumption (Box 6-6; Campbell et al., 2021). This approach not only has the power to mitigate the risks associated with disease exposure but also to create awareness among entire communities of food providers, especially those residing in remote areas with limited access to vital information about the transmission of zoonotic diseases in the agricultural sector. Box 6-7 lists a series of suggested questions to facilitate a dialogue regarding risk awareness. These questions are designed to be informal, allowing for a nuanced understanding of risk perception among smallholders from various backgrounds and responsibilities.

BOX 6-6

Practical strategies for effective communication in the context of zoonotic disease prevention

A comprehensive Situation Analysis report using Social and Behavioural Change (SBC) messaging identified strategic communications and stakeholder engagement success factors in relation to wildlife disease risks (Campbell et al., 2021):

- Messaging and communications should be directed to the most appropriate target audiences.

- Base messaging on pre-existing values.
- Use positive social messages, not just negative environmental (or health) messages.
- Ensure messengers are relevant and can speak credibly and with authority on the issue.
- Focus on what is relevant to and resonates with locally specific audiences.

Clarify and simplify guidance on change, and enabling, rather than instructing.

BOX 6-7
Communicating Risks: Risk awareness and perception towards spillover events

As individuals, our interactions with animals are shaped by our lifestyle choices or may also be influenced by our occupations. Recognizing the points of contact with animals, where and when they occur, can help mitigate the risks of zoonotic disease transmission. By posing these questions to oneself, a person can become aware of the risks they may incur:

- What significance do animals have to you?
- What types of animals are in close proximity to you?
- In what kind of environment do you and the animal coexist?
- Are you aware of what disease animals can carry?
- Do you feel like you have the capacity to assess animal health or recognize the signs and symptoms of a sick animal?
- Are you aware of the risk of exposure to zoonotic diseases when in contact with animal body fluids, blood, carcasses, faeces, and whether the animal is healthy or sick?
- Are you aware of any biosecurity guidelines and animal welfare standards currently in place, in relation to the animal?

CRITICAL POINTS OF CONTACT BETWEEN HUMANS AND ANIMALS IN THE VALUE CHAIN IN SOUTHEAST ASIA AND ASSOCIATED COMPLEX RISK FACTORS

Zoonotic disease hazards are interlinked and multifaceted, arising from a complex interplay of numerous factors. To comprehensively understand and address these risks, a One Health approach rooted in genuine interdisciplinary research has been proposed throughout this guidebook and in other avenues. Developing effective and sustainable interventions within such complex systems necessitates an in-depth understanding of the various risk factors (variables that are associated with an increase of zoonotic disease transmission) and actors involved. It is crucial to recognize that risk emergence within these systems typically results from elaborate interactions among multiple components, often entangled in complex feedback loops that are exceptionally challenging to identify (Ghai et al., 2022).

This complex web of both direct and indirect causal relationships complicates the prediction of intervention impacts across ecological, economic, social, and cultural dimensions whether at local, regional, or global scales. Focusing solely on isolated risk factors identified through research on specific subsections of the system, such as epidemiological studies on cross-species transmission risks between wildlife and domestic animals, is likely to fall short of achieving the real-world impact required. Such an approach often neglects the broader direct and indirect effects, as well as feedback loops within the entire ecological and social system.

The challenge lies in bridging diverse knowledge domains and cultures, encompassing individual, local, specialized, strategic, and holistic knowledge (Parkes et al., 2005). It is overly simplistic to compartmentalize wildlife, domestic animals, and humans as distinct entities isolated within the vast ecological and social system of our planet. Instead, the critical factors leading to the emergence of climate change and pandemic risks are the shifts in dynamics within this complicated system. This includes alterations in the frequency of interactions, consequently affecting the flow of pathogens among wild animals, domestic animals, and humans (Lefrançois et al., 2023). These shifts elevate the potential for cross-species transmission and genetic alterations that can enhance transmissibility. The mechanisms underpinning increased contact between various susceptible hosts, be they wild or domestic animals, or humans, are linked to phenomena such as rising deforestation or heightened demand for wildlife as pets or for consumption and other purposes (Box 6-8).

BOX 6-8
Navigating trade-offs between prioritizing food security and wildlife conservation: Malaysia example

Food security awareness varies from country to country and community to community (Gallegos et al., 2023; Breene, 2016). In rural communities characterized by predominantly lowland paddy fields, upland crop cultivation, or coastal-aquaculture reliance, the countryside farmers and their cooperatives sustain their livelihoods while experiencing periodic short-term fluctuations in demand. With readily accessible crops and backyard microfarms, the approach to food security is rather straightforward—to cultivate a modest amount of produce primarily for household consumption or local markets.

Despite land ownership for crops, fish farming and animal farms, Malaysia imports around 30% of its rice along with a substantial amount of other farm produce and animal feed from other countries (ITA, 2024). A recent investment in modern technologies to increase planting and production by the Malaysian government emphasizes the importance of this group of stakeholders for a sustainable food industry (Zalani, 2023). Food security and the role of smallholders in this country (and other Southeast Asian countries) are vulnerable to numerous factors, some of which are beyond stakeholders' control. These factors include political dynamics, ecosystem variations, such as unpredictable wet-dry seasonal changes, migration patterns, and land holdings or farm locations in rural areas. While government financial subsidies aim to enhance agrarian agriculture, several other factors pose a potential threat to the success of the National Food Security Policy Action Plan (Ministry of Agriculture and Food Security Malaysia, 2024) and all other initiatives if not closely monitored. One critical aspect is the zoonoses and risks of zoonotic diseases.

Examples of risk factors include (but are not limited to):

- Housing nested within these farms/estates allows animals to access cooking and sleeping areas
- Household practices and perception of standard hygiene and food safety
- Limited access to veterinary services and other healthcare facilities
- Limited awareness of zoonotic disease prevention and control practices such as vaccination, surveillance, quarantine, monitoring and evaluation
- A lack of incentives to improve biosecurity in animal farming
- Absence of transparency and enforcement in wildlife habitat protection

Sabah and Sarawak are geographically blessed with abundant marine resources, mangrove forests, mountain rainforests of rich biodiversity, and various mammals and bird species (Figure 6-4) that have the potential to act as reservoirs or intermediate hosts for the emergence of new infectious diseases in humans (Sabah State Government et al., 2020). Lands in this region are slated for transformation into modern agriculture hubs (Khazanah Research Institute, 2022) and are projected to become one of Malaysia's major rice production centres in the next decade. Land development and repurposing exert stress and pressure on the local environment and biodiversity leading to the loss of wildlife habitats and the expansion of contact zones between human and animal reservoirs of disease-causing pathogens (Plowright et al., 2021). Modern agrotechnology with improved biosecurity measures (Youssef et al., 2021) and active engagement from various stakeholders could mitigate the risks associated with zoonotic disease transmission while simultaneously ensuring food security.

FIGURE 6-4 Local flora and fauna. Images depicting the Bornean horseshoe bat, Irrawaddy dolphins, and small-toothed palm civets found in Sabah and Sarawak. The breathtaking Gunung Mulu in Sarawak, along with other mountains, serves as a magnet for ecotourism enthusiasts. Photo source: Mammals of Borneo.

Small-scale agrarian socio-economy and zoonotic disease risks in Southeast Asia

In Southeast Asia, small-scale landowners, predominantly individuals and families (Figure 6-5), play a crucial role in the local animal value chain (Mason-D'Croz et al., 2022). Together with the diversity of crops and food produced, and the different types of agricultural infrastructure employed, these factors place the local agrarian socio-economy as a proven practice to achieve national and global food security, poverty reduction, and sustaining rural livelihood. Such agrarian economies often involve the use of domesticated animals for a variety of activities and benefits (Turcotte et al., 2017).

FIGURE 6-5 Smallholder farmers in Myanmar (Burma). Photo credit: Pexels.

Farmers rely on farm animals for their labour in cultivation and use manure for fertilizer, amongst other animal-dependent agrarian activities, including livestock rearing, fishing, and aquaculture. The Southeast Asia region hosts a multitude of smallholder farms or backyard producers with daily direct and indirect contact with animals (Mason-D'Croz et al., 2022). While variation exists from one country to another, these smallholder farms typically involve family-operated farms (Thapa and Gaiha, 2014) that raise a limited number of heads that are fed with a combination of commercial and naturally available feeding sources.

Smallholder farming is highly dependent on its natural surroundings for ecosystem resources and services essential to the functioning of their livelihoods (Fan and Rue, 2020). An example case is the traditional smallholder cattle raisers in Southern Luzon, Philippines, as documented by Galang and Calub (2020a). Historically recognized for their cattle raising, these communities now face challenges posed by unprecedented climate change and increased risk of disease exposures (Box 6-9).

BOX 6-9
Smallholder cattle raisers in Southern Luzon, Philippines

In Southern Luzon, Philippines, the cattle raising system is traditionally a mixed cut-and-carry grazing model, highly dependent on several natural ecosystems around their landscape. During the rainy season, cattle raisers utilize grasslands teeming with healthy grasses and shrubs. However, when these grasslands dry during the summer, cattle are moved to natural forests in upland areas and riparian forests along riverbanks, where they can graze over perennial shrubs present in these ecosystems. Furthermore, cattle raisers gather additional feed from forest trees as supplementary biomass for their cattle. In recent years, dependency on natural and riparian forests has intensified due to a shortening of the rainy season. Compounded by other drivers such as overexploitation and privatization of grasslands, cattle raisers are increasingly compelled to source food from forests, increasing the risks of human-wildlife encounters that have the potential to spark zoonotic disease transmission (Galang and Calub, 2020a).

In general, the growing rate and intensity of zoonotic disease transmission have been shown to be driven in a large proportion by the intensification of animal agriculture and other human-induced, or anthropogenic environmental drivers (Rohr et al., 2019). Examples of critical anthropologic socio-ecological drivers of risks are:

1. **Human encroachment,** exemplified by urbanization and agricultural expansion into natural ecosystems leads to extensive land-use changes (Lawler et al., 2021; Simkin et al., 2022). These developments not only threaten biodiversity but also expose humans to animals by creating novel assemblages of all the species existing in a particular habitat, thereby providing pathogens with new opportunities to seek out and exploit alternative host species (Daszak et al., 2000).
2. **Intensification of animal production** results in larger and denser animal populations within confined facilities, which encourages disease spread among animals and between animals and workers, and often leads to waste and wastewater discharges that can harbour pathogens (Bernstein and Dutkiewicz, 2021). Large-scale animal production can generate discharges well in excess of the local ecological carrying capacity for nutrients in the land, which may drive use of manure lagoons or litter piles to capture the excess wastes (Davis et al., 2011). The pathways by which pathogens can move around and off production facilities can relate to their facilities and processes for biosecurity (prevention of disease introduction) and biocontainment (prevention of disease release) (Davis et al., 2011). For example, capture (e.g., in a lagoon) and then spread of manure or litter onto crop fields locally or at a distance can allow for runoff of pathogens into surface waters, direct exposure of wildlife on the fields, and contamination of crop products, which may be consumed by either people or livestock populations. If pathogens can survive desiccation (drying), they also may be present in the soil and in airborne dusts, exposing workers and community members (Davis et al., 2011). At the same time, these environmental media (wastes, wastewater, surface water, soil, or air) can be leveraged for disease surveillance activities using environmental sampling methods, e.g., eDNA (Module 5).
3. **Expansion of the types of animal husbandry** gives rise to new forms of subsistence-based animal consumption. For instance, in China, the expansion of wildlife farming in the 1990s prompted many smallholder farmers to turn to wildlife trade (legal or illegal) as a means of income generation, and this trend persists to date (Wang et al., 2019).

Several reports also indicate that agricultural workers and people living in rural areas adjacent to these agricultural lowlands and uplands, as well as those in semi-urban areas, are at higher risk of exposure to zoonotic diseases from both domestic and wild animals, and this heightened risk is attributed to inadequate biosecurity measures and vaccination protocols (Jori et al., 2021; Magouras et al., 2020). For instance, backyard and small-scale farmers often rear free-ranging poultry and livestock in close proximity to households. This intermixing allows wildlife and farmed animals to access humans' sleeping, eating, and cooking areas, creating a situation where human–animal interactions are frequent. Additionally, cohabitation of multiple other species (chickens, ducks, pigs) within the same environment leads to an elevated risk of cross-species transmission.

In the region, the limited adoption and enforcement of biosecurity measures in backyard farms remain challenges, primarily due to the high cost of such measures or affording more space for different types of animals. There is also a severe lack of awareness of these biosafety and biosecurity guidelines, extending not only to the farmers themselves but also to local governing bodies who have jurisdiction over these backyard farms. Furthermore, healthcare services should be meeting and engaging with farmers and other community members *in situ*—where they work—to reinforce the need for cross-governmental collaborations with health departments etc., thus ensuring that backyard farmers stay updated with immunizations and maintain good health. In Malaysia, permits for urban farming in residential areas typically fall under the jurisdiction of the local municipality (Murdad et al., 2022), but the temporary presence of farm animals such as cows and goats in residential compounds for Muslim celebrations is permitted with approval from the Department of Veterinary Services (DVS). Box 6-10 illustrates an example of biosafety and biosecurity concerns in small-scale backyard poultry farms in Indonesia.

Hygiene practices in these communities tend to be minimal and occasionally insufficient, with some relying on unsafe water sources and lacking access to improved sanitation. These small farming households often face challenges in accessing both human and animal veterinary health services, in addition to a wide range of household practices are linked to a heightened risk of exposure to zoonotic pathogens. For examples, the following household practices could contribute to increased likelihood of exposure: inadequate handwashing and hygiene practices, improper handling of poultry upon slaughtering (Vong et al., 2009), consuming of undercooked meat (Petersen et al., 2010), feeding animals raw meat (Stull et al., 2013) and culling sick animals for consumption and eating animals found dead (Osbjer et al., 2015).

BOX 6-10

Challenges and opportunities in West Java's poultry industry: A biosecurity perspective

West Java, Indonesia, is a region renowned for its fertile agricultural landscape and agrarian-centred economy. Here, animal farms, domestic poultry, and a variety of avian species constitute commonplace commodities. The province has been particularly hard-hit by HPAI H5N1 outbreaks, largely due to its extensive poultry trade, diverse poultry industries, and substantial poultry population (Karo-karo et al., 2019). The struggle to contain the spread of this disease stems from various factors, including an ineffective vaccination strategy, underreporting of cases out of fear of inadequate compensation for culling, and unsuccessful implementation of biosecurity measures (Indrawan et al., 2018).

To exacerbate the situation, unwell poultry have been making their way into the market through traditional distribution channels. For example, agricultural products from rural or small-scale backyard poultry farms are frequently marketed as fresh poultry meat without proper refrigeration or freezing (Indrawan et al., 2021). Local customers tend to favour freshly culled poultry meat, which they perceive as being the freshest due to its warm, freshly-cut nature, over chilled or frozen poultry meat (Indrawan et al., 2021). Given the severity of the situation, government intervention is of greatest importance. It is imperative to halt the sale of diseased sick poultry through these channels and educate the community about food safety, all while enhancing the implementation of biosecurity measures.

Innovative strategies such as circular economy practices, have the potential to mitigate the risk of zoonotic disease transmission (Rejeb et al., 2023). Circular economy initiatives promote efficient resource use and reuse, adoption of sustainable technology innovations, and responsible behaviours, for example, using crop residues and agro-industrial byproducts for animal feed or implementing precision livestock farming to minimize waste (Yang et al., 2023). These approaches not only help reduce the need for additional resource extraction links to deforestation or mining, but also safeguard biodiversity and ecosystems, while curbing encroachment activities in areas where potential zoonotic diseases may emerge. Circular economy measures such as sustainable farming practices, diversified crop systems, and improved animal welfare, can effectively lower the risk of zoonotic diseases emerging within farm environments (Possas et al., 2021; Rejeb et al., 2023). A strong enforcement and implementation of circular economy initiatives at the local level, such as those illustrated in Figure 6-6, can minimize disease transmission associated with long-distance transportation as well as limit the spread of disease through extensive or global animal supply chains.

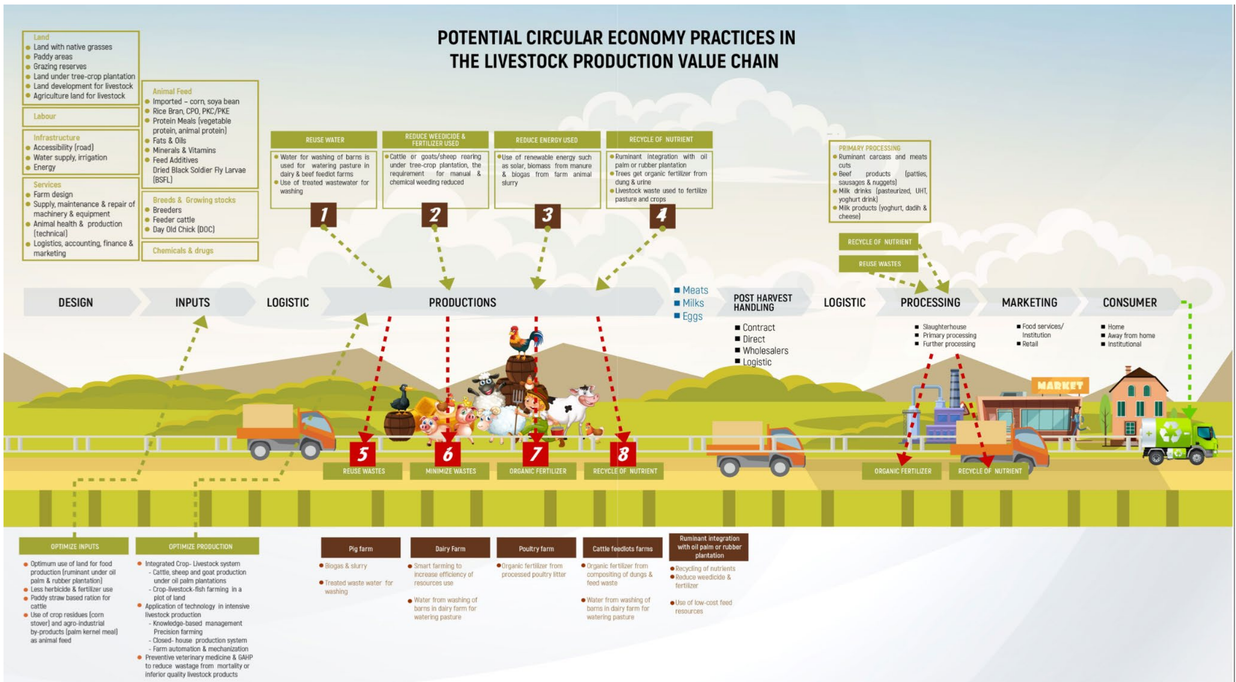

FIGURE 6-6 Potential circular economy practices in the livestock production value chain. Source: MPC, 2020.

Uncovering potential cultural and behavioural risk factors in Southeast Asia

Southeast Asia is home to a mixture of ethnicities and religions each with its own unique practices and beliefs. Within this context, the utilization of animal meat extends beyond mere subsistence and income, extending to ritual slaughter, religious sacrifice, offerings, and celebratory events. Some examples include the use of domesticated animals for Muslim animal sacrifice (al-Qayrawani, 2019), birds and pigs for Balinese Hindu ritual (Bali Spirit, 2024) and the practice of animal sacrifice in Lao Buddhism (Sprenger, 2005). While practices and beliefs hold significant importance across various countries in Southeast Asia, legal inconsistencies across the region may also lead to welfare concerns and unethical practices (Boxes 6-11 and 6-12).

BOX 6-11
Legal inconsistencies across region

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FIGURE 6-7 Dog and cat meat trade in Southeast Asia. Dogs in cages near a dog meat restaurant in Vietnam. Photo credit: FOUR PAWS and Animal Reader.

While dogs and cats are cherished as the most commonly kept companion animals in many parts of the world, in certain regions of Southeast Asia, they are often viewed as a source of food and are featured in celebratory meals (FOUR PAWS, 2020). In these areas, regulations and oversight concerning the capture, transportation, and slaughter of these animals are not sufficiently stringent (Figure 6-7). This lack of oversight raises significant concerns related to animal cruelty, the theft of pets, and the potential for zoonotic diseases such as rabies to emerge and reemerge (FOUR PAWS, 2020; ICCWC et al., 2022). To counter this issue, dedicated advocacy groups such as the Dog Meat-Free Indonesia Coalition (DMFI), Soi Dog, FOUR PAWS, and others, are actively working to advocate for government intervention. Their aim is to enforce stricter penalties for those engaged in this trade, ultimately fostering a more humane and responsible treatment of dogs and cats in these regions.

BOX 6-12
Wildlife conservation and challenges: Religious establishments, animal welfare, and collaborative efforts in Southeast Asia

FIGURE 6-8 Macaques symbolize both revered spiritual connections and the challenges of animal welfare in Southeast Asia. Photo credit: K. Yoganand.

Many religious establishments in Southeast Asia are closely associated with symbolic animals, such as macaques (Figure 6-8) or felines, adding to their allure as local attractions (Wessing, 2006). In rural parts of these countries where animal welfare organizations are scarce, these establishments also serve as crucial rescue centres for abandoned animals. However, the well-being of these animals is often compromised by the lack of veterinary resources, proper care, and education (FOUR PAWS, 2021; Nizamuddin and Rahman, 2019). Consequently, they frequently suffer from malnutrition and zoonoses, posing a potential risk of disease transmission to humans (FOUR PAWS, 2022; Nizamuddin and Rahman, 2019). Furthermore, in rural areas, there exist cultural leaders, tribal communities, and animal specialists who often collaborate with various stakeholders to address similar challenges. These stakeholders may include government or non-governmental agencies engaged in jungle expeditions, search-and-rescue operations, ecotourism and biodiversity initiatives, research endeavours, or efforts to combat illegal hunting. However, these groups often encounter barriers and gaps, such as lack of adequate information, necessary empowerment, and support when it comes to animal welfare issues. These collaborative efforts are also critical to mitigate unsustainable practices such as wildlife capture and trade harvesting.

The dependence on resources, which are at times limited, often conflicts with deeply ingrained cultural practices that promote livestock farming. Farmers are often forced to seek means of enhancing production, occasionally resorting to unlawful methods, all in pursuit of economic advancement (Marks et al., 2015). Growing diversity in agribusinesses in Southeast Asia tends to drive land-use changes to meet booming trade demands, oftentimes at the expense of natural forests, biodiversity, and wildlife habitats (Liu et al., 2020). Some examples include:

- High-grades durian farming, palm oil and rubber plantations, and cattle farming have led to deforestation
- Aquaculture often leads to the destruction of mangroves and coastal habitats
- Increasing ownership of exotic pets and demand for commercially extinct species, especially in urban communities where well-off households can afford to keep exotic

pets. Social media platforms and online dark marketplaces have further fuelled this trend, encouraging petting of exotic animals as part of the new lifestyle

FIGURE 6-9 Rats, frogs, squirrels, and monitor lizards are often sold in local fresh markets in Lao PDR. Photo credit: K. Yoganand.

Human behaviour and unregulated or illegal animal sourcing activities play a critical role in shaping the structure of live animal value chains and significantly influence the risks associated with pathogens spread through or amplification within these value chains (Module 3). For instance, in large cities in Vietnam, the consumption of wild animal meat has evolved from previously only being accessible to the high-income strata of the population, to becoming a much more widespread cultural practice (Shairp et al., 2016). This has led to increased wildlife hunting activities (Anh et al., 2021) to meet the demand of consumers.

In addition to behavioural factors, weak regulatory frameworks and mechanisms are closely associated with illicit trade activities (UNODC, 2023), which create conditions and opportunities favourable for the emergence and spread of zoonotic diseases. This issue has been consistently observed throughout the region, highlighting the need to address inadequate action and enforcement practices, involving multiple sectors and stakeholders, to mitigate the increased risk of zoonotic disease outbreaks.

In some parts of Southeast Asia, the wet market scene typically features an array of hunted species made available for human consumption, further exacerbating the risks for zoonotic transmission (Naguib et al., 2021) and providing another way for zoonotic infectious diseases to come into close proximity with humans. In these places, species not subject to wildlife trade restrictions are openly traded (Figures 6-9 and 6-10). Specifically, one of the long-standing issues in the region is wildlife trafficking (Module 3), particularly the illegal trade in endangered species and their products. Legal inconsistencies and loopholes in action and policy measures (license revocation etc.) pertaining to wildlife vary across regions (Jiao et al., 2021). Variations in penalties for wildlife crimes prevent the development of a unified strategy between and within countries in the region for addressing wildlife crime, contribute to difficulties in effective wildlife protection, and create disparities in the conservation efforts for different wildlife species (ACET, 2019).

FIGURE 6-10 A variety of animals serve as meat sources in the region. Grilled rats are commonly sold in streets of Cambodia (top left); monitor lizards and rodents are sold in an Indonesian market (top right); and several amphibian, reptile, bird, and mammal species are sold in local fresh markets along with fishes across the Southeast Asia region (bottom four photos). Photo credit: K. Yoganand.

Examples of culturally driven practices that may introduce zoonotic risks include the substantial market demand for premium high-end products and other regional delicacies such herbal chicken, bird nests, rats, fried tarantula, bats, amphibian dishes, Kopi Luwak coffee, and snake wines believed to have preventive and wellness benefits. Similarly, in the Philippines, *balut* eggs are a common street food. *Balut* is a delicacy that consists of a duck embryo boiled and eaten within its shell. Some believe that it contains aphrodisiac attributes (Alejandria et al., 2019). Similar dishes with different preparations can also be found throughout other Southeast Asian countries, such as Vietnam and Lao PDR (Hochberg and Bhadelia, 2016). Notably, Kopi Luwak coffee consists of partially digested coffee cherries, which have been consumed and defecated by

Asian palm civets (Gaiser, 2024) (Figure 6-11). Consequently, civets have been increasingly captured in the wild, raised, and traded for this purpose (Shepherd, 2012), creating a direct connection from wild animal products to consumers. In this case, ineffective welfare monitoring and law enforcement often result in animals held in captivity enduring substandard living conditions, lacking access to necessary veterinary care, and frequently exposed to stressful environments during recreational events featuring loud music, overcrowding, and an influx of visitors (Coleman, 2021).

FIGURE 6-11 The common palm civet (*Paradoxurus hermaphroditus*), native to South and Southeast Asia, in its cage on a wildlife farm in Vietnam in 2017. Photo credit: Wildlife Conservation Society, Vietnam.

In addition to live wet markets in the open, illegal virtual marketplaces, some operating through social media platforms or black-market websites, have proliferated in Southeast Asia. These platforms cater to diverse customers, offering a variety of animal and animal products that can be discreetly purchased and shipped. This creates opportunities for animal-based illegal trade and enables criminal networks to operate and thrive (Fallin, 2021; ASEANPLUS, 2023).

Animals are also used in recreational, sports and games, and local ecotourism activities (Zamri and Md-Zain, 2022) (Figure 6-12). Some examples include:

- Animal commodification for entertainment and tourism, such as elephant riding, tiger petting, local animal contests, and cockfighting, which are considered to have a potential role in the spread of avian influenza viruses. Some countries promote these activities, including gambling, as tools to boost tourism. In the Philippines, recent cases have involved virtual versions of cockfighting, usually live streamed through websites or social media platforms (Murphy, 2023). In contrast, other countries' governments have made all forms of gambling involving animal fighting illegal and prohibited animal fighting and baiting altogether (AWI, 2024; Mota-Rojas et al., 2022).
- Sought-after attractions, such as street and alleyway traditional wet market venues which are popular among tourists (Seneviratne, 2020). Some wet markets are poorly structured, without doors or gates, and are susceptible to intrusions by stray animals in search of refuge at night.
- Hobby farms, small-scale animal-based businesses, and individual pet owners. In these cases, the confinement and captivity of animals in inadequate living conditions can lead

to significant physical and physiological stress (Fischer and Romero, 2019; World Animal Protection, n.d.), exacerbating the risk of zoonotic disease transmission.

Southeast Asian countries exhibit varying operating guidelines, policies, and practices concerning animal welfare, rights, and ethics, particularly regarding the use of animals for human interests such as animal tourism, sports, and local competitions (Nizamuddin and Rahman, 2019; Rivera et al., 2021). The Southeast Asian Zoos and Aquariums Association (SEAZA) was established in response to the growing need for standards and guidelines for zoos and conservatories in Southeast Asia, but more support is needed to keep up with animal welfare standards. In addition, the lack of access to veterinary care, poor hygiene practices, and overall absence of regulatory measures further exacerbate the potential for zoonotic diseases to emerge, thereby posing a significant threat to both animal and human health (UNEP and ILRI, 2020).

FIGURE 6-12 Ecotourism images of long-tailed macaque monkeys interacting with human tourists at the Batu Caves in Selangor, Malaysia. Photo credit: Meghan Davis.

Human behaviour is shaped by personal knowledge, beliefs, experiences, and values, among other factors. External factors, such as the socio-cultural and economic-political systems by which actors live, are critical in shaping these behaviours (Burke et al., 2009). Module 8 further includes practical suggestions on how to engage all parties involved in the animal value chain to help manage zoonotic risks. To effectively address these risks, an essential step is identifying and understanding the human behaviours contributing to them. This calls for a participatory approach that integrates diverse knowledge systems, especially local knowledge, to enable a more comprehensive understanding of key actors and their potential contributions to creating these risks. Participatory methods and community engagement go a long way to ensuring critical stakeholder inclusion and successful implementation of public health response writ large. Module 8 (How to use this guidance: applying participatory methodologies to countering spillover) outlines some of the key components of the implementation process, including the cultural, social, economic, and political contexts. By meticulously mapping out animal value chains and the associated risk pathways, specific stages where risk originates, and actors need to be involved in the conversation could be effectively identified. Indeed, Module 8 emphasizes that this guidebook is useful only if the approaches described in it are implemented by the intended actors.

CONCLUSION

Efficiently preventing and controlling the emergence and transmission of infectious pathogens with pandemic potential require the active involvement of diverse stakeholders interconnected within the socio-ecological system. These stakeholders occupy varying roles, all of which either influence the risks at play or are directly affected by the resultant hazards and mitigation measures. Recognizing and comprehensively understanding the multifaceted local contexts and their impact on pandemic risks is the foundational step towards crafting effective risk mitigation strategies.

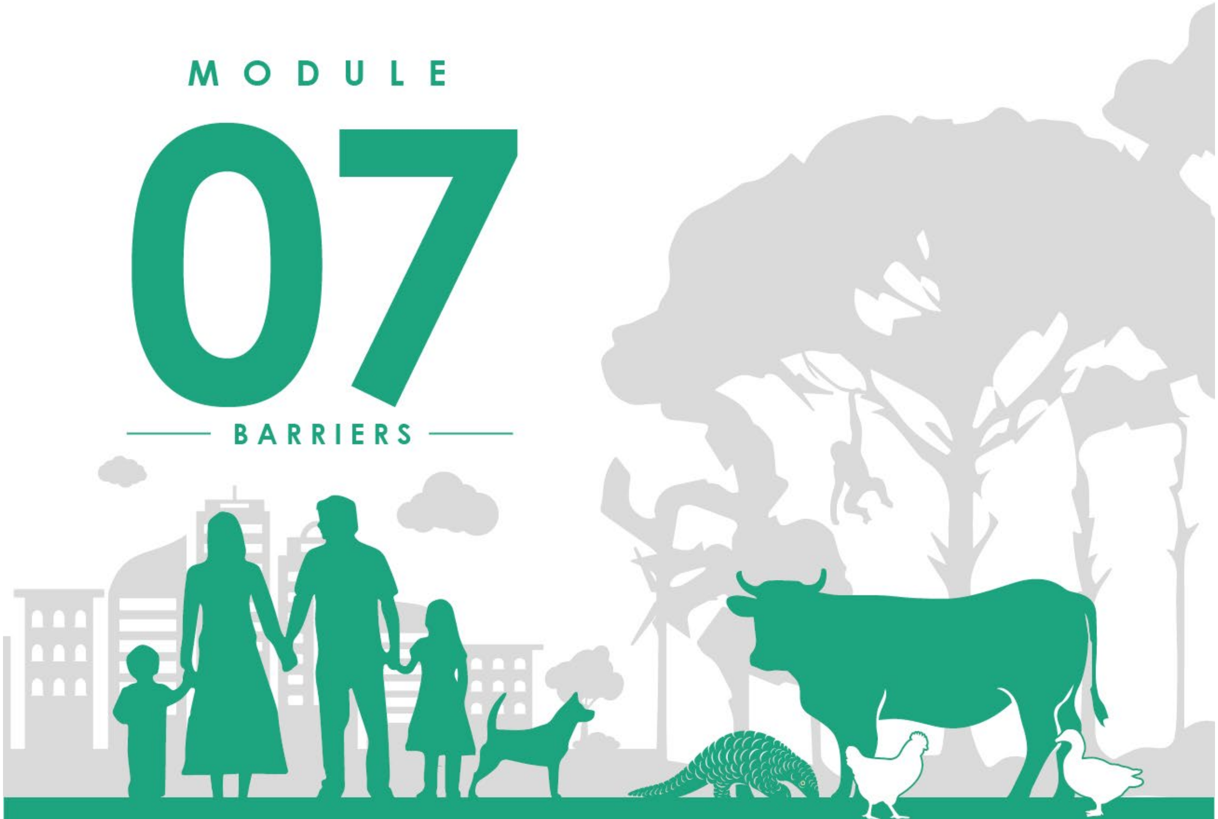
Central to this process is the imperative engagement of stakeholders, fostering a co-production of knowledge that empowers them to take ownership of the interventions under development, thereby maximizing the likelihood of their effectiveness and long-term sustainability. Furthermore, it is crucial to acknowledge the dynamic nature of socio-ecological systems. Any intervention can trigger direct and indirect consequences, reverberating through intricate feedback loops that are challenging to predict, potentially altering the socio-ecological system in unforeseen and undesirable ways. This dynamism isn't confined solely to human behaviour but extends to the natural and ecological systems, owing to their inherent complexity. Effective stakeholder engagement is pivotal for capturing the intricacies of the social dimension within the underlying socio-ecological system.

In the pursuit of harmonious coexistence between humans and animals, identifying tailored solutions to mitigate the risk of zoonotic transmission between humans, livestock, and wildlife remains critical. It is essential to acknowledge that intervention plans and biosecurity measures cannot adhere to a 'one-size-fits-all' paradigm, given the unique circumstances of each operation. Stakeholders must join forces, collaboratively striving to prevent zoonotic transmission by employing the most effective strategies aligned with their specific communities, culture, or regions. Simultaneously, relevant authorities must multiply their efforts to raise awareness among local communities involved in the animal and animal products value chain regarding the significance of zoonotic diseases and the critical importance of preventive control measures.

MODULE

07

BARRIERS



How to Enhance Zoonotic Disease Management by Addressing Knowledge Gaps and Implementation Barriers

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HOW TO ENHANCE ZOONOTIC DISEASE MANAGEMENT BY ADDRESSING KNOWLEDGE GAPS AND IMPLEMENTATION BARRIERS

Introduction

In the face of evolving disease threats, the need for adaptable and integrated public health measures cannot be overstated. This module examines barriers to implementing public health strategies to prevent and mitigate zoonotic spillover and the critical knowledge gaps (areas where we need more information to act) preventing implementation to give the reader tools for improvement in their local, regional, and national environment. Key areas where knowledge is lacking include information to inform health security plans at every level, supply chain infrastructure, determining the most effective education and training methods, tools to assess the spillover problem throughout the chain, and ways to evaluate the best policies to effect change in the human–animal–environment interface.

The module details practical actions to address technical, coordination, collaboration, communication, and institutional challenges that hinder the effective implementation of integrative public health strategies. It features several case examples from Southeast Asia and other regions to illustrate how individuals and organizations overcame barriers to enhance outcomes. The focus spans local, national, and regional supply chain interactions, emphasizing an integrated approach to One Health implementation for preventing and mitigating zoonotic spillover. Integration is particularly crucial in the context of low- and middle-income countries and areas in Southeast Asia known to have an intricate and dynamic interface between humans, animals, and the environment (see 'Module 6: Strategies to Engage Diverse Stakeholders Across the Live Animal Value Chain to Address Risk').

The module is structured around nine key barriers or gaps (Figure 7-1), and actionable plans addressing these challenges within the summarized framework for enhancing resilience against zoonotic disease threats in Southeast Asia (Box 7-1):

1. **Resource constraints**
2. **Operationalizing One Health**
3. **Communication, collaboration, and coordination**
4. **Data management, sharing and security**
5. **Transboundary disease surveillance**
6. **Human behaviour and consumption**
7. **Workforce and human capacity development**
8. **Laboratory capacity and biosafety**
9. **Engagement of commercial entities**

FIGURE 7-1 Overview of the nine key areas of barriers and gaps for implementation of policies related to zoonotic spillover. These interconnected barriers necessitate a collective approach to lay the foundation for a robust strategy aimed at enhancing Southeast Asia's resilience against zoonotic disease threats.

BOX 7-1
Framework for enhancing resilience against zoonotic disease threats in Southeast Asia

The following framework proposes three cross-cutting strategies to enhance Southeast Asia' resilience against zoonotic disease threats, emphasizing the importance of collaboration, resource optimization and coordinated action to safeguard public health and ecosystem in the region:

Coordinated and collaborative action: Harmonize efforts through collaboration and coordination of activities among diverse sectors and agencies responsible for human health, animal health (domestic and wildlife), and environmental health. These efforts should include cross-border cohesion and regional strategies that integrate various sectors across borders through joint efforts in surveillance, research, and response initiatives.

Efficient resource allocation: Address existing disparities, inadequacies, and variation (Coker et al, 2011a) (in resources such as weak and varied surveillance systems, services, research, etc.). Variation leads to challenges in estimating disease burden and difficulty in conducting transboundary, cross-country comparisons, as well as substantial underreporting of diseases. To overcome this, strategies such as increasing public awareness and education about disease reporting and improving capacity that enhances healthcare workers' ability to detect, diagnose, and report zoonotic diseases.

Expertise pooling: Sustain a reservoir of skilled professionals adept at addressing the interface of human, animal, and environmental health in the region. Encourage collaboration and knowledge exchange among experts in various fields extending beyond national borders enables Southeast Asia to tap into a wealth of collective intelligence. Cross-border collaboration enable experts from different countries to perform joint research projects, collaborative data analysis, and policy development.

BARRIER 1: RESOURCE CONSTRAINTS

Unequal allocation: Limited resources pose a significant barrier to effectively prevent and mitigate spillover from zoonotic diseases in Southeast Asia. Although adequate financial, human capacity, and infrastructure resources are essential for effective control strategies, the region faces challenges in both the availability and equitable allocations of these resources. In Southeast Asia, unequitable distribution is a major obstacle where more funding is usually directed to the human health sector, leaving agriculture, veterinary establishments, and animal surveillance under-resourced (Coker et al., 2011a). This imbalance hinders comprehensive disease prevention efforts, as all sectors are crucial in mitigating spillover risk. This challenge is highlighted in 'Module 3: Efforts to Prevent Transboundary Disease Outbreaks in the Southeast Asia Region'.

Neglected issues and misaligned priorities: Zoonotic diseases of wildlife origin are also often neglected globally, partly due to the challenge of integrating across sectors, as well as limited funding and lack of awareness. Promoting transdisciplinary systems approaches such as One Health or EcoHealth underscoring the interconnectedness of humans and wild animals within ecosystems, and considering environmental and ecological changes is crucial. Unfortunately, while collaborative effort offers opportunities for strategic investment, securing financial resources remains challenging. Donor priorities further complicate the issue, as programs funded by donor, which are commonly external to Southeast Asia, may not align with the specific needs of individual countries or the region (Coker et al., 2011a).

Inadequate funding: Historically, health policies and programs, such as the International Health Regulations (WHO IHR, 2005) have primarily emphasized disease prevention, preparedness, and response (PPR), often neglecting the upstream drivers of disease emergence. Emerging evidence highlights the pivotal role of these drivers in disease outbreaks, necessitating a re-evaluation of primary prevention measures upstream at the driver interface. However, securing financial resources for effective PPR remains a limitation that requires attention from policymakers at the country level.

Siloed government funding: Traditionally, government funding often is channelled through a siloed sector-specific system, hindering cross-sectoral fund and resource sharing. Fortunately, a shift towards collaborative effort is occurring where governments, global funders, and partners are now recognizing the importance of collaborative efforts to combat zoonotic diseases, embracing the One Health approach. This collaborative effort between donors and local authorities offers opportunities to determine strategic investment priorities across relevant sectors. The need for such collaboration becomes more pronounced during epidemics and pandemics, particularly in low-resource developing regions, as it allows for efficient use of all available funding and financing mechanisms.

Case Example 7-1
Lessons from SARS in Singapore

A recent study examined how the Singapore government's effort to combat the SARS outbreak informed its effort to control both the country and cross-border spread of SARS-CoV-2 (Kim et al., 2022). The study indicates that Singapore successfully used lessons learned during SARS to implement a 'whole-of-government' response to combat COVID-19. Here are four key approaches that Singapore adopted:

1. Ensuring vital healthcare resources and developing contingency plans. Singapore's experience with SARS underscored the importance of maintaining access to essential healthcare infrastructure. This led to the establishment of ample essential healthcare resources with contingency plans, including resource stockpiling and distribution, the creation of temporary medical facilities, and the government's swift designation of the National Centre for Infectious Diseases as the main hospital for critically ill COVID-19 patients—showcasing their proactive crisis preparedness and prevention strategies (Kim et al., 2022).
2. Mobilizing the private sector and collaborations for whole-of-society response. Recognizing the limitations of relying solely on public health institutions, the Singapore government-initiated collaborations with private hospitals through initiatives such as the Public Health Preparedness Clinic (PHPC) scheme. This program harnessed the capacity of private entities such as clinics and hospitals to partner with the government, providing essential healthcare services, medications, tests, and vaccines (Kim et al., 2022; Lum et al., 2021). Additionally, private entities such as Grab, a Singapore-based app that provides ride-sharing and food delivery services, played a pivotal role, offering rides for healthcare professionals (Baharudin, 2020; Kim et al., 2022).

3. **Combine bottom-up with top-down approaches.** Singapore's management policies utilized both top-down, centralized styles and bottom-up approaches during the COVID-19 pandemic (Kim et al., 2022). The government partnered with non-governmental organizations (NGOs) to support vulnerable populations, ensuring equal access to essential services. Collaborations such as the VIsualAId project highlighted the importance of involving private actors and volunteers beyond the healthcare sector, including local and international business entities, non-profit organizations, academic institutions, and other countries, ensuring a holistic and inclusive response (Kim et al., 2022; Lee, 2020).
4. **Leveraging scientific research and digital technology.** As the pandemic persisted, the Singapore government tapped into the expertise and knowledge of the private sector, including private telemedicine providers. These partnerships enabled virtual consultations and supervised self-swab tests, easing the burden on hospitals. Additionally, the collaborations between academia, tech industries, and the government led to innovative solutions, including diagnostic tools, contact-tracing apps such as TraceTogether, and health passports for safe border reopening (Chow et al., 2023; Kim et al., 2022).

Actionable guidelines to address resource constraints for zoonotic disease prevention

1. **Strengthen local and regional collaboration:** Encourage collaboration among governments, NGOs, communities, and other relevant stakeholders to develop a comprehensive approach to address high-risk health behaviours associated with zoonotic disease spillover. Engage local communities, civil society groups that are already active in the target area, traditional leaders, religious organizations, and indigenous groups to ensure the development of culturally sensitive strategies.
2. **Develop targeted resource mobilization:** Focus on allocating resources strategically to enhance preparedness and response capabilities in regions identified as disease 'hotspots'. This approach should span local, transboundary, and international levels to ensure a coordinated response to potential outbreaks.
3. **Sustain funding for One Health:** Establish funding mechanisms for applied research that operates within the One Health framework, through collaboration with the Quadrilateral UN agencies. Reallocate funds strategically to address Sustainable Development Goals (SDGs), including funding for transboundary disease surveillance as outlined in the International Health Regulations (IHR).

BARRIER 2: OPERATIONALIZING ONE HEALTH

FIGURE 7-2 One Health is the interconnected idea linking human, animal, environmental, and plant health. See also Figure 1-1, Module 1.

While the concept of linking human, animal, environment, and plant health under the One Health framework is now widely accepted (Figures 7-2, 7-3), practical implementation of its integrated approach remains challenging. In the Asian Pacific, region-specific core competencies for preventing, controlling, detecting, and responding to zoonotic disease capacities have been defined as: (1) Management, (2) Culture and Beliefs, (3) Leadership, (4) Values and Ethics, (5) Collaboration and Partnership, (6) Communication and Informatics, and (7) Systems Thinking. Achieving these core competencies is crucial for effective implementation of the One Health approach and aligns with several international strategic and action-oriented programs and initiatives such as the International Health Regulations (IHR). In 2005, the World Health Organization (WHO) Regional Offices for South-East Asia and the Western Pacific formulated the Asia Pacific strategy for Emerging Diseases (APSED), aimed to create a common framework for countries in both regions, enhancing their abilities to manage and respond to emerging infectious diseases (EIDs), in alignment with the core capacity criteria outlined by the IHR.[1]

[1] In the decade since, the remit of APSED has broadened to an all-hazards approach to include non-infectious hazards (APSED III).

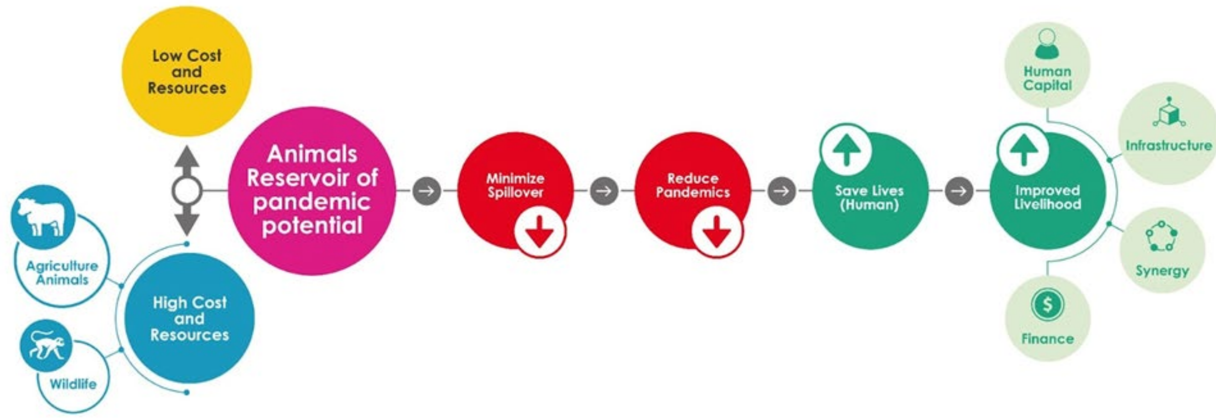

FIGURE 7-3 One Health operational framework. Interconnected factors of negative drivers of spillover are in red and improving livelihoods and saving lives are in green. Source: National Academies of Sciences, Engineering, and Medicine (NASEM) Spillover Workshop, Singapore, 2023.

The avian influenza A (H5N1) crisis in 1997 in Hong Kong, China highlighted the need for functional, multisectoral coordination between human and animal health domains (Chan, 2002; Ching, 2018). It was a turning point for adoption of the One Health concept in the region. In response, guidance was jointly developed in 2009 by WHO, the Food and Agriculture Organization (FAO), and the World Organisation for Animal Health (WOAH) called *Zoonotic Diseases: A Guide to Establishing Collaboration Between Animal and Human Health Sectors at the Country Level* (WHO et al., 2009). In 2019, given the growing need for global standardized guidance on the One Health approach, FAO, WHO, and WOAH, published *Taking A Multisectoral One Health Approach: A Tripartite Guide to Addressing Zoonotic Diseases in Countries* (FAO et al., 2019). In 2021, the previously tripartite organizations later expanded to include the United Nations Environment Programme (UNEP) to form the Quadripartite. A year later, in 2022, the Quadripartite launched the *One Health Joint Plan of Action, 2022-2026*, the first joint One Health plan aimed at creating an integrated systems framework to better prevent, detect, and respond to health threats (FAO et al., 2022). Examples of One Health standing coordinating bodies in the Southeast Asia region that support this framework can be found in Box 7-2.

Operationalizing One Health requires undertaking specific collaborative efforts across sectors at the human–animal–environmental interface, involving actors in sustainable agriculture, animal health, plant health, forest health, aquaculture, food safety, antimicrobial resistance (AMR), food security, nutrition, and livelihoods (FAO et al., 2022; FAO, n.d.-b.; Velazquez-Meza et al., 2022). Political will, adequate financing, collegiality, trust-building, and reducing territorialism among sectors are also essential for successful implementation (EMPHNET, 2023; Nzietchueng et al., 2023).

Local engagement and partnership building with key players such as industries, conglomerates, food-animal producers, consumers, government regulators, academia, NGOs and civil society organizations (CSOs) are essential (FAO, n.d.-a.). In addition, integrating environmental and socioeconomic factors related to disease emergence and spread into the development and implementation of One Health interventions is essential (Degeling et al., 2015; FAO et al., 2022). Currently, collaboration primarily focuses on domestic animal and human health sectors, with passive involvement of wildlife, ecosystems, and environmental health sectors. Many activities remain to be sector-specific, lacking multisectoral integration and transdisciplinary approaches therefore hindering the effectiveness of a holistic one health systems-based approach.

When operationalizing the One Health approach, it's crucial to recognize that monitoring and evaluation (M&E) are integral parts of the successful implementation of the programs that integrate human–animal–environmental–plant health (Hall and Le, 2015). While current M&E efforts in Southeast Asia often rely on qualitative insights such as case examples and success stories, and supplemented by descriptive statistics, there is a need to aim for longer-term evaluations and broaden evaluation frameworks that involve incorporating measurable key performance indicators that mirror the region's defined core competencies.

Case Example 7-2
The Lawa model in Khon Kaen Province, Thailand

The following example to eradicate a foodborne trematode (fluke) in Thailand illustrates the importance of an innovative approach that integrates the One Health and EcoHealth concepts, emphasizing biodiversity as part of the main strategy (Lerner and Berg, 2017). The *Opisthorchis viverrini* is primarily transmitted to humans through the consumption of traditional freshwater fish dishes and results in liver fluke infection.

Endemic to Southeast Asia, particularly Thailand, Laos, Cambodia, and Vietnam (Sithithaworn et al., 2012; Sripa et al., 2010), human cases of Southeast Asian liver fluke *O. viverrini,* persist in certain Thai regions and beyond (Crellen et al., 2021). Despite prior and long-standing control efforts in Thailand, O. viverrini infection rates remained high in northeastern provinces. In response, a joint One Health/EcoHealth strategy, known as the Lawa model, was implemented in the Lawa Lake region of Khon Kaen province, an area endemic for liver fluke infections. The Lawa model, developed by the Tropical Diseases Research Center (TDRC) at Khon Kaen University, incorporates anthelminthic treatment, intensive health education initiatives in communities and schools, ecosystem monitoring, and active community participation (Figure 7-4) (Sripa et al., 2015).

Thanks to the integrated nature of the strategy, the Lawa model has achieved remarkable success in reducing O. viverrini infection rates from 50% to approximately one-third and has reduced bile duct cancer occurrences across 10 villages surrounding the Lawa Lake community (Sripa et al., 2015). Additionally, prevalence of intermediate host fish species (Figure 7-5) dropped to less than 1% from a baseline of 70%. Due to the success of this initiative, it is being expanded to other parts of Thailand and neighbouring Mekong countries (Sripa et al., 2011). This exemplifies a transdisciplinary strategy fostering collaboration among various stakeholders, including government agencies, academia, and local communities, while enhancing disease surveillance and control at the intersection of human, animal, and environmental health.

FIGURE 7-4 Community-based health programs run by village health volunteer workers in Khon Kaen province, Thailand. Source: Sithithaworn et al., 2012.

FIGURE 7-5 (Panel A) *Bithynia* species snails, which serve as the intermediate hosts for *Opisthorchis viverrini*. (Panel B) Fishing activity in Chonnabot District, Khon Kaen Province, Thailand. (Panel C) Cyprinoid fish caught from natural water courses in the district. (Panel D) *Koi-pla,* a traditional dish made from uncooked cyprinoid fish. *Koi-pla* is often contaminated with viable, infectious metacercariae of *O. viverrini*. Source: Sripa et al., 2011.

Case Example 7-3

Interagency task force response to Reston ebola outbreak in the Philippines

FIGURE 7-6 The Reston ebolavirus has been implicated in cross-species transmission among pigs, macaques, and humans, which prompted extensive epidemiological inquiries involving Philippine health and veterinary authorities, alongside experts in filoviruses. Photo credit: Pixabay and Flickr.

This case outlines the response efforts in the Philippines following a Reston ebola outbreak among monkeys and pig farms in the 1990s and 2000s, which subsequently led to infection among farm workers who had close contact with sick pigs in 2009 (Miranda and Miranda, 2011; WHO, 2009). The Philippines has faced challenges in managing infectious disease outbreaks such as Henipavirus sourced from bats and transmitted through infected horses in Mindanao in 2014 (Ching et al., 2015). Response teams, formed in reaction to such outbreaks, usually disband after the crisis subsides, but the agility and flexibility of outbreak management is dependent on the continuity and maintenance of operational groups. To reverse this trend, experts recommended establishing a task force with consistent and frequent meetings of operational groups to maintain awareness and preparedness for infectious diseases' potential risks over time. A task force was established with external funding and support and composed of individuals from organizations such as the Department of Health (DOH), Department of Agriculture (DA), and the Department of Environment and Natural Resources (DENR).

The Philippines also grapples with the autonomy of local governments, leading to diverse and sometimes conflicting policies at the local level, further complicating national coordinated efforts. To help integrate more collaboration across levels, the College of Public Health at the University of the Philippines with support from USAID and Chevron, established a master's program on One Health, through the Southeast Asia One Health University Network (SEAOHUN). The Graduate school curriculum includes 'Fundamentals of One Health' and related modules). The Philippine One Health University Network collaborates with the Bureau of Animal Industry to investigate leptospirosis in swine, specifically in food production farms in Los Banos. Furthermore, the IHR PVS (Performance of Veterinary Services) National Bridging Workshop, organized by the Tripartite (WHO, FAO, WOAH) and hosted in the Philippines, exemplifies the nation's commitment to strengthening its preparedness and response mechanisms despite the challenges faced.

Actionable guidelines for operationalizing One Health

1. **Institutionalize collaboration:** Establish permanent interministerial bodies for sustained collaborations across ministries and institutions, moving beyond transient interministerial committees.
2. **Develop a national One Health joint action plan**: Develop a comprehensive national plan involving all relevant sectors, leveraging global guidance, such as the Quadripartite One Health Joint Plan of Action (FAO et al., 2022), while customizing it to the specific, local context.
3. **Promote active coordination and information sharing:** Facilitate collaboration and the exchange of information among a broad spectrum of stakeholders.
4. **Implement a country-specific coordination framework:** Institute a country-level coordination framework within an agreed-upon structure, e.g., Thailand's One Health Steering Committee rooted in the Ministry of Public Health (Coker et al., 2011b; Rüegg et al., 2018; Tangwangvivat et al., 2019).
5. **Strengthen and expand national capacities:** Utilize existing resources such as the Tripartite Zoonoses Guide and operational tools to augment existing national capabilities (FAO, 2019) in one health implementation.
6. **Invest in workforce development:** Equip professionals from various sectors with the skills and knowledge necessary for effective collaboration and coordinated action on zoonotic disease threats.

BARRIER 3: COMMUNICATION, COLLABORATION, AND COORDINATION

The integration of sectors along the human–animal interface that spans local, national, and regional domains hinges on effective and efficient communication, collaboration, and coordination. However, limited capacity and siloed organizational systems can hamper these activities, leading to a loss of trust, and prevent sustainable collaboration across ministries, disciplines, and sectors (Delesalle et al., 2022; dos S. Ribeiro et al., 2019). Fostering a culture of cooperation and information sharing among partner organizations is critical to address the spread of infectious diseases (Liverani et al., 2018). Providing knowledge integration for stakeholders and leaders across various disciplines is fundamental to operationalizing the One Health approach. Introducing One Health concepts into educational curricula, from medical schools to social sciences and relevant business and engineering units, facilitates a deeper understanding of the concept and its practical applications (Docherty and Foley, 2021; Haxton et al., 2015; Rabinowitz et al., 2017).

For outreach and communication with community partners, fostering engagement in a multicultural and multidisciplinary manner is critical, given that policies and practices are better received if they are simple and easy to understand, compatible with pre-existing community behaviours, have observable benefits, and offer relative advantages to the implementing community (See 'Module 8: How to Use This Guidance: Applying Participatory Methodologies to Countering Zoonotic Spillover'). In this, management of bidirectional information flow (between government entities and communities) is essential and includes attention to misinformation and disinformation. Strategies for risk management need to be built within narratives that empower behaviours to reduce risk without creating or promoting unintended consequences such as stigmatization of groups of people or animals, e.g., global media attention on bats associated with the COVID-19 pandemic (Nanni et al., 2022). Accurate and appropriately timed information sharing is critical to address preventive, control, and mitigation efforts when epidemics of zoonotic spillover origin happen. Efforts for accurate communication must be based on reliable data evidence. Communication based on unreliable data could lead to confusion, costly product rejection, as well as lack of trust of the public health (including veterinary) system (HHS, 2021).

In addition to these approaches, the successful adoption of the One Health concept often requires a top-down initiative. International agreements such as the IHR, the Cartagena Protocol on Biosafety, and the Biological Weapons Convention serve as international models, catalysing top-down changes within member countries (Eggers and Mackenzie, 2000; Millett 2010). These agreements have spurred local efforts such as the APSED III, demonstrating the potential for regional collaboration. Compliance with these agreements is evaluated through mechanisms such as the Joint External Evaluation (JEE), highlighting progress and areas needing improvement (Razavi et al., 2021).

BOX 7-2
Southeast Asian countries with a standing One Health coordinating body

Thailand: The Coordinating Unit for One Health (CUOH) in Thailand is designed to expedite One Health implementation in the country (Tangwangvivat et al., 2019).

Vietnam: The One Health Partnership for Zoonoses (OHP) unites One Health stakeholders from both national and international governmental and non-governmental sectors, all operating under the leadership of the Government of Vietnam (Nguyen-Viet et al., 2022).

Indonesia: Legislation of One Health in Indonesia, Presidential Instruction number 4 of 2019, strengthened coordination and implementation of One Health in Indonesia under the leadership of the Coordinating Ministry for Human Development and Cultural Affairs (Cabinet Secretariat of the Republic of Indonesia, 2019).

Singapore: The One Health Framework in Singapore highlights involvement of a transdisciplinary approach and multiple agencies to understand, prevent, prepare for, and address cross-sectoral public health threats spanning human, animal, water and environment health domains (Lian et al., 2019).

Malaysia: The Emergency Ordinance of 1979 can activate the National Security Council to create an authoritative platform for multisectoral collaboration and resource sharing during the period of impending need (Common LII, n.d.). The interagency One Health activities for zoonoses and other One Health-relevant issues are based on rotational chairmanship among ministries, with close intersectoral coordination for zoonoses between human, animal, and environmental health ministries. The One Health concept and training are championed by the Malaysian One Health University Network (MyOHUN).

Case Example 7-4
Regional initiatives in fostering communication and collaboration in One Health

Strengthening One Health communication: INGSA and NASEM's exchange with Thai NIH

In 2022, as part of the data gathering process to create this guidebook, INGSA and NASEM undertook a collaborative visit to Thailand's Ministry of Public Health and the National Institute of Health (NIH). Thailand's Department of Disease Control (DDC) shared information about the resources employed in Thailand to address public health challenges and delved into the intergovernmental networks established by Thai officials to effectively tackle the complexities of zoonotic spillover. Furthermore, the delegation shared comprehensive details on Thailand's One Health operating procedures specifically tailored for disease outbreak control, offering a glimpse into the nation's strategies for promoting integrated and collaborative approaches to safeguard public health. The information presented was used to inform the creation of this guidebook.

FIGURE 7-7 Building bridges for One Health. INGSA and NASEM workshop participants visit the Thailand Ministry of Health. Photo credit: Meghan Davis.

Southeast Asia One Health University (SEAOHUN)

FIGURE 7-8 Some of the more than 300 health practitioners, educators, and researchers from 30 countries who gathered at the 2022 SEAOHUN International Conference. Photo credit: Nation Thailand, 2022.

The Southeast Asia One Health University Network (SEAOHUN) was formed to be a catalyst for fostering effective communication and collaboration among diverse stakeholders committed to the intersection of human, animal, and environmental health and to strengthen the ability of countries within the region to prepare for, detect, and respond to infectious disease outbreaks (SEAOHUN, n.d.; USAID and SEAOHUN, 2021). SEAOHUN's collaborative efforts extend beyond academic realms, involving partnerships with other public agencies. Through these collaborations, SEAOHUN actively contributes to strengthening One Health education across Southeast Asia, creating a robust foundation for addressing complex health challenges (USAID and SEAOHUN, 2021). A noteworthy initiative undertaken by SEAOHUN is the organization of student summits, aimed at developing the next generation of One Health leaders. This approach is designed to ensure that a cohort of young professionals are well-equipped to navigate the intricacies of interconnected health domains (SEAOHUN, 2021).

Field simulation exercises between Malaysia and Thailand

Malaysia-Thailand exemplify multinational and multi-sectoral efforts to combat rabies through field simulation exercises focused on zoonotic diseases, including avian influenza and rabies. These exercises play a crucial role in strengthening the '3Cs'—communication, collaboration, and coordination—within and between the two countries. Practicing against realistic zoonotic disease outbreak scenarios allows participants to test the readiness and effectiveness of outbreak response mechanisms by simulating realistic scenarios (Jahis et al., 2021). Additionally, Malaysia conducts similar multisectoral exercises at state and national levels, involving various stakeholders from government, academia, and local authorities, to enhance coordinated efforts in disease detection, response, and control.

Actionable guidelines for improving communication, collaboration, and coordination

1. **Empower local communities:** Empower local leaders through targeted training programs to enhance early warning, detection, and outbreak response skills. Foster local leadership in public health initiatives.
2. **Engage diverse public service expertise:** Redesign public service hiring and employment to include diverse expertise from various sectors, e.g., Thailand's One Health Steering Unit employs veterinarians and environmental health experts.
3. **Share staff among ministries:** Facilitate staff exchanges among ministries to foster cross-agency familiarity that will enhance coordination in the event of an outbreak. Recognize that this is a short-term solution while workforce systems adapt to changing needs.
4. **Integrate manuals and coordination methods:** Develop and implement integrated manuals and coordinated methods for harmonized surveillance efforts.
5. **Share leadership and cross-sectoral engagement:** Promote shared leadership, conduct high-level cross-sectoral field engagements. Leaders incentivize cross-sectoral communication, collaboration, and coordination in organizations.
6. **Use team-based and participatory approaches:** Utilize team-based and participatory approaches in outbreak/pandemic response (Module 8): For planning and implementation:

- engage agribusinesses when implementing safety and agricultural practices (HSSCP) (see Barrier 9, below) to create long-term relationships, reciprocal policies, and fewer foodborne illnesses. Although increased costs can be associated with implementing safety measures, discussions with agribusiness and locals might identify ways to reconcile differing viewpoints.
- pursue government-led incentives—possibly including legislative requirements—to encourage prompt reporting of outbreaks by farmers and locals (e.g., from WOAH). Destigmatize outbreak and disease identification and reporting amongst local stakeholders, including smallholder animal keepers.
- develop regional biosecurity policies engaging governmental agencies and other partners in farming, wildlife, and conservation communities. Experts can facilitate communication of long-term benefits of conservation beyond costs (i.e., disease prevention, health security, natural capital accounting) to government officials.

BARRIER 4: DATA MANAGEMENT, SHARING, AND SECURITY

Integrating One Health to stop zoonotic spillover and to better respond to disease outbreaks requires overcoming data-related challenges and better ways to track, store and share information between organizations and across initiatives (Module 5). The challenges lie in collecting and integrating data from diverse sectors[2]; establishing compatible robust data management systems; and ensuring smooth data integration and analysis of diverse data types such as pathogen information, human and animal case data, and relevant metadata. The latter has the added challenges of dismantling silo-minded and credit-seeking behaviour among stakeholders.

Case Example 7-5
Examples of data sharing that strengthened surveillance and response efforts

Thailand: Participatory One Health Digital Disease Detection (PODD)

In Chiang Mai, Thailand, the PANORAMA project introduced the PODD platform to combat zoonotic spillovers and monitor emerging animal and environmental health threats (Yano et al., 2018). A diverse team, including veterinarians, public health and livestock officers, community volunteers, technologists, economists, social scientists, and critically, geographic information system (GIS) experts, collaborated on this initiative. Community volunteers using the PODD mobile app play a crucial role in reporting potential disease outbreaks and environmental hazards. The PODD platform uses a smartphone and web application to make the information as accessible as possible to the community, empowering individuals to report unusual disease events involving domestic pet and wild animals, as well as humans. These reports inform local health officials who then investigate and may have a better idea of the diseases within the community and can more efficiently take action as needed.

[2] Common gaps often include environmental sector data on funding sustainable land-use planning as a preventive measure against disease emergence as well as commercial data, particularly from livestock surveillance.

Kenya: Mobile-Based Surveillance for Rift Valley Fever

Kenya's Ministry of Agriculture, Livestock, and Fisheries' initiative (MALF), funded by the Global Health Security Agenda (GHSA), created a mobile phone-based network to monitor for outbreaks of Rift Valley fever (Munyua et al., 2019; Oyas et al., 2018).[3] Trained healthcare workers and community volunteers collect data related to RVF in their respective areas, including information on animal health, human cases, and vector (mosquito) populations. Using specially designed mobile applications and/or text message reporting, the data are transmitted in real time to a central database or directly to public health authorities. By continuously monitoring these data, health authorities can swiftly identify potential outbreaks or emerging RVF trends.

Actionable guidelines for better data management

1. **Prioritize data collection at high-risk areas**: Focus data collection efforts, emphasizing high-risk animal populations and environments and animal–human interfaces (Modules 2 and 3). This optimizes resource allocation and effectiveness.
2. **Harmonize processes and improve data interoperability:** Standardize processes for data collection, management, and access across One Health domains; develop strategies to enhance interoperability among relevant datasets, including opportunities to link governmental surveillance data with academic research or NGO activities.
3. **Map existing datasets:** Create comprehensive maps detailing high-priority existing datasets for use when needed.

BARRIER 5: TRANSBOUNDARY DISEASE SURVEILLANCE

Cross-border well-coordinated surveillance systems are imperative to the early detection of priority pathogens in both the environment and in human and animal hosts, allowing for a swift response across all pertinent sectors. However, balancing the economic benefits of animal trade with the crucial need to safeguard public health and biodiversity presents a significant challenge. Encouragingly, many Southeast Asia countries, for example, Vietnam (Module 3), have taken initial steps by implementing bans on wildlife trade and consumption, indicating a shift towards prioritizing health and conversation.

Efforts are often siloed by respective countries with no transboundary considerations (Module 3). It is important to have the call for a unified, cross-border approach focusing on strengthening law enforcement and regulation and the integration of health professionals into wildlife management. Additionally, a holistic strategy that combines stakeholder perspectives and community engagement aligning with national and regional strategies, within the One Health framework, is needed for managing zoonotic disease outbreaks while ensuring a sustainable coexistence between humans and wildlife.

[3] This viral disease primarily affects animals but can also be transmitted to humans, leading to flu-like symptoms and severe complications like hemorrhagic fever and encephalitis, or even death.

BOX 7-3
The importance of assessment tools for improving disease surveillance

The importance of robust assessment tools for assessing surveillance systems in the context of wildlife and environmental services is important. While there are established evaluation tools in the public health and veterinary services, such as the WHO Joint External Evaluation (JEE) and World Organisation for Animal Health (WOAH) Performance of Veterinary Services (PVS) Pathway (de la Rocque et al., 2023). A similar emphasis on initiatives such as the Tripartite tool for Surveillance and Information Sharing Operational Tool (SIS OT) meets the need for comprehensive evaluation mechanisms across all facets of disease surveillance. The introduction of these evaluation tools would help pinpoint surveillance gaps and opportunities for enhancement. This has been noted in 'Module 2: How the Past Informs the Future—Opportunities in Southeast Asia to Prevent and Respond to Zoonotic Spillover,' wherein it was mentioned that cost and effort are some of the greatest barriers to establishing effective spillover surveillance across the region. This involves money, detection capability, field workers, and laboratory capability. A solution for this is the data reduction strategy—by conducting surveillance at high-risk human–animal interfaces and at geographical areas known to have been the site of pathogen emergence (Gray et al., 2021).

The broader implementation of evaluation tools and the standardization of surveillance practices and priority disease selection across countries remain challenges. Addressing these issues is crucial for incorporating wildlife health and environmental factors into public health surveillance systems, risk assessments, health security strategies, training programs, funding initiatives, and implementation efforts (Machalaba et al., 2021).

Case Example 7-6
Regional initiatives in preventing transboundary disease outbreaks: The Mekong Basin Disease Surveillance (MBDS) network

In 2001, the MBDS network was founded by six Ministers of Health from countries in the Greater Mekong subregion, including Cambodia, China (specifically Yunnan and Guangxi), Lao PDR, Myanmar, Thailand, and Vietnam. The network's objectives include enhancing both national and regional capacities in infectious disease surveillance, fostering interregional collaboration, responding to outbreaks, and facilitating information exchange for swift and effective management of public health risks. For a broader understanding of these efforts and to access additional case examples, please refer to Module 3 section on 'Case Examples and Other Efforts,' where we explore in greater detail the lessons learned and strategies employed in various regions to strengthen transboundary disease surveillance and response.

Actionable guidelines to improve transboundary disease outbreak response

1. **Establish sentinel surveillance systems:** Develop and implement sentinel surveillance systems that regularly monitor and collect data on wildlife populations, domesticated animals, and human communities to detect potential disease threats early.
2. **Move from reactive to proactive surveillance**: Implement a registration or permitting system for farms and hunters involved in wildlife and domesticated animal trade. Ensure

that activities are conducted in a controlled and traceable manner, facilitating better disease monitoring and management.

3. **Regulate wildlife movement:** Establish policies to monitor the movement of wildlife across borders, particularly by human traders. Establish and enforce wildlife trafficking laws and measures to reduce illegal wildlife trade.
4. **Develop registries, documentation, and incentive structures:** Develop comprehensive registries and documentation systems to track the movement of animals and animal products along the value/supply chain. This information should be transparent and accessible to relevant authorities in multiple countries.
5. **Implement penalty structures**: Establish and enforce penalties for those who do not adhere to regulations or fail to report disease outbreaks promptly. Penalties should be sufficient to deter risky behaviour.

BARRIER 6: HUMAN BEHAVIOR AND CONSUMPTION

In some communities, encouraging sustainable behavioural change is essential to prevent zoonotic spillover and control potential disease threats (Module 6). Human behaviour plays a critical role in either driving or mitigating the transmission of zoonotic diseases and can increase or decrease the risk of spillover events. Several human behaviours are associated with animal trade, both wild and livestock, including hunting, culling, selling, trading, cooking, and consuming animals (Figure 7-9). These behaviours are influenced by various factors such as limited awareness of zoonoses risks, poor literacy and education, poverty, the need to sustain livelihoods, cultural beliefs, religious practices involving animals, traditional or long-standing animal handling practices, limited access to personal protective equipment, and the high demand and value of wild animal products.

To prevent and protect against spillover events, each country in Southeast Asia can benefit from identifying and analysing behavioural factors, patterns, and intervenable control points related to wildlife hunting and trade and domestic and peri domestic animal keeping that may pose risk for spillover. Practitioners may then design culturally congruent behavioural interventions that effectively convey risks to critical populations including the Indigenous Peoples, which could include changes to animal handling practices, conducting community training, or raising awareness about potentially risky behaviours. For example, mass culling of infected herds, flocks, etc., is a principle response to controlling outbreaks. The approach is being reevaluated in many communities based on ethical, economic, and ecological implications.

FIGURE 7-9 The image presents a sequence of human behaviours that can potentially drive disease spillover from animals to humans. These behaviours include hunting, which typically involves wild animals, but the cycle extends to livestock, through processes such as culling, trading, cooking, and consuming.

Despite numerous instances of animals (wild or domesticated) carrying known or potentially unknowable viruses, epidemiological data are often collected in, and analysed by scientists who are based in high-income nations (Alba et al., 2020; Skopec et al., 2020). Low- and middle-income countries are underrepresented in the literature, leading to a skewed perception of global risk (Yegros-Yegros et al., 2020). Investing in and improving local data collection and analysis would provide more accurate and evidence-based data for informing public health measures.

Qualitative methods that could be used to characterize high-risk behaviours include participant observations, in-depth interviews, and focus-group discussions. Further, engaging social and behavioural scientists in the identification of high-risk health behaviours and possible intervention points, as well as their design and implementation, will likely improve the quality and sustainability of the behavioural interventions, given their expertise in behavioural change theories and practice, as well as past successes and failures in behaviour-based interventions. In addition, integrated behavioural change models can be developed and used to identify opportunities for intervention and changes in behaviours that mitigate the risk of spillover.

Case Example 7-7
Regional initiatives to minimize human behavioural factors that contribute to zoonotic spillover: The Wildlife Conservation Society (WCS) in Cambodia

The WCS's goal is to protect wildlife and promote sustainable practices related to wildlife trade and it works to raise awareness about the importance of wildlife conservation and safe and sustainable wildlife trading practices in countries in the region. In Cambodia, WCS conducts policy advocacy, research, and education initiatives designed to reduce the risks associated with wildlife trade and consumption (WCS Cambodia, 2024). They intervene to achieve sustainable behavioural change by advocating for supportive policies and, through community engagement, by educating key local populations.

Actionable guidelines for addressing human behaviours

1. **Identify how and why people engage in unique risky behaviour, by employing qualitative research methods:** Human behaviour that can contribute to zoonotic spillover is often unique to the context, and may differ among villages, provinces, or subnational regions. It is important for those trying to affect behaviour to understand how and why individuals engage in such behaviours within the target population and their surrounding social environment.
2. **Design and implement culturally congruent interventions and risk communication methods:** Prospective interventions benefit from social listening efforts, in which they attempt to understand individuals' primary interests, concerns, and misconceptions about the topic (i.e., animal-to-human spillover of zoonotic pathogens). Based on the social listening findings, interventions that resonate with the target population's values, beliefs, and communication styles can be developed. This might involve using local metaphors, partnering with trusted community leaders, or leveraging existing communication channels.
3. **Promote participatory approaches:** Involve communities in intervention design and implementation to ensure their ownership, sustainability, and effectiveness.

BARRIER 7: WORKFORCE AND HUMAN CAPACITY DEVELOPMENT

A resilient workforce, capable of addressing the dynamic challenges posed by zoonotic disease and global health threats, relies on professionals with transdisciplinary skills and competencies. In addition, health literacy is an important requirement for the management and prevention of disease after spillover, and to emphasize competencies to access, understand, appraise, and apply information to make health decisions. In Southeast Asia, local and national-level strategies for strengthening workforce and human capacity to combat infections disease are pivotal, impacting overall system performance and ensuring the viability of any reforms. Historically, the different specialties have been created separately but combating zoonotic spillover necessitates a cross training strategy to enable professionals to navigate seamlessly across sectors and agencies. To address the complex challenges of zoonotic diseases, we need a multifaceted approach to workforce development:

- Transdisciplinary expertise: Professionals must move beyond their silos, developing cross-training that allows them to collaborate effectively across sectors. This includes strong communication skills for interacting with diverse audiences, as well as experience in team-based problem-solving and conflict resolution (Togami et al., 2023).
- Public health literacy: Empowering individuals with the ability to access, understand, and apply health information is crucial for disease prevention and management, especially after spillover events (Ellwanger and Chies, 2021; Vora et al., 2023)
- Strategic planning in Southeast Asia: Southeast Asian nations must proactively strengthen their health workforces through local and national initiatives. This includes creating leadership roles to overcome institutional hurdles and foster cross-sectoral collaboration.

- Sustainable training: Interdisciplinary training programs must be designed with long-term career progression in mind to ensure the continued impact of these initiatives (Nicholson et al., 2019).

BOX 7-4
Existing barriers and gaps in workforce development

An overarching impediment in developing workers who are comfortable across sectors and disciplines are disparities in investment and funding among human health and agriculture/veterinary and environmental education programs. For example, agricultural-relevant tertiary education in some SEA countries, including veterinary education, often lacks robust quality assurance measures, posing a significant challenge in developing a workforce comfortable navigating diverse sectors in the changing disease landscape. A rigid curriculum structure limits adaptability and responsiveness to evolving needs in the One Health workforce. Table 7-1 details specific concerns with workforce development in SEA. These barriers and gaps must be addressed strategically to strengthen the workforce in SEA to effectively tackle complex zoonotic disease spillover challenges.

Table 7-1 Challenges and their impact on workforce development in Southeast Asia

Challenge	Impact
Limited university autonomy	Ministerial oversight restricts universities' ability to recruit diverse faculty, develop relevant curricula, and adapt programs to meet emerging needs. This limits the talent pool and curriculum alignment with zoonotic disease preparedness.
Inadequate workforce data	Lack of comprehensive data on workforce composition (disciplines, subspecialties, distribution) hinders effective planning and development. This makes it difficult to identify shortfalls and prioritize areas for investment.
Workforce structure imbalances	Imbalances based on specialization, location, gender, or resource allocation lead to disparities in capacity across different aspects of zoonotic spillover disease response (e.g., surveillance, outbreak management). This can create critical gaps in preparedness.
Limited cross-sectoral training	Absence of institutionalized cross-disciplinary training programs hinders collaboration and development of comprehensive skills needed for tackling complex challenges such as zoonotic diseases. Professionals struggle to work effectively across sectors due to lack of shared knowledge and understanding.
Limited workforce capacity and engagement	Many professionals lack the necessary knowledge, skills, or resources to effectively participate in cross-sector initiatives. This hinders their ability to collaborate effectively with colleagues from other sectors and contribute to the success of these initiatives.
Lack of enabling institutional ecosystems	Existing institutional structures often impede, rather than promote, collaboration across different sectors. These structures may favour individuals with specific backgrounds or expertise, hindering the inclusion of diverse perspectives and skillsets crucial for tackling complex challenges such as zoonotic diseases.

Case Example 7-8
Regional initiatives to improve workforce and human capacity to combat zoonotic spillover

A. SEAOHUN/USAID One Health Workforce - Next-Generation (OHW-NG)

Since 2015, a series of comprehensive programs has engaged over 50,000 participants, including students, academics, and officials, across the region in multidisciplinary One Health training, as documented in the SEAOHUN Secretariat OHW-NG annual reports. These initiatives encompassing locally curated competency-based education, research opportunities, fellowships, internships, and student clubs, have equipped participants with the knowledge and skills necessary to collaborate effectively to address complex One Health challenges.

B. Field Epidemiology Training Programs (FETPs)

FETPs play a vital role in building the capacity of the public health workforce to conduct field epidemiology and other critical services for disease surveillance and spillover prevention and enhanced epidemiology capacity at the local levels. These programs are modeled after the Epidemic Intelligence Service (EIS) of the US CDC and have been adapted to include veterinarians (FETPV). This collaboration provides services with countries and communities across the region and aligns with the One Health Joint Plan of Action (Seffren et al., 2022) implemented through Tephinet. Examples are listed in Appendix A.

FIGURE 7-10 Thailand FETPs working on COVID-19 management guidance for factories. Source: CDC.

FIGURE 7-11 Opening ceremony of the 22nd cohort of the Advanced Chinese Field Epidemiology Training Program on March 1, 2023. Source: Chinacdc.cn.

A. TVET Program in Southeast Asia

The Technical and Vocational Education and Training (TVET) program can serve as a valuable roadmap for addressing workforce development challenges and enhancing collaboration in the One Health domain (UNHCR, n.d.). For example, in Malaysia, MyOHUN has been engaging vocational students in One Health innovations and teaching and learning activities since 2021 with the aim to 'meet the industry demand and contribute to economic growth, in line with globalization while supporting a knowledge-based economy and technological advancement and enhancing global workforce mobility'.

B. Global Laboratory Leadership Programme (GLLP)

The GLLP offers specialized training in leadership and management for leaders overseeing human and animal health laboratories, including those with public health significance (such as environmental, agricultural, food, or chemical laboratories). The six partners (Association of Public Health Laboratories (APHL), US CDC, European Centre for Disease Prevention and Control (ECDC), FAO, WHO, and WOAH) enlisted the expertise of more than 140 global professionals in human and animal health and laboratory science during its development. These partners are dedicated to the program's vision of empowering laboratory leaders worldwide to enhance national laboratory systems using a One Health approach, thereby strengthening global health security (WHO, 2023c).

C. Indonesia's cross-sectoral training initiative for zoonotic diseases

Indonesia has implemented a cross-sectoral training initiative for zoonotic diseases[4]. This initiative utilizes Joint Risk Assessment (JRA) within its training modules, empowering 761 officers from 17 provinces with the necessary knowledge and skills for zoonoses prevention and control using the One Health system-based approach.

[4] Indonesia's multidisciplinary and multisectoral collaboration in Implementing Joint Risk Assessment (JRA),Training of Trainers (ToT) and many other initiatives like IHR-PVS National Bridging Workshop

Actionable guidelines for One Health workforce development in the region[5]

1. **Invest in faculty development in One Health understanding and increasing necessary skill sets:** The demand for professionals equipped with transdisciplinary skills can be met through workforce development via education and cross-sectoral training.
2. **Enhance or develop interprofessional education among One Health domains:** Develop and incorporate interprofessional education modules in existing curricula that explore interconnected aspects of One Health domains focusing on a wide range of topics such as genetics, biodiversity, economics, and healthcare in the specific context of Southeast Asia.
3. **Develop subspeciality or certification programs for One Health in related degree programs:** Create subspecialty or certification programs in One Health within relevant degree programs to build expertise and establish key referral points for individuals or teams within the field to improve local, national, and regional expert capacities in addressing critical health challenges related to zoonotic diseases.
4. **Define and clearly outline target One Health skill sets and competencies for in-service professionals:** Clearly outline the essential One Health skill sets and competencies required for in-service professionals, focusing on their ability to collaborate effectively across disciplines and sectors.
5. **Institutionalize integrated and multisectoral programs/trainings:** Formalize and integrate multisectoral training programs into existing institutional frameworks to ensure their sustainability and systematic execution.
6. **Develop robust leadership training programs for top management:** Develop robust leadership training programs that focus on building strategic thinking, decision-making, communication, and team-building abilities towards shared goals.
7. **Diversify the public health workforce:** Actively recruit individuals from non-traditional disciplines and fields with relevant expertise in public health agencies (e.g., veterinarians, environmental scientists). Encourage engagement with both government and non-governmental organizations to bridge sectoral gaps. For example, Thailand Ministry of Public Health hires veterinarians and other cross disciplinary expertise into their workforce pool[6].
8. **Actively utilize internship programs for trainees from different backgrounds:** Foster inclusivity, collaboration, and synergy by engaging individuals with diverse experiences, all while maintaining shared focus on addressing zoonotic disease.
9. **Modernize hiring and recruitment systems and their terms of references:** Adapt hiring and recruitment processes to accommodate evolving workforce needs and foster a more dynamic work environment. Revising job descriptions and utilizing modern methodologies will ensure that workforces remain relevant and effective in meeting demands of today's rapidly changing landscape.

[5] When possible, engage ASEAN (e.g., ASEAN Workplan on Education) and SEAMEO (Southeast Asia Ministers of Education Organization) for high level buy-in for One Health workforce transformation.

[6] Thailand's experience and strategy in enhancing public health with cross-disciplinary expertise is discussed in Yamada et al. (2014).

BARRIER 8: LABORATORY CAPACITY AND BIOSAFETY

Laboratory infrastructure and capability play a pivotal role in the early detection and effective management of zoonotic diseases (FAO et al., 2022; Kan, 2022). The strengthening of diagnostic capacity in laboratories within national animal health and public health systems is essential for effectively controlling zoonotic spillovers. Adequate laboratory analysis capability contributes significantly to the early detection of diseases and ensures rapid response during outbreaks. Good laboratory capacity includes the ability to conduct robust diagnostic techniques (Gronvall et al., 2023) such as genotyping and phenotyping, the development of genome-based tracking systems with necessary bioinformatics, and integration into regional and global platforms, and should be accompanied by enhancement of biosafety measures.

Laboratory biosafety in Southeast Asia encompasses the practices, guidelines, and regulations that ensure the safe handling, containment, and disposal of biological agents and materials within laboratories. Biosafety protocols in Southeast Asia are not uniform, as they are shaped by each country's available resources, infrastructure, and regulatory environment. Nations develop their biosafety systems to address local needs while conforming to international guidelines and recommended best practices. While biosafety practices can vary between countries in the region,[7] there are overarching principles and initiatives aimed at promoting biosafety and biosecurity. Web-based tracking studies have gathered information about existing and emerging biological containment laboratories. These studies also evaluate the biosafety and biosecurity oversight efforts to coordinate the function of these laboratories. In addition, there are resources to assess public health or pandemic preparedness in individual countries that include data about labs and biosafety/biosecurity programs.[8]

Case Example 7-9
Leveraging existing laboratory infrastructure integrating animal health and zoonotic diseases at local, national, and regional levels

Effective management of emerging infectious diseases pertinent to zoonotic origins requires robust infrastructure, continuous specialized training, and the adoption of advanced, rapid, and accurate diagnostic technologies. These efforts, along with continuous infrastructure upgrades and maintenance, can be cost-and resource-intensive. Southeast Asian countries have the opportunity to actively participate in a range of collaborative efforts and approaches, collectively enhancing regional disease surveillance networks and regional health security (Module 5). This includes knowledge exchange, joint research and development, and the establishment of a unified framework for biosafety and biosecurity training.

Across the globe, clinical laboratories dedicated to improving human health are well established. In Southeast Asia, the focus on communicable and noncommunicable human diseases is central to the

[7] The ASEAN report, Regional Strategic Framework for Laboratory Capacity Building and Networking in ASEAN, identified significant disparities in laboratory capacity among ASEAN member states. A notable concern was the limited sharing of high-quality data, which was particularly evident during the control stages of multicountry outbreaks, such as the high-pathogenic avian influenza outbreak.

[8] See, for example (1) WHO Health Emergency Dashboard, (2) WHO IHR States Parties Self-Assessment Annual Reporting Tool, (3) WHO Joint External Evaluation, (4) International Federation of Biosafety Organizations, (5) Global Biolabs, and (6) Global Health Security Index.

health of each nation (Fritz and Fromwell, 2022). This can be seen through many development programs for infectious disease specialists and public health professionals, training programs conducted by many agencies such as ASEAN Plus 3 Field Epidemiology Training Network (ASEAN+3 FETN), and centres of excellence in tropical diseases across the region. Moreover, recognizing the interconnectedness between tropical diseases and zoonotic diseases—in their causes and the environments in which they emerge—promotes multidisciplinary approach to finding solutions. This understanding encourages participation of veterinarians, exemplified by programs such as the Regional Field Epidemiology Training Program for Veterinarians (R-FETPV) in Thailand. A similar context can be adapted to enhance the work of laboratory clinicians and scientists, by integrating technologies used in human disease laboratory capacity planning, biosafety measures, funding, research activities, capacity building, and human resources with veterinary diagnostic and research laboratories—a key strategy for comprehensive pandemic preparedness and response.

Actionable guidelines for strengthening laboratory capacity and biosafety in the region

1. **Standardize laboratory-associated training in both biosafety and biosecurity:** Ensuring that laboratory personnel are well trained is critical for effective laboratory operation and biosafety. Implement comprehensive, standard biosafety training for all laboratory personnel involved in zoonotic disease research and diagnostics (see Appendix B).
2. **Standardize laboratory services**: Ensure the provision of standardized, proficient, and quality laboratory services for the detection of zoonotic disease outbreaks for timely and accurate e-diagnosis.
3. **Mobilize resources for field-based systems**: Mobilize resources for the development and deployment of field-deployable diagnostic systems via the ASEAN regional Strategic Framework for Laboratory capacity to facilitate resource allocation.
4. **National strategy**: Implement national strategies and policies that facilitate the efficient and sustainable provision of laboratory services. These strategies should encompass infrastructure development, personnel training, and quality assurance.
5. **Establish laboratory information systems**: Encourage the establishment of interoperable laboratory information systems and facilitate data sharing among stakeholders. This promotes efficient data exchange and collaboration in disease surveillance and response efforts.

BARRIER 9: ENGAGING COMMERCIAL ENTITIES

Animal and animal-product trading, along with the livestock and agriculture sectors form a significant role in the economy of Southeast Asia, catering both national and regional markets (Module 6). The region records some of the highest number of foodborne illness-related deaths globally. The risk of contamination spans the entire supply chain (from farm to fork). The emergence of zoonotic diseases is closely linked to various factors. The list below, while not comprehensive, outlines key vulnerabilities[9] that predispose animal-based food industry in Southeast Asia, to the risk of spread of zoonotic pathogens:

- Limited biosecurity measures, veterinary care, and infrastructure: inadequate preventive and response measures in animal health management
- Complex supply chains: the presence of multiple intermediaries and informal markets complicates traceability and biosecurity
- High-density livestock production: farming in densely populated areas elevates the risk of disease spread
- Environmental changes: urbanization, land use changes, and climate change contribute to the emergence and spread of diseases
- Diverse agricultural practices: variability in animal farming techniques can influence disease risk
- Regulatory challenges: limited enforcement of health and safety regulations exacerbates vulnerabilities
- Wildlife trade: Both legal and illegal wildlife trades are significant risk factors for zoonosis
- Cross-border dynamics: Porous borders facilitate the cross-border movement of diseases due to trade and travel

Within commercial ecosystems tied to the animal-based food industry, there exist hotspots for future emerging zoonotic diseases and practices that facilitate the spread of disease. Beyond production losses, animal diseases incur substantial costs due to the need to implement mitigation strategies. The engagement of commercial entities within Southeast Asia in the fight against zoonotic spillover of high-consequence pathogens is paramount but challenging.

Industrial food animal production has seen a global surge in market share. These operations often exceed the carrying capacity of the local ecosystem, leading to numerous challenges such as persistent viral presence and the risk of strain reassortment, both of which can contribute to the emergence of dangerous pathogens (Davis et al., 2011).

Some challenges at these large facilities include the persistence of viruses in large-scale production facilities. The high stocking density and continuous throughput and frequent introduction of immunologically naïve animals perpetuates viral circulation. Achieving full decontamination without depopulation is challenging. Large inventories of live animals increase the potential for viral strain reassortment and host selection. This can lead to the emergence of viruses with critical traits like high transmissibility and virulence. The global trade in animals, feed, and food products involves multi-national corporations. Regional and country-level efforts may need to leverage economic and political determination to drive change.

[9] Relevant reports for animal farming from Institute of Animal Law of Asia; Farm Animal Investment Risk and Return (FAIRR)

Case Example 7-10
The need for innovative business models integrating preventive measures for the spread of zoonotic pathogens

Industrial-scale animal-based food and food products in Southeast Asia faces significant challenges related to foodborne and waterborne zoonotic diseases, which are often caused by pathogenic microorganisms contaminating food, water, or surfaces within the production process, leading to outbreaks (Todd, 2014; Hassan, 2014). While quality assurance measures like HACCP (Hazard Analysis and Critical Control Points) are in place within the value chain before products reach consumers, there is a need to shift focus to the early stages of the value chain to prevent the spread of zoonotic pathogens. It is essential to implement innovative business models that incorporate early-stage interventions and embrace inclusive approaches that foster active participation from all relevant stakeholders, including the broader public who collectively play a crucial role in addressing the emergence and spread of zoonotic pathogens.

The circular economy, with its principles of sustainability and resource efficiency, offers a promising framework for mitigating these risks. The circular economy movement is gaining momentum across Southeast Asia with ASEAN at the forefront of promoting circular economy through its five strategic priorities as documented in the *Framework for Circular Economy for the ASEAN Economic Community*:

1. Standard harmonisation and mutual recognition of circular products and services
2. Trade openness and trade facilitation in circular goods and services
3. Enhanced role of innovation, digitalisation, and emerging/green technologies
4. Competitive sustainable finance and innovative environmental, social, and governance (ESG) investments
5. Efficient use of energy and other resources

While circular economy concepts and initiatives have gained traction in Southeast Asia[10], efforts have predominantly focused on the sustainable environmental perspective, with limited attention given to preventing the spread of zoonotic pathogens—a critical aspect in accelerating the success of the commercial trade and industries. There is a need for initiatives that integrate preventive measures for the spread of zoonotic diseases into circular economy strategic priorities. Measures may include:

- identifying priority areas within the circular value chain where disease transmission can be effectively mitigated
- research and development focusing on disease risk mitigation efforts
- collaboration between circular economy stakeholders, veterinarians, healthcare personnel and scientists, and policymakers
- considering disease prevention as a key performance indicator

By integrating preventive measures, such as circular initiatives designed with disease risk reduction in mind, Southeast Asia can create a more resilient and sustainable food industry that prioritizes human–animal–environmental well-being.

[10] Other organizations advocating circular economy include Asian Development Bank (ADB), A Systems Approach for Transitioning Southeast Asia to a Circular Economy | Development Asia

Actionable guidelines to engage commercial entities

1. **Enforce environmental decontamination and fallow period:** For all-in, all-out production models, emphasize thorough environmental decontamination. Include a fallow period before re-population to prevent viral persistence (i.e., don't leave the poultry litter on the floor—clean it out and disinfect), consider environmental reservoirs at all height levels, and consider the importance to decontaminating the air and water systems too.
2. **Improve waste management:** Develop waste management practices that minimize the export of infectious agents. Avoid exporting waste into neighbouring communities, other sectors of the agricultural system, or across local, national, or regional boundaries.
3. **Tailor engagement to the entity:** Large, powerful corporations often function like state-like entities with the ability to influence policymaking. Countries often let large-scale companies set their own policies. Tailor engagement strategies based on the size and influence of the corporation. Consider other relevant issues, such as occupational health, to craft effective approaches. Promote the idea that adopting public health behaviours is the easiest path for large companies, encouraging them to align their practices with spillover prevention efforts.

CONCLUSION

The module outlines nine key obstacles to boosting resilience against zoonotic disease threats in Southeast Asia, showcases examples of existing efforts, and presents actionable plans within a structured framework overview organized thematically. These nine barriers are interconnected and have persisted through past local and regional disease outbreaks, impacting various societal sectors, with vulnerable communities facing disproportionate effects. Bridging efforts, scalable and adaptable strategies, tailored to varied operational capacities and governance structures across Southeast Asia are necessary to address existing gaps and barriers. As of the publication of this guidebook, issues such as resource constraints, porous borders, and the need for improved global surveillance (among others) remain major challenges in the region. This calls for a stronger integrated approach, resources, and expertise to find impactful solutions. The responsibility spans multiple sectors for realizing the solution to these issues, requiring cooperation among public health officials, veterinarians, and scientists, and calls for community engagement, policy advocacy, and research support, underlining a collective duty to protect public health and regional biodiversity.

Appendix A: Field Epidemiology Training Programs (FETPs)

Country	Program	Entities	Target sector	Topical focus	References
Thailand (national and regional)	R-FETPV	Thai gov't FAO (UN)	Veterinarians	Veterinary epidemiology of animal diseases	Iamsirithaworn et al., 2014
China	FETPV	Chinese gov't FAO (UN)	Veterinarians	Veterinary epidemiology of animal diseases	FAO China, 2017
Malaysia	MyOHUN	MyOHUN	Intersectoral	Field epidemiology AMR	MyOHUN - Malaysia One Health University Network n.d.-b.
Indonesia	PELVI	INDOHUN CDC	Veterinarians Public health	Veterinarian epidemiology	FAO Indonesia, 2017
Singapore	S-FETP	NUS-SPH NCID Nat'l Parks	Medical and public health officers Veterinarians	Field epidemiology	S-FETP
Viet Nam	V-FETP	Vietnamese gov't WHO US CDC	Medical officers Veterinarians	Outbreak investigation, surveillance, SciComm	V-FETP n.d.-a.
Regional	FETP	WHO Western Pacific			R-FETP

Appendix B: Region biosafety organizations and resources

Burma (Myanmar) National Health Laboratory, Myanmar https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0273380
Cambodia National Institute of Public Health; Institut Pasteur du Cambodge https://niph.org.kh/niph/about/index.html https://pasteur-network.org/en/members/asian-region/institut-pasteur-du-cambodge/
China National Security Commission; Wuhan National Biosafety Laboratory; Biosafety Level 4 training; *Biosafety Law of the People's Republic of China*, October 17, 2020 https://www.tandfonline.com/doi/pdf/10.1080/10670564.2015.1075717 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6478205/ http://www.npc.gov.cn/npc/c30834/202010/bb3bee5122854893a69acf4005a66059.shtml
Indonesia Indonesia Biosafety Clearing House; Indonesian Biorisk Association https://indonesiabch.menlhk.go.id/ https://internationalbiosafety.org/ifba_members/indonesian-biorisk-association/
Lao PDR Institut Pasteur du Laos https://www.pasteur.la/project-carried-on-in-the-lab/project-03/biosafety-lab/
Malaysia Malaysian Biosafety and Biosecurity Association https://mbba.my/ https://internationalbiosafety.org/ifba_members/malaysian-biosafety-biosecurity-association/
The Philippines Biorisk Association of the Philippines; National Training Center for Biosafety and Biosecurity https://internationalbiosafety.org/ifba_members/biorisk-association-of-philippines/

https://nih.upm.edu.ph/institute/national-training-center-biosafety-and-biosecurity
Singapore Biorisk Association of Singapore; Ministry of Health Biosafety https://biorisk.sg/ https://www.moh.gov.sg/biosafety/home
Thailand Biosafety Association of Thailand; BIOTEC Biosafety Program https://internationalbiosafety.org/ifba_members/biosafety-association-of-thailand/ https://www.biotec.or.th/home/en/biosafety-program-en/
Viet Nam Viet Nam Field Epidemiology Training Program https://www.tephinet.org/training-programs/vietnam-field-epidemiology-training-program

MODULE

08

— PARTICIPATORY —

HOW TO USE THIS GUIDANCE

Applying Participatory Methodologies to Countering Zoonotic Spillover

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How to Use this Guidance: Applying Participatory Methodologies to Countering Zoonotic Spillover

INTRODUCTION

Guideline development can be considered complete, not when it is published, but when the intended actors implement it. Our ultimate vision of *implementation* is when the contents, strategies, and recommendations in the previous modules are taken up by diverse actors (e.g., researchers, practitioners, and policymakers) for purposes that inform current and future practices and policies. More importantly, the process of implementation should be *participatory*, such that there should be genuine engagement of diverse actors across all points of implementation. A *participatory approach to implementation* will not only ensure a more holistic and contextualized implementation but can pave the way to better ownership, salience, and legitimacy of the process, outputs, and outcomes of implementation. Guided by this, Module 8 outlines some of the key components of the implementation process, including the cultural, social, economic, political, and environmental contexts, the characteristics of the people involved, as well as the guidebook itself. In writing this module, we draw insights from multiple lenses, including implementation science, participatory research, and the social sciences. We present case examples from the Southeast Asia (SEA) region, participatory methods, and five practical tips for the implementation of new guidelines and policies.

We begin by emphasizing the overarching message of Module 8: the need to tailor approaches for the diversity of contexts, as there is no one-size-fits-all approach or framework to implementing the guidelines. When seeking to develop useful and effective guidelines, the *cultural, social, economic, environmental, and political contexts* of the country, region, or organization must be carefully accounted for because they will impact the uptake and implementation of proposed actions and strategies. This is particularly essential for the Southeast Asian region, which is richly diverse. Thus, engagements that aim to catalyse guideline use should carefully tailor and account for this diversity. For example, subregional contexts may differ significantly, even within one country, due to climate, industrial, or religious factors. All forms of engagement, including the use of participatory approaches to aid implementation (outlined later in this module), require that implementers understand the implications of implementation in diverse contexts. We therefore strongly encourage having a strong grasp of context from the onset of the program and implementation.

Understanding the Context from Multiple Levels

Ensuring that implementation is tailored to the local context is essential to guarantee that actions and decisions are appropriately formulated based on the socio-political, cultural, institutional, and ecological needs and capacities. The context comprises several layers of the social environment: public policies and regulations, intra- and intercommunity relationships, organizational culture, interpersonal exchange, and individual factors (Figure 8-1). Addressing individual factors starts with understanding who must be involved and when, as described in the succeeding section[1]. Two

[1] Insights into Virulence, Disease Transmission, and Socio-Ecological Drivers in Cambodia' in Module 6 illustrates a practical way for which this can be accounted. Another way is to use a Participatory STEEP Analysis described in the section on participatory approaches later in this chapter

examples of individual-level factors are their attitudes towards the current policies and attitudes towards modified or new practices that the guidelines promote. It may also be useful what their attitudes are towards any kind of change in general. In Module 2, the Case Example 2, 'Nipah Virus Outbreak in Malaysia and Singapore', illustrates how a fear of change can impact not only the success of the farming industry but also whether guidelines like this NASEM/INGSA collaboration are used.

FIGURE 8-1 The social environment in which One Health challenges arise, adapted from the socioecological model.

Individual factors are only part of the context. There are higher levels that can hinder or facilitate implementation, and these can be studied or assessed in various ways (e.g., research and reviews). A useful way to help uncover higher levels of context is to learn from past challenges and successes. For example, the One Health Workforce Program, which established the Southeast Asia One Health University Network (SEAOHUN), used a unified approach and close collaboration network that has fostered robust university networks and educational programs across SEA (Nguyen-Viet et al., 2012). However, it faced issues with its funding that is time-limited and dependent on one entity, eventually jeopardizing the long-term implementation of the program (Togami et al., 2023). Thus, we recommend that in the initial stages of guideline development and implementation, it would be useful to map out and answer questions such as: What programs and projects have succeeded here? What has failed, and why? Which layers of the context played a significant influence on the outcomes of implementation?

CHARACTERISTICS OF THE PEOPLE ENGAGED

Engaging local leaders and potential partners in implementation refers to building relationships and collaborating with individuals or groups who have the power to influence decisions, policies, or opinions within a specific context. Specifically, engaging leaders and partners across the animal value chain is essential to tailor the key messages of each module to the local context. Having appropriate partners can offer more meaningful engagement and committed partnerships. They can serve as catalysts and champions for transformational changes in the community relevant to One Health. For example, the section titled, 'Adoption of Wildlife Health Surveillance into National Policy in Laos,' in Module 3, exemplifies that engaging the right partners, such as animal rescue centres, scientists, and decision-makers, can mobilize to create a network to successfully produce operating standards for wildlife health surveillance for the management of disease information. They should ideally be involved in each step of implementation—from the planning, designing, and drafting —to the finalizing stage.

Local leaders or partners for implementation can be selected based on the populations they represent and serve, area of expertise, and type of affiliated institution (e.g., national, provincial, and local governments, research institution), as well as geographic representation, type and length of experience, career stage, and gender. We take note that selecting local leaders or potential partners will require careful reflection on their legitimacy, credibility, and power dynamics held over their respective organizations or constituencies. We recommend a thorough mapping and review of who these actors may be. A simple Participatory Social Network Mapping (see Table 8.1) can be done with diverse actor groups, organizations, and sectors of the local context. The social network output from this participatory approach can help carefully identify which local leaders or potential partners are perceived by the locality to be more trustworthy and deemed better to deliver the collective goals. However, we caution that selecting participants in a network mapping exercise or any related participatory approach should in itself be done with caution. Participants may have their vested interests or existing alliances that will favour certain leaders or groups. This process can benefit from pre-process activities such as a review of documents or informal conversations with actors.

Engaging with local leaders and partners is often a long-term endeavour that requires patience, persistence, and adaptability. Building strong relationships grounded in trust is essential for meaningful collaboration and influence in decision-making (Dreier et al., 2019). While ways to engage local leaders and potential partners vary depending on the context, some universal best practices can be used:

- **Networking to build trust and respect:** Once key individuals or groups with influence in areas of interest have been identified, establish professional connections and relationships through networking to build mutual trust and respect. Having a sufficient understanding and knowledge about individuals or groups can be an asset.
- **Inclusive listening and feedback:** During convenings, listen to opinions, concerns, and suggestions shared by all parties involved, regardless of ranking, expertise, and seniority. Some local contexts might also require you to follow certain socio-cultural protocols (e.g. letting community elders speak first). It is also beneficial to be transparent and open about intentions for engagement and any potential limitations of activities. Seeking feedback and insights from local leaders and partners is a critical element to building trust, such as promoting storytelling, as illustrated by numerous powerful stories shared throughout this guidebook. There should be spaces and mechanisms for dynamic and timely feedback, thus improving final outcomes.
- **Delivering mutual value:** Provide value, such as information, expertise, or resources, that benefits all parties' interests and aligns with their goals and priorities. It is also essential to be open to compromises to find common ground.
- **Effective and tailored communication:** As highlighted in many modules of this guidebook, tailoring the communication style and language used, as well as carefully

selecting non-technical words and examples that are relevant to local leaders at every step of the animal value chain, will level the ground for any participatory activities, co-producing of actionable products, and pave the way for follow up discussions.

- **Maintaining sustainable partnerships:** Sustaining relationships is critical, especially between spillover events, so each party involved is ready to act if such events occur. Using tools to regularly assess the effectiveness of engagement efforts with local leaders and partners can also help adjust engagement strategies to create meaningful collaborations.

PARTICIPATORY APPROACH TO IMPLEMENTATION

Illustrating a Participatory Approach Through Our Guidebook Development

The considerations suggested above pertain to implementation processes in general. In this section, we delve into the *participatory approach to implementation* that we believe can be beneficial in achieving desirable outcomes to implementation. In fact, the very development of this guidebook— from Modules 1 to 8— served as a model of how to operationalize such a participatory approach. At the beginning of our project, a core team was formed at the U.S. National Academy of Sciences, Engineering, and Medicine (NASEM) and the International Network for Governmental Science Advice (INGSA) to crystallize the scope and goal of the guidebook. Participants for developing this guideline were selected intentionally and iteratively with authors representing over 25 countries, including Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, and Vietnam (see Figure 8-2 for program structure). There was diversity across career stages, from international non-governmental organization (NGO) employees, university faculty, government representatives, and Ph.D. trainees, each bringing a unique set of experiences and perspectives. The team was composed of experts including virologists, public health practitioners, wildlife veterinarians, natural resource experts, and social scientists. Although social scientists are often only recognized marginally in guideline development on infectious diseases, or brought onto the team later in the process, this team embraced the community-based participatory research approach.

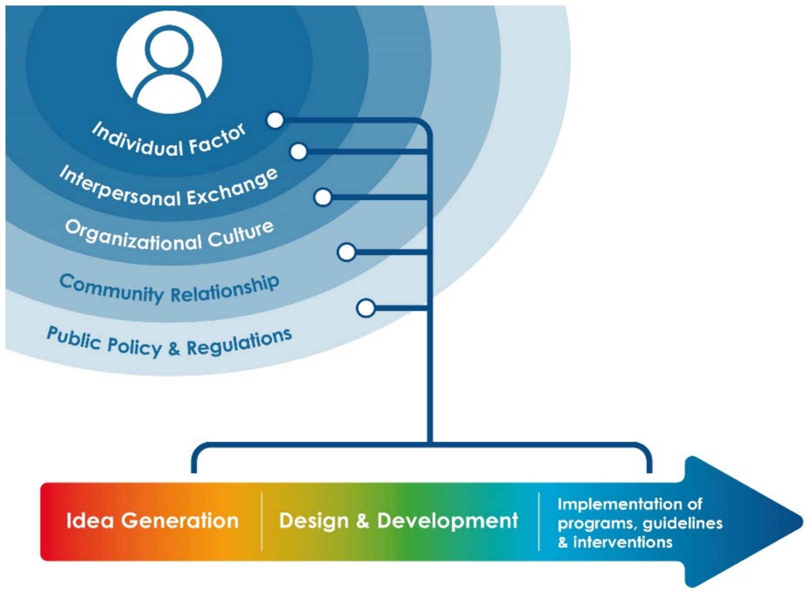

FIGURE 8-2 Mapping the socio-ecological systems of One Health innovations and implementation.

The authors attempted to 'practice what we preach' by illustrating that a participatory approach to implementation can be operationalized. We acknowledge that the primary goal of this project, to disseminate effective guidelines aimed at the mitigation of zoonotic spillover, was predetermined by NASEM. We were guided by this pre-determined goal to conduct participatory processes to ensure that the guidelines themselves would be acceptable, useful, tailored, and thus utilized in the various communities, countries, and regions represented by our partners. We hope that our guidebook development process can exemplify how we envision a participatory and iterative engagement in implementation.

Operationalizing Participation in Implementation

A participatory approach to implementation means that there is genuine engagement of diverse actors (see Module 6: Strategies to Engage Diverse Stakeholders Across the Live Animal Value Chain to Address Risk) in informing, shaping, and delivering implementation. We acknowledge that participation and engagement can be defined along a continuum from simple consultation by community representatives to processes that aim to promote 'full control' to community partners. It is generally accepted that participation should involve stakeholders 'at all stages' of the process, from the inception of an idea through implementation, evaluation, and dissemination. Engagement and participation should not be limited to tokenism, as in the case of infrequent and casual public consultation or having a predefined number of underrepresented groups in meetings. Rather, it should be empowering and provide the ability to facilitate longer-term partnerships. These allow for developing and implementing policies, strategies, and actions that are more holistic and better perceived as legitimate and credible to counter zoonosis—effectively addressing the key messages of each module.

A participatory approach allows actors to actively share their knowledge, expertise, experiences, and personal insight during the process. More importantly, these approaches allow them to learn from each other, build trust, and converge for a collective aspiration of implementation. Empowering diverse actors can translate to a sense of ownership and accountability, eventually allowing for better uptake of outcomes emerging from their collective outputs. Several cases and examples across this guidebook have shown this, including:

- World Health Assembly establishing a WHO convention on pandemic prevention, preparedness, and response (known as 'WHO CA+'). Located in 'Module 3: Efforts to Prevent Transboundary Disease Outbreaks in the Southeast Asia Region'.
- Wildlife Conservation Society's (WCS's) Counter Wildlife Trafficking Program operates in 32 countries along major supply chains with locally led programs working in partnership with governments, in-house law enforcement, and criminal justice expertise. Located in 'Module 3: Efforts to Prevent Transboundary Disease Outbreaks in the Southeast Asia Region'.
- Stakeholder Mapping Using Power-Interest Grids (X-Y Chart). Located in 'Module 6: Strategies to Engage Diverse Stakeholders Across the Live Animal Value Chain to Address Risk'.
- 'Case Study 7-2: The Lawa Model in Khon Kaen Province, Thailand. Located in 'Module 7: Enhancing Zoonotic Disease Management by Addressing Knowledge Gaps and Implementation Barriers.'
- Regional initiatives in preventing transboundary disease outbreaks: The Mekong Basin Disease Surveillance Network. Located in 'Module 7: How to Enhance Zoonotic Disease Management by Addressing Knowledge Gaps and Implementation Barriers.'

We outline several participatory methods below that can be used in multiple decision-making points relevant to each module of this guidebook. These participatory methods are meant to aid implementation, such that critical decision-making questions that need to be considered for effective implementation are answered collaboratively. We provide decision-making questions common in participatory approaches and guidebook modules that can serve as a key reference (i.e., provide examples or content). Several references (e.g., Calub, 2004; Chambers, 2012; Kaner et al., 2014; Narayanasamy, 2009) can guide further operationalization of these methods, especially those that are rooted in participatory rural appraisal (PRA) methodologies (e.g., UN FAO PRA Manual, CGIAR Participatory Frameworks). These approaches can be used to complement or supplement each other, depending on the time and resources available. While our example decision questions are set for a community level, these approaches can be applied to multiple scales (e.g., province, regional, national).

TABLE 8-1 Participatory Methods Relevant to Implementation

Goal	Example Decision Question
Participatory Seasonal Calendar	
To co-identify regular activities, phenomena, and other time-related indicators in a calendar year, especially for indicators that have high seasonal nuances (e.g., monsoon-season specific). (e.g., Catley et al., 2002)	Which socio-cultural activities (Module 6) coincide with the occurrence of priority pathogens (Module 4) or an increase in illegal wildlife trade (Module 3) in the community?
Participatory Trends or Change Analysis	

Goal	Example Decision Question
To co-develop long-term trends of key indicators over a series of periods, especially for indicators that have no or minimal prior data (as in the case of several community-level indicators) (e.g., Calub, 2004)	How have aspects of agri-food systems and community well-being changed over the years in the community (Module 6)?
Participatory Timeline Building	
To co-develop key events or phenomena that happened before or after an event of interest, especially to explore whether these events are associated (e.g., Hurtubise and Joslin, 2023)	What are the available policies and other regulatory measures before and after (Module 3) a major health event in the community (Module 2)? What have we learned from a specific event (Module 4) that can be applied to other events by a specific set of actors (Module 6)?
Participatory Transect Walks	
To co-develop indicators in spatial points of interest, especially to observe on-ground social and ecological dynamics of indicators. Unlike Participatory Landscape Mapping, this approach focuses on what can be observed in a well-connected area (e.g., roads) (e.g., Leuenberger et al., 2022)	Which spatial points in the community are humans at most risk from priority pathogens (Module 4), and what makes these points high risks (Module 2)?
Participatory Landscape Mapping	
To co-develop the importance of spatial areas of interest using pre-identified indicators, especially for indicators that require on-ground validation (especially highly contested/conflicted areas). Unlike Participatory Transect Walks, this approach focuses on the actual spatial scale as seen from the top view of a map. (e.g., Boongaling et al., 2023)	Which spatial areas of the community that are reservoirs of the priority pathogens are closely located (Module 4), and who are the actors around these spaces (Module 6)?
Participatory Systems Modelling	
To co-identify important dynamics of systems of interest, especially when trying to see if parts of a system enable certain events to occur (e.g., Suwarno et al., 2009)	What actor groups, establishments, and processes constitute the food system of the community (Module 6), and which ones serve as facilitators of illegal wildlife trade (Module 3), or disease spread (Module 4), or surveillance (Module 5)?
Participatory Social Network or Stakeholder Mapping	
To co-identify important actors or actor groups and their relationships, especially when identifying which actors can influence certain issues (e.g., Boyle et al., 2022).	Which stakeholders (Module 6) strongly influence systemic issues in One Health (Module 7) in the community?

Goal	Example Decision Question
Participatory Voting and Prioritization	
To co-identify which requires the most urgent attention, especially for those that require strong community consensus (e.g., Castelli et al., 2021).	Which priority pathogens (Module 4) should receive community resources or efforts for community-led monitoring (Module 2)?
Participatory Drivers Assessment	
To co-identify social or ecological drivers that influence certain events, especially drivers on which we have minimal or lacking knowledge in terms of the direction it can plausibly take (Truong et al., 2019).	What are the drivers that hinder the operationalization of One Health in the community (Module 7)?
Participatory Scenario Development	
To co-imagine plausible alternative futures given certain highly uncertain and impactful drivers or assumptions, especially when imagining futures for longer-term planning (Shantiko et al., 2021)	What will the community's agri-food systems look like (Module 6) under different One Health strategies (Module 7) and after implementing risk-based surveillance (Module 5)?
Participatory Social, Technological, Ecological, Economic, and Political (STEEP) Analysis	
To co-identify the political, technological, social, economic, and ecological implications of decisions (e.g., Ngor et al., 2010).	What are the potential political, technological, social, economic, and ecological strategies (Modules 6 and 7) and outcomes of implementing stricter regulations for wildlife trade (Module 3)?

Several of the participatory approaches outlined in Table 8-1 can help better understand the local contexts of the area planned for implementation. For example, building a participatory timeline can help identify the kinds of programs and projects that have previously been implemented. The timeline can initiate critical reflection and conversation on the factors that determined how these programs persisted, changed, or evolved over time. Another way is to use a participatory seasonal calendar to see what different local socio-cultural conditions and ecological events the local context of interest views as important.

An example of co-creating decisions using participatory approaches is available in the Module 6 case on smallholder cattle-raising in the Philippines (Galung and Calub, 2020a). Module 6 describes the seasonal trends of cut-and-carry, a feeding strategy in which freshly cut grass is fed to farming animals throughout the grazing season. Using participatory seasonal calendars, key areas of the community where cut-and-carry and grazing occur (e.g., grasslands, natural forests) across two seasons (i.e., summer and rainy) were collectively identified by the cattle raisers. This case also emphasized increasing dependency on areas (i.e., natural forests) that were explored using participatory trends analysis, in which cattle raisers had to collectively decide which areas had been getting more dependent over the others. The participation experience in the process helped the smallholder cattle-raising community better reflect on the socio-ecological changes in their landscape, which in turn can have profound implications for zoonotic spillover.

Another example of the use of participatory method is with Ortega et al. (2021). They described how cattle-raising in the Philippines is a family livelihood. In another example, Galang and Vaughter (2020b) identified that animal production in Southern Philippines strongly depends on land sharing and commonality. This was uncovered using a modified participatory landscape mapping, in which they used photographs of key spatial areas of the community and asked diverse residents to identify the importance of each spatial area for their well-being and livelihood regardless of land ownership. The outputs of the participatory approach allowed the diverse members of the community to see their reciprocal interaction with their environment and one another, especially those who do not normally have regular interactions with their environment (e.g., youths, non-farming residents, decision-makers). Overall, such an approach provided insights into potential pathways for zoonotic transmission.

Tapping Existing Networks to Initiate Engagements

Ensuring genuine and durable participation for implementation necessitates targeted investments (e.g., time, financial, and personal). In several cases, higher levels of contexts are often disconnected from community needs (Figure 8-2) and can hinder participation and engagement even if individual factors are in place. Thus, we recommend that initiating engagements can benefit from tapping existing networks. Organizations that have a long history of working in varied contexts can also be tapped to learn from their (non)successes, including learning from their strategies. In Southeast Asia, several networks and organizations exist that can help catalyse a participatory implementation of the contents, strategies, and recommendations of this guidebook:

- **USAID's One Health Workforce – Next Generation Project,** performed pre-service One Health education as a means to train university and postgraduate students.
- **US Centers for Disease Control and Prevention (CDC)** aids in training programs and outbreak investigations worldwide (CDC, 2021).
- **EcoHealth Alliance**: This international organization works on various One Health initiatives in Southeast Asia, including research on zoonotic diseases and their transmission dynamics, as well as efforts to conserve biodiversity and protect ecosystems (Kessler, 2024).
- **World Health Organization (WHO)** provides technical assistance and guidance to Southeast Asian countries in managing zoonotic diseases and public health emergencies. They support capacity-building and response efforts. The Regional Office for the Western Pacific, based in Manila, Philippines, serves as the gateway for communication between WHO and Member States in Southeast Asia (WHO, n.d.-c.).
- **Food and Agriculture Organization (FAO)** has been actively involved in supporting efforts to control zoonotic diseases. They work on projects related to disease surveillance, capacity-building, and risk assessment and establish reference laboratories for key pathogens (FAO, n.d.-d.).
- **International Livestock Research Institute (ILRI)** is a research organization that focuses on livestock-related issues, including animal health, food security, and livelihoods, in various parts of the world, including Southeast Asia. ILRI plays an important role in public health and pandemic preparedness, including studying the transmission dynamics of diseases such as avian influenza and developing strategies to prevent their spread. ILRI also

studies livestock value chains in Southeast Asia, from production to marketing and consumption (ILRI, n.d.). As discussed in Module 6, understanding these value chains helps identify opportunities for improving food security and safety.

- **Wildlife conservation societies** collaborate with government agencies to monitor and study zoonotic diseases in wildlife (WCS, n.d.-a.).
- **ASEAN One Health University Network (ASEAN-OHUN)** Brings together universities and institutions across Southeast Asia to promote education, research, and training in One Health principles. It aims to build capacity in the region for addressing health issues at the human-animal-environment interface (SEAOHUN, n.d.).
    - **College of Public Health with the University of the Philippines** is developing a master's program on One Health, received grants from USAID and Chevron through the Southeast Asia One Health University Network
    - **Philippine One Health University Network** has a partnership with the Bureau of Animal Industry to look into leptospirosis in swine in Los Banos, especially in farms for food production (PhilOHUN, n.d.).
    - **Thailand One Health University Network (THOHUN)** brings together universities in Thailand to promote One Health education and research, fostering collaboration between different disciplines (THOHUN, n.d.).
    - **Cambodia One Health University Network (CAMBOHUN)** aims to strengthen the capacity of universities and institutions in the country to apply One Health principles in research and education (CAMBOHUN, n.d.).
    - **Malaysia One Health University Network (MyOHUN)** brings together universities and government agencies across Malaysia towards capacity-building and research and development activities through collaborative multidisciplinary teams (MyOHUN, n.d.-a.).
    - **Indonesia One Health University Network (INDOHUN)** of higher education institutions across Indonesia promotes multidisciplinary teams across the One Health sectors (INDOHUN, n.d.).
- **Regional Emerging Diseases Intervention (REDI) Centre**: in Indonesia is dedicated to research and training in the field of emerging infectious diseases, with a focus on zoonotic diseases. It plays a crucial role in strengthening regional capacity for disease surveillance and response (Hoff et al., 2011).
- **The Mekong Basin Disease Surveillance (MBDS)** regional network, comprising several Southeast Asian countries, focuses on improving disease surveillance and response in the Mekong Basin region. It aims to prevent and control diseases, including zoonoses, through a collaborative One Health approach (Phommasack et al., 2013).
- **Vietnam One Health Partnership for Zoonoses (OHP)** program in Vietnam focuses on addressing zoonotic diseases and antimicrobial resistance through a multisectoral approach. It involves cooperation between human and animal health sectors and emphasizes community engagement (Nguyen-Viet et al., 2022; Vietnam One Health Partnership for Zoonoses et al., 2022).
- **Philippines Emerging Infectious Disease Research and Training Center (EIDRTC)** focuses on research, training, and capacity-building related to emerging infectious diseases, including zoonoses (Republic of the Philippines, Department of Health, Research Institute for Tropical Medicine, n.d.).

- **The Chinese Center for Disease Control and Prevention** addresses public health priorities that affect China and the world through collaborations that aim to improve global health security by training field epidemiologists and support for the publication of public health information (China CDC, n.d.).
- **National Centre for Infectious Diseases (NCID)** in Singapore is a state-of-the-art facility dedicated to the management and prevention of infectious diseases, including zoonotic diseases. It serves as a hub for research, training, and clinical care, emphasizing the importance of an integrated approach to disease control (NCID, 2024).
- **Southeast Asian countries' Ministries of Health, Agriculture, and Forestry** are also essential partners to help implement disease surveillance and control measures to prevent the spread of zoonotic diseases.
    - **One Health Unit, Ministry of Health (MOH)** in Malaysia has established a One Health Unit that focuses on coordinating efforts to address zoonotic diseases. This unit works in collaboration with other relevant government agencies and stakeholders to prevent and control disease outbreaks (Ministry of Health Malaysia, n.d.).
    - **Departments of Veterinary Services** are responsible for animal health and welfare. They play a crucial role in monitoring and controlling zoonotic diseases, such as avian influenza (bird flu) and rabies for example, through surveillance and vaccination programs (Mohd Nor et al., 2003; National Parks Board Singapore, n.d.; Australian Aid, Australian Government, and Indonesian Ministry of Agriculture, 2015).

PRACTICAL IDEAS ON HOW TO FOSTER GENUINE ENGAGEMENT

All types of engagements in a participatory approach to implementation, including face-to-face discussions, working meetings, and real-time drafting of documents, can be inclusive and productive in working towards a common goal. However, engaging participants in a meeting room can be challenging. This challenge arises because engagement is not achieved by simply having the appropriate participants in the room, but rather by having them actively engage the discussion and feel ownership of the task at hand. Several barriers, especially along the individual factor context (Figure 8-1.1), can be addressed to foster engagement, such as:

1. **Language barriers:** Navigating language barriers becomes challenging during dynamic discussions, hindering the ability to express nuanced opinions in a non-native language in real time. For instance, understanding conversations in a certain language may be possible, but articulating rebuttals effectively in that language may remain a struggle.
2. **Cultural barriers:** Reluctance or hesitancy to participate in discussions due to unspoken cultural norms and hierarchical pressures (e.g., ‘I must not speak up to someone who is more experienced than me.’)
3. **Balancing priorities:** Tasks and responsibilities compete for the participants’ attention during a meeting (e.g., ‘I have an important, but unrelated, report due tonight, so the only time I can edit my draft is during this meeting.’)
4. **Politics and values**: Politics, values, and ideas among participants that might conflict with one another.

Illustrating How to Foster Engagement in a Multicultural and Multidisciplinary Setting

From the 1st to the 3rd of June 2023, a group of experts from the development committee of this guidebook gathered in Kuala Lumpur, Malaysia to reflect on the final stages of guideline development and to better reflect local perspectives in the final draft. The following questions and tips supported improved participant engagement when engagement was low, potentially due to language and cultural barriers, and competing responsibilities (Table 8-2).

TABLE 8-2 Possible Actions by a Meeting Facilitator, Questions to Assess, and Next Steps to Improve Participant Engagement

#	Facilitator Action	Question to Assess	Next Steps
1	Agree on common communication, rules of engagement, and standards	Provide a base for 'ground rules' (e.g., being present and on time, respecting differences, asking questions, acknowledging contributions, etc.) and ask the audience what else could be added to this list.	Encourage active participation based on these ground rules while periodically evaluating the effectiveness of these established communication rules. Adjust as needed.
2	Observe the interpersonal dynamics in the meeting	Is the discussion being dominated by only a few participants? Are people looking at their computers for unrelated tasks?	Consider switching from an open discussion to an engagement exercise, using sticky notes, posters, whiteboards, etc. Writing down thoughts will give participants time to reflect, formulate, and distil thoughts at their own pace. Activities can also consider personal, group, and paired discussions to ensure that various ways of thinking and discussing are supported
3	Try to maintain language that is understandable by everyone	Is there use of jargon or words with multiple meanings depending on disciplines?	Remind speakers to avoid the use of acronyms and abbreviations.
4	Identify participants who may have difficulties with the common language spoken at the meeting	Are there multiple participants with a common language(s) that could be paired for mutual translation support? Are non-native language speakers able to contribute to the discussion?	Engage in individual conversations to identify participants who may struggle and pair them with bilingual participants. Use live translation such as Google tools. Make sure to provide more pauses for these participants to catch up. Use visuals and live captions if on Zoom and provide written information that may be more readily comprehended than verbal

			communications for non-native language speakers. Arts-based approaches (e.g., illustrations, poetry, songs) can also be explored to provide different opportunities for participants to better communicate and express their thoughts.

A Focus on the "Gatekeepers" for Implementation

Engagement requires careful observation and accounting of potential gatekeepers, or actors who are empowered to move forward with certain aspects of the implementation process (Singh and Wassenaar, 2016). These aspects range from power over the necessary social capital or community networks needed to bring diverse actors into the participatory approaches to access different data that are important for evidence-based decision-making. Gatekeeping can hinder implementation by controlling these aspects; however, we also believe that gatekeepers can serve as trusted allies and catalysts for implementation. Several cases have shown us the role of gatekeepers in One Health or zoonosis management, such as the successful decentralization of a One Health system in response to an anthrax outbreak in the Nakuru County, Kenya (Sitawa et al., 2023). This example highlights the importance of active engagement from various actors, including farmers, veterinarians, and local health departments, for disease outbreak mitigation. Thus, it is important to understand the characteristics of the actors who may serve as gatekeepers and find ways to also engage them in the implementation process.

Participatory social network mapping, for example, can show who these potential gatekeepers are. Usually, these are the actors who are 'most central' to the community or those who have the most relationships among other actors. They may also be the 'key bridges' to those who connect important actor groups or clusters of organizations in the community. More information on this can be found in the 'Case Example 6-3: Stakeholder Mapping at the Retail Step of the Value Chain Using Power-Interest Grids (X-Y Charts)' in Module 6.

Not only should we engage local and other types of experts to get guidelines utilized, but it is also beneficial to understand the characteristics of the individuals who will be the gatekeepers in the process of getting these guidelines used.

Characteristics of the Guidelines, and Policies and Practices Encompassed that Make Them Up

So far in this module of the guidebook, the authors have tried to illustrate how implementation of guidelines is facilitated by a thoughtful, active, and sufficiently resourced plan that accounts for engaging the 'right' *people* in appropriate collaborative and participatory *processes*, taking into consideration the *contexts* (e.g., the traditional cultures, the political characteristics of the organizations or institutions, etc.) in which the guidelines will be used. Guideline implementation that includes policies and practices usually does not occur spontaneously, naturally, or by accident, even if these guidelines seem to be based on established science. Thus, we now turn our attention to consider the ways in which we can tailor guidelines to help overcome perceived barriers such as 'It is too much trouble to change my behaviours now', or 'The guidelines are too confusing or contradictory', and 'I don't see how these guidelines will really benefit the situation in the long run'.

We have learned that guidelines get used when the practices and policies they promote are easy to understand (**Complexity**) when the costs of changing behaviour are low (from both a monetary and a psychological perspective), especially if there is a perception that one can back off new behaviour and return to old practices if necessary (**Trialability**), when the guidelines' practices and policies lead to plainly observable benefits (**Observability**), when the guidelines promote behaviours that clearly work better than what is currently being done (**Relative Advantage**), and when the guidelines promote solutions that are not terribly different from what people are used to doing (**Compatibility**) (Figure 8-3).

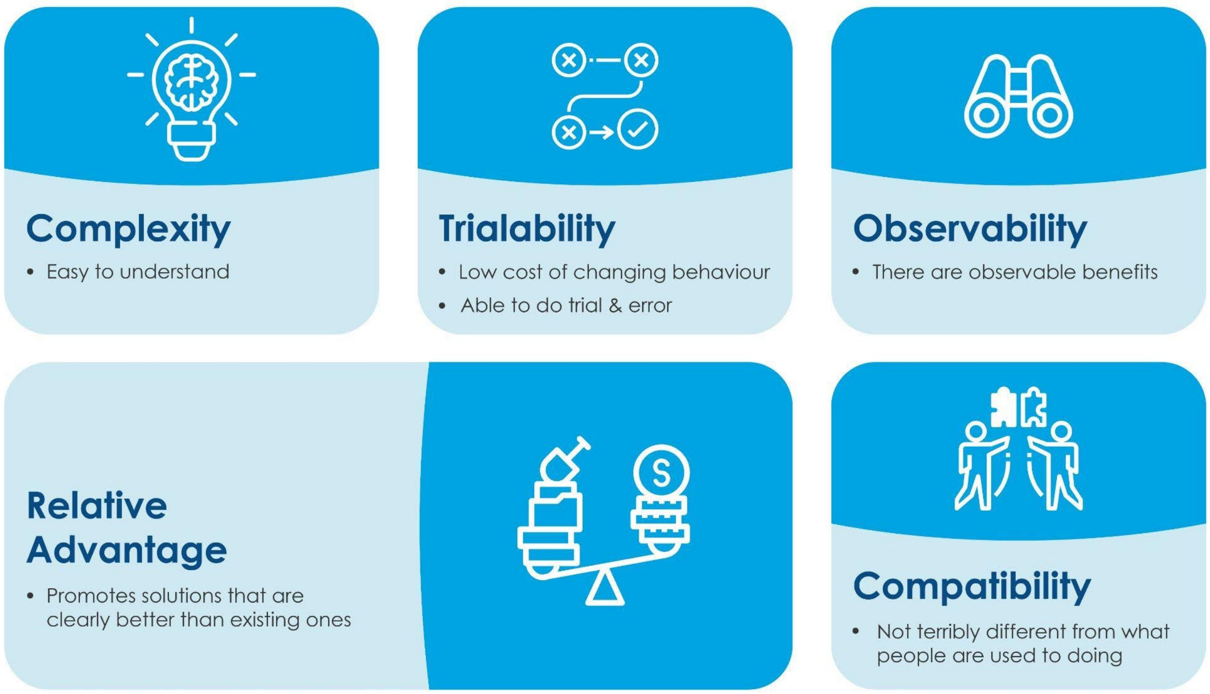

FIGURE 8-3 Characteristics of a successfully implemented guideline.

A look back to previous case examples presented in this guidebook can help illustrate some of these points and offer examples of elements to consider when attempting to implement the practices and policies recommended in our guidelines. These case examples illustrate the initially successful application of strategies that effectively mitigated zoonotic spillover. However, close scrutiny of the cases illustrates barriers and facilitators of sustained implementation of these strategies. The cases are offered so that you, the reader, might contemplate how to adapt similar solutions to local and regional contexts of implementation and how to engage stakeholders in a 'whole of society response' that utilizes both bottom-up and top-down approaches.

Hendra in Australia: Challenges to long-term, sustained implementation

In Australia, years of research resulted in a 'mechanistic' understanding of local zoonotic spillover events (Eby et al., 2023). The discussion outlined below was the result of multidisciplinary and cross-module collaboration and discussion between participatory scientists who co-authored this module and ecologists who co-authored Module 2 of this guidebook. These discussions facilitated an exchange of ideas and strategies to address the complex issue of spillover of Hendra virus from bats to horses in subtropical Australia (Eby et al., 2023).

Put simply, a loss of native habitat drove bats to encroach upon agricultural and urban landscapes, encountering horses and other domestic or traded animals (Eby et al., 2023; Plowright et al., 2015). To address the issue, native flowers and five species of trees were planted to conserve, restore, and rehabilitate severely depleted winter habitats for the bats (Eby et al., 2023). However, attempts to make this research-based solution routine and sustained practice have encountered difficulties related to social and cultural pressures. Land-use change policies have proven difficult to implement due to potentially competing interests by stakeholders in development, industry, and agriculture. It has been difficult for researchers to build the amount of evidence needed to effect changes in legislation. In addition, local communities have balked at such interventions because of the negative perceptions of the bats as 'nasty, disease-ridden, blood-sucking' pests.

In response, individuals working with local communities, including anthropologists, epidemiologists, and ecologists, have turned to a creative solution. When presenting restoration and rehabilitation interventions, advocates refrained from focusing on bats, instead portraying efforts to provide habitat for pollinators such as birds and gliders, which have the same migratory cycles and/or nomadic behaviours as bats. Koalas also depend on the same tree species and were also used in marketing strategies for habitat restoration initiatives. In pivoting to this approach, implementers have provided a locally palatable, culturally compatible, simple-to-understand solution (NSW, 2022). Years of monitoring Hendra virus cases and dissemination of findings to engaged stakeholders will improve the observability of results and answer the question of whether the effort will be perceived to clearly work better than what transpired before and is sustainable. This is especially important because the strategy of increasing the spatial separation of reservoir hosts and potential spillover hosts is not novel. After the Nipah virus outbreak in Malaysia in 1998-1999, mango trees and other trees preferred by bats were removed from the proximity of piggeries (Epstein and Field, 2015). Though considered a successful case, additional investigation is required to understand the barriers and facilitators of implementation so that lessons learned can be transferred and adapted to other local contexts.

Nipah in Bangladesh

A Nipah virus outbreak in Bangladesh also proves illustrative in terms of the characteristics of an intervention that impacts implementation. After an outbreak in Bangladesh, scientists were unsure of how the virus was being transmitted from bats to people (Luby et al., 2009). Teams of anthropologists linked the issue to date palm sap consumption by bats and humans and worked with local communities to identify a solution (Islam et al., 2016; Rahman et al., 2012). Bamboo skirts were placed over the top of sap collection pots, denying bats access to the sap (Seppa, 2009). The skirts were relatively cheap (though any additional cost is a barrier), simple, compatible (they resembled fishing and other types of bamboo nets used by local communities), and an effective solution (Nahar et al., 2013). The relative advantage of harvesting cleaner, clearer sap for the market was easily observable. However, routine use of the skirts has been elusive. Voluntary implementation of the skirts has not been sustained, as utilizing bamboo skirts has been continued only where programs are present to sustain the intervention. Additionally, fearing the further spread of the outbreak, the national government banned the consumption of date palm sap entirely (Parveen et al., 2016). Therefore, placing bamboo skirts on sap collection pots to make the sap less risky for consumption was a type of harm reduction strategy for a practice that was prohibited by the government. This policy has been met with resistance from local communities because date palm consumption is a culturally ingrained practice that continues despite the mandate to cease consumption. This context presented challenges in risk communication for infection prevention. Should there be messaging for reducing the risk of infection for a practice—date sap consumption—that has already been banned by the government, given that community members may not be adhering to the rules?

Strategies for Implementing Zoonotic Prevention Measures

In general, some suggestions regarding the characteristics of the solution/innovation to be implemented include the tips outlined below. These tips also aim to provide ideas on how to address various characteristics of a successfully implemented guideline (Figure 8-3).

TIP 1: Keep it simple.

Halting the transmission chain from animals to humans through separation is perceived as a simpler idea compared to implementing complementary and essential practices such as incorporating new technology to increase biosafety measures or introducing extensive surveillance. In developing local guidelines, what are the costs and benefits of emphasizing 'simple' solutions that are more likely to be accepted and practiced versus potentially more effective but also more complex solutions that are less likely to be practiced?

TIP 2: Focus on compatibility.

Among the 'additional solutions' in the case of the Nipah virus in Malaysia and Singapore was to encourage the traditional practice of keeping smaller and less-connected pig operations, operated family-style and by generation to generation. These practices may be attractive because of their familiarity with 'how things have always been done' and thus avoid the perceived objection of cultural incompatibility and just plain reluctance to change. Are there ways to make practices and policies not seem alien or strange?

TIP 3: If it works, make sure the results are plain to see.

Educating consumers and stakeholders about the potential health risks of consuming high-risk species such as civets and pangolins via media campaigns, community outreach programs, and collaboration with local NGOs and wildlife conservation groups is an example of raising public awareness about the risks associated with wildlife trade. However, though there is a tendency to focus on the observability of the *problem* on one end of the value chain (the consumers), sustained use of innovative policies and practices needs to be better promoted by those at the other end of the value chain (producers, for instance). And yet, one must also consider the observability of *solutions* that 'work'. The visibility of the solutions may be disseminated by media or by interpersonal information exchange (e.g., reputation among the community of a successful business, etc.)

The Participatory One Health Digital Disease Detection (PODD) in Chiang Mai, Thailand referenced in Module 6 is an example of data management, sharing, and security (Yano et al., 2018). Recall that, working together with a diverse team consisting of veterinarians, public health officers, livestock officers, community volunteers, and geographic information system experts, the PANORAMA project introduced smartphone and web-based platforms to combat zoonotic spillovers and monitor emerging animal and environmental health threats. The success of this initiative became widely publicized (PANORAMA, n.d.; IUCN, n.d.).

TIP 4: Make sure to develop guidelines that include practices and policies that are plainly going to be perceived as 'better' than what is currently in place.

TIP 5: Ensure that there is 'low risk' for the people adopting new behaviours by allowing for the possibility that practices and policies are flexible according to circumstances. This provides an opportunity for adopters to be able to 'back out' of their commitments.

Our Ultimate Vision of a participatory approach to implementation

What we outlined in this module is not prescriptive, but rather ideas to consider. While we borrow from multiple lenses of implementation science, participatory research, and social sciences, these are also not exhaustive but rather build on our own experiences within these fields. We cannot emphasize enough our overarching message on the need to tailor to a diversity of contexts. We encourage users of this module to make this a central thought going through the different ideas we presented in this module: *How is this participatory tool applicable to our context? Which network or organization had prior successes in our context, and what can we learn from them? What characteristics of implementation should we bring more attention to?* These are just some of the questions for reflections that can help guide a participatory approach to implementation.

We end by sharing our own vision of how our guidebook can catalyse participation and engagement (see Annex 1 for full details). We hope that through our guidebook, we can mobilize and engage actors in academia and research, civil society groups and non-governmental organizations, national governments and regional bodies, local government units, and private sector and industry (Figure 8-4). We hope that actors collaborate in implementing the contents, strategies, and recommendations of this guidebook in addressing zoonotic spillover in terms of its multidimensional, multidisciplinary, multisectoral, and multinational needs, gaps, and potential solutions.

FIGURE 8-4 A collective vision for the use of this guideline among actor groups

ANNEX 1- AUTHORS' COLLECTIVE VISIONS ON THE USE AND IMPLEMENTATION OF THE GUIDEBOOK

In June 2023, the authors of the modules of this guidebook participated in a workshop session to co-develop 'collective visions' on the potential usage and implementation of this guidebook across organizations, actor groups, and scales. Specifically, we brainstormed what approaches and channels can leverage this guidebook's uptake and eventual implementation among diverse user groups. These collective visions also reflect our personal aspirations to inspire readers on this guidebook's value as a tool and reference to counter zoonosis in Southeast Asia.

We first present our general collective vision for this guidebook. Then, we outline our visions for each potential user group, including why we believe this vision is plausible and some ideas on how to realize these visions. Afterward, we outline our proposals for the knowledge dissemination of this guidebook. For the participatory approach we have followed to develop these visions and suggestions, please see texts below.

A General Collective Vision by the Authors

Our ultimate aspiration for this guidebook is that it becomes a useful, insightful, and inspiring product for all actor groups, especially those employing a One Health approach to their work in communities. We hope it provides holistic guidance for actor groups in formulating and implementing more sustainable research, local and national policies, and public agendas (e.g., national strategies) to prevent disease spillover. We hope this guidebook can empower actor groups to tailor their efforts to SEA's local challenges and needs, eventually catalysing local ownership of One Health projects and programs. More important than its potential role in individual capacity and knowledge-building, we hope this guidebook will inspire actor groups on the importance of collaboration and working proactively across sectors, interests, and disciplines (Figure 8-4).

Moreover, we hope that readers of this guidebook, not only the actor groups currently involved in One Health, will have a better appreciation of the role of our ecosystems in human health, especially in the human-animal-environment interface. We hope we can inspire the general readers of this guidebook with the level of thought placed on the complexity of addressing zoonotic spillover in terms of its multidimensional, multidisciplinary, multisectoral, multinational needs, gaps, and potential solutions.

A Vision for Academia and Research

We hope this guidebook provides directions in teaching and research across higher education institutions and research centres in Southeast Asia. This guidebook can serve as a reference that can capacitate faculty and researchers to teach and mentor next-generation One Health leaders in conducting more integrated and comprehensive research on zoonoses and the components tightly associated with them, such as pathogens, hosts, environment-animal interface, and food systems. Ultimately, we envision this guidebook to catalyse the continuation of existing and development of new large-funding collaborative research activities involving teams of multidisciplinary researchers across the region─ allowing us in the long term to provide evidence-based and actionable knowledge to close the gap between One Health education, research, and public advocacy and policy.

Why do we believe we can achieve this vision for this actor group?

- Academia and research actors in Southeast Asia have a strong shared and revitalized interest in combating the next pandemic, commitment to solutions, and conscience for ecosystem andhuman health. This is especially true after the devastating impacts of the COVID-19 pandemic on lives and livelihoods in the region.
- One Health research is a fast-emerging area that can encourage researchers, especially early career researchers, to focus their research efforts and performance. It is also receiving global and regional attention, including opportunities for acquiring research funding.

What are some ways for this actor group to achieve our vision?

- Recruiting local One Health education and research champions who can be trained under tailored capacity-building programs using this guidebook.
- Engaging students and researchers in medical, veterinary, and allied health sciences and those in related fields (e.g., agriculture, sociology) in One Health education and training for the region.
- Using the guidebook to identify and set core One Health educational competencies, from primary education (e.g., high school) to higher education (master's and doctoral studies).

A Vision for Civil Society Groups (CSGs) and Non-governmental Organizations (NGOs)

We hope this guidebook can serve as a comprehensive reference to develop information, education, and communication (IEC) tools and approaches for CSGs and NGOs, especially those working with key One Health actors (e.g., farmers, market workers, natural resource-based workers). We believe that this guidebook can facilitate extension service programs to introduce fundamental concepts of One Health and allow local and community-based actor groups to reflect on their relationships and roles in the animal-human-ecosystem health interface. We also envision this guidebook to enhance cross-sectoral and cross-organizational collaboration for One Health among CSGs and NGOs by providing key contacts on which actors are relevant for which component of One Health (i.e., 'Who are the appropriate actors to talk to about particular topics?').

Why do we believe we can achieve this vision for this actor group?

- CSGs and NGOs in Southeast Asia are trusted messengers of knowledge and have been historically passionate about initiating positive changes in the local communities they work with. This role was particularly heightened with the impacts of the pandemic when these local communities suffered severe economic consequences, and existing relationships with CSGs and NGOs became essential channels of communication and support.
- Several funding and other emerging opportunities for One Health now require strong community-based engagement, so relationships built by CSGs and NGOs are becoming increasingly critical.

What are some ways for this actor group to achieve our vision?

- Engaging CSGs and NGOs in training programs, especially working with them on developing IEC tools and materials (e.g., videos, flip charts, and other forms of audio-visual aids) that can translate key messages of this guidebook into versions appropriate and tailored for the actor groups they work with.

- Using this guidebook to guide the development of training manuals tailored for CSGs and NGOs in the region, especially for the Training of Trainers of potential local champions of One Health

A Vision for National Governments and Regional Bodies in Southeast Asia

We hope this guidebook can pave the way for deep reflections among decision-makers in relevant state ministries and departments to take ownership and accountability of the problems relevant to One Health. This guidebook contains important cases and experiences in Southeast Asia that can empower national governments and regional policy institutions to lead executive measures and advocate for legislation that will address problems on foundational drivers of a pandemic, financing, community engagement, and locally relevant solutions. We envision that this guidebook opens ideas for national governments and regional organizations to develop and implement programs that invest in human and ecosystem health co-benefits. Ultimately, we hope this guidebook leads to collaborative leadership for One Health, where relevant state-level offices and regional organizations have clear roles and responsibilities.

Why do we believe we can achieve this vision for this actor group?

- National governments in Southeast Asia aspire for and are well-positioned to take global leadership, especially in hopes of leaving positive legacies on achieving the United Nations 2030 Agenda for Sustainable Development (SDGs). Prioritizing One Health is an emerging convincing approach that tackles this multidimensionality of sustainable development.
- Experiences during the pandemic have heightened awareness among citizens and communities to demand accountability and call to be proactive on One Health leadership from national governments. The call to action from the Quadripartite (a consortium of four leading international organizations, WHO, WOAH, FAO, and UNEP) and its associated One Health High-Level Expert Panel has further accelerated this positive change toward invigorating One Health efforts.

What are some ways for this actor group to achieve our vision?

- Engaging decision-makers in national governments and regional policy institutions to co-develop national implementation strategies to operationalize the contents of this guidebook in the form of potential laws and executive memos, especially tailoring it to the country's changing needs.
- Using the cases and recommendations of this guidebook to reflect on power dynamics among national ministries and departments and develop a national and regional strategy for better interorganizational collaborations (i.e., 'how can we synergize our One Health efforts across ministries and departments towards a common goal.')

A Vision for Local Governing Bodies

We hope that this guidebook heightens the sensitivity of local (i.e., subnational) governments in understanding their roles, goals, interests, and power over issues in One Health. We believe that this guidebook can provide the knowledge for local decision-makers to carefully identify the complex problems in their communities. By mapping the complexity of the problem, they can formulate One Health solutions that will proactively account for potential unintended consequences and offer corrective measures. We believe that decision-makers capacity for such holistic and forward-looking thinking can more efficiently balance competing needs among different local actor groups, given the local government's usually shorter policy cycle period and limited resources. We also envision that the knowledge from this guidebook can inspire local decision-makers to lead community-based monitoring and evaluation of critical indicators to combat disease spillover.

Why do we believe we can achieve this vision for this actor group?

- The role of local governing bodies has been proven critical, especially with the recent experience of managing the COVID-19 pandemic. Performance on One Health-relevant issues has become central to public perception─ shaping prestige, legitimacy, and potential re-election for several local positions.
- Local governance in Southeast Asia is gaining empowerment, opening opportunities for local actions and regulatory measures to be more critical in identifying and addressing One Health issues and agenda.

What are some ways for this actor group to achieve our vision?

- Engaging champions among local governing bodies in the region to explore the operationalization of this guidebook, including potential funding incentives, resource sharing, and allocation, and network building to exchange local experiences and cases.
- Translating the guidebook into digestible forms (e.g., videos and illustrations) that local governing bodies can use as easy and accessible reference in their daily local governance.

A Vision for the Private Sector and Industry

During the workshop, we also briefly explored our vision of the potential use and implementation of this guidebook for the industry in Southeast Asia. However, unlike the other actor groups, we did not dive deep into this aspect. We lacked full representation from private sector and industry actors who could provide more in-depth ideas in our envisioning process.

We hope that this guidebook can guide industry leaders and private actors to know where to invest, especially the knowledge about the economic implications of breeding certain livestock under specific spatial-temporal patterns of infectious diseases important for disease spillover. We hope this guidebook can support a better understanding of the different regulations and guidance relevant to One Health, such as wildlife trade, farming, and food preparation. We believe that the cases and examples in this guidebook can help industry actors better prepare for future uncertainties, as was the case of the COVID-19 pandemic, that can have profound economic implications for the industries in the region. More importantly, we envision this guidebook to heighten awareness and eventual actions for critical issues in which the private sector serves as essential direct or indirect drivers for a potential disease spillover, such as food safety, wet market regulation, dynamics between global market needs, and local production.

Proposals for Knowledge Dissemination

We reflected on the possible approaches to how knowledge from this guidebook can be disseminated to the public and across relevant actor groups. These are simply examples of how we, as authors, can think about potential communication channels within the organizations we represent or networks we belong to. We recommend tailoring knowledge dissemination approaches based on the audience and critical messages.

- Distribution of the guidebook to libraries, medical and veterinary centres, government offices, research centres, faculties, and universities
- Engaging the press and media, including the use of social media platforms
- Tapping the One Health Network in the region and national/local One Health organizations
- Circulating along relevant regional and global bodies such as agencies of the United Nations and the Association for Southeast Asian Nations (ASEAN)
- Conducting educational activities, virtual or in-person, for students, researchers, policymakers across levels, and sectoral actors (e.g., farmers, fisherfolks)
- Presentation at conferences, meetings, and other scientific or social gatherings

Participatory Approach to Co-Develop Collective Visions on the Use and Implementation of the Guidebook

The goal of this participatory approach was to create a shared vision of implementing the guidebook across scales, including the potential facilitating factors of the uptake among actor groups. Several authors of this guidebook, across all modules, participated in this visioning exercise.

FIGURE 8-5 A multidisciplinary group of experts and researchers collaboratively working together to produce the guidelines on preventing zoonotic spillover.

Before creating the visions of the future use and implementation of the guidebook, we first began our approach by remembering our lived experiences of co-developing the different modules of this guidebook. We divided the whole group into smaller groups of three or four to 'remember our past' by sharing: 'What was most memorable in this journey of co-developing your modules?' Each smaller group then shared a word or a phrase that best represents their journey. The goal of this activity was to allow the participating authors to reflect on their shared efforts in developing the guidebook and create a collective sense of ownership and accountability.

Figure 8-6 The figure illustrates Elson Galang and Eri Togami delivering a presentation on Workshop 5 hosted by INGSA and NASEM at Sunway University in Kuala Lumpur, Malaysia.

We then listened to a brief talk by one of the authors of Module 7 on the different attributes of the guidebook to allow the authors of the other modules to reflect on:

- The cost of adopting the key messages of their module
- The relative advantage and compatibility of their recommendations over the existing practices
- The simplicity of how they presented their respective messages.
- The observability of the potential outcomes and trialability of their recommendations

The goal of this activity was to allow the authors to critically evaluate the way they have written and structured their respective modules, especially what kind of messages and recommendations they are emphasizing that are important to achieve the visions of the guidebook.

FIGURE 8-7 Workshop participants and committee members engage in group discussions, representing multidisciplinary and multisectoral engagement in the Southeast Asian region, to strategize on implementing the guidebook recommendations.

We then divided the whole group into another set of smaller groups— each group representing the following actor groups in the context of the region:

- Academia and research
- Civil societies groups and non-governmental organizations
- Local governing bodies (i.e., village to provincial governments)
- National governments and regional bodies

- Private sector and industries

We asked the participating authors to select which smaller group they felt they can contribute to the most.

- Each smaller group discussed: 'How would your actor group use this guidebook? Which modules would you prioritize?' Everyone was encouraged to place their ideas and answers in sticky notes and flipcharts. After the discussion, each smaller group shared a summary of their discussion.
- The goal of this activity is to co-imagine how the guidebook can be used by their actor group as leverage to achieve important future milestones to counter zoonosis in the region. The outputs of this activity shaped the actor group-specific visions presented in this Annex.

Participants then went around the room (i.e., 'gallery walk') to look at the different outputs, while asking them to reflect and vote using coloured stickers on the following questions:

- [Yellow Sticker] Which future use of the guidebook will be the most feasible?
- [Green Sticker] Which will be the most impactful?
- [Orange Sticker] Which will face the most barriers?

The goal of this activity is to allow participants to explore the visions co-developed by other smaller groups and provide insights into the potential of these visions for actual future implementation.

Participants then quietly described their personal aspirations for the guidebook by writing them on a coloured sheet. We asked participants on certain coloured sheets to share their aspirations for the group. The goal of this activity is to allow the participants to connect their own personal visions to the actor group-specific visions. Outputs of this activity were synthesized to write the general collective vision in this Annex.

Participants were asked to go back to their respective smaller groups to do the 'Iceberg Exercise'. Participants discussed four questions, each representing a layer of the iceberg:

- Layer 1: Is the guidebook accessible enough so recommendations can be implemented by this actor group? If not, what can make it more accessible? Layer 2: Are these actor groups 'ready' to get on board? If not, what can facilitate their readiness (e.g., capacity development) for the guidebook?
- Layer 3: What are the inner characteristics of this actor group that can facilitate the uptake of the guidebook (e.g., vital interests in zoonosis)?
- Layer 4: What is the socio-cultural-political context by which this actor group operates that can facilitate the uptake of the guidebook (e.g., substantial funding)?

At the end of the activity, each group shared a summary of their discussions. The goal of this activity is to allow the participants to carefully think about the feasibility of their visions, including the potential facilitating and hindering factors to achieving these visions. Outputs of this activity were synthesized to write the subsections (i.e., 'Why we believe we can achieve this vision' and 'What are ways to achieve this vision') of each actor group-specific vision in this annex.

FIGURE 8-8 Participants, committee and staff members pose together at the conclusion of Workshop 5, holding awards in recognition of their collaborative efforts and contributions.

To end the participatory approach, we asked the participants to quietly imagine how they would disseminate the key messages and recommendations they had written in the guidebook. We asked them to write these down in coloured sheets, asking some of them to share their thoughts with the whole group. The goal of this activity is to allow the participants to begin thinking of small but doable ways that can contribute to achieving the visions they just co-developed. Outputs of this activity were synthesized to write the proposals for knowledge dissemination in this Annex.

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