Workshop Summary

Prioritizing Zoonotic Diseases for Multisectoral One Health Collaboration in Singapore

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Photo 1. View from Sungei Buloh Wetland Reserve, Singapore.

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Photo 2. Sunda flying lemur (*Galeopterus variegatus*) in a Singapore forest.

EXECUTIVE SUMMARY

The One Health Zoonotic Disease Prioritization (OHZDP) workshop for Singapore aimed to prioritize zoonotic diseases of greatest concern using a One Health approach with equal inputs from representatives of human, animal (livestock and wildlife), and environmental health sectors and other relevant partners.

The specific workshop goals were to use a One Health approach to:

1. Prioritize zoonotic diseases of greatest concern for Singapore; and
2. Develop next steps and action plans to address the priority zoonotic diseases in collaboration with One Health agencies.

During the workshop, participants developed a list of zoonotic diseases for prioritization for Singapore, defined the criteria for prioritization, and determined questions and weights relevant to each criterion. A total of five zoonotic diseases were identified as a priority using the mixed methods One Health Zoonotic Disease Prioritization Process, developed by the U.S. Centers for Disease Control and Prevention (CDC) (Appendix A).

After identifying the priority zoonotic diseases, participants developed next steps and action plans to address the priority zoonotic diseases in collaboration with One Health partners.

The priority zoonotic diseases for multisectoral, One Health collaboration in Singapore are:

- Avian Influenza
- Coronavirus Disease 2019 (COVID-19)
- Salmonellosis (Non-typhoidal)
- Yellow Fever
- Leptospirosis

Singapore also identified ten other zoonotic diseases for close monitoring. These diseases are Nipah Virus Disease, Rabies, Japanese Encephalitis, Dengue, Zika, Hantavirus Disease, Campylobacteriosis, Hepatitis E, Severe Acute Respiratory Syndrome (SARS), and Middle Eastern Respiratory Syndrome (MERS).

This report summarizes the OHZDP Process used to prioritize zoonotic diseases of greatest concern for Singapore. Next steps and action plans were also identified to jointly address these zoonotic diseases using a One Health approach including human, animal, and environmental health ministries/ agencies, and other relevant sectors.

Photo 3. Officers processing mosquito samples in the insectary for research.

Table 1. Priority zoonotic diseases for One Health collaboration in Singapore, listed in ranked order.

Zoonotic Disease	Human Disease Burden	Animal Disease Burden	Treatment and Prevention
Avian Influenza	Singapore is currently free from avian influenza. This disease, however, has been reported from countries within the Western Pacific region with a case fatality rate of 38–56% based on the highly pathogenic avian influenza (HPAI) strain of H5N1, H5N6 and H7N9 (World Health Organization, 2023a).	In most wild birds, avian influenza viral infections are subclinical except for the recent H5 HPAI viruses of Eurasian lineage. H5 HPAI is associated with high mortality in wild and domestic birds (including poultry). HPAI may infect other animals as well (Centers for Disease Control and Prevention, 2023a), with mortality as high as 100% in a few days (Swayne, 2023).	There is currently no effective vaccine for humans, and the seasonal influenza vaccines do not protect against avian influenza infection (World Health Organisation, 2005). Inactivated vaccines may be used in poultry. Potential reassortment with influenza vaccines, however, may lead to increased virulence (Swayne & Brown, 2021). In humans, antiviral drugs like Tamiflu (Oseltamivir) are often used for symptomatic treatment and may be offered as prophylaxis (European Centre for Disease Prevention and Control, 2023). In animals however, antiviral treatment is not approved or recommended (Swayne, 2023).
Coronavirus Disease 2019 (COVID-19)	Over 770 million confirmed human cases of COVID-19, including 6.9 million deaths have been reported globally as of 27 Aug 2023 (World Health Organization, 2023b)	COVID-19 in animals have been reported in over 36 countries in Americas, Africa, Asia, and Europe (World Organisation for Animal Health, 2023a). Most of these animals, however, had been in close contact with humans (Centers for Disease Control and Prevention, 2022b). The case fatality rate of COVID-19 infected animals is estimated to be about 1.4% (Bonilla-Aldana et al., 2021).	Effective vaccines and treatments are available for humans but there are no approved vaccines for animals in Singapore (Chew, 2021). Several approved antiviral medications are used to treat persons infected with COVID-19 who have mild to moderate symptoms (Centers for Disease Control and Prevention, 2023b). For animals, COVID-19 infections are normally mild and self-limiting (American Veterinary Medical Association, n.d.).
Salmonellosis (Non-typhoidal)	The annual global incidence of non-typhoidal salmonellosis in humans was estimated to be 93.8 million cases with a case fatality of 14.5% in 2017 (Majowicz et al., 2010; Stanaway et al., 2019).	*Salmonella* spp. have been found in all species of mammals, birds, reptiles, and amphibians that have been investigated Asymptomatic infections are particularly prevalent in poultry, swine, reptiles, and amphibians (Spickler & Leedom Larson, 2013b). Clinical cases are common in cattle, pigs and horses but are relatively uncommon in cats and dogs. Newborn animals are especially vulnerable, where mortality may reach 100%, depending on the host's genetic background and strain virulence (Grünberg, 2022).	To date, no vaccine has been licensed against non-typhoidal *Salmonella* and *Salmonella* Paratyphi for humans (Baliban, Lu, & Malley, 2020). The mainstay treatment for humans is supportive care, while antibiotics are typically used only for severe cases in vulnerable populations. On the other hand, vaccines are available and licensed for use in livestocks (e.g., pigs, cattle, and chickens) and appear effective against certain *Salmonella* serovars (e.g., Dublin, Typhimurium, Abortusequi, and Choleraesuis) (Grünberg, 2022).

Zoonotic Disease	Human Disease Burden	Animal Disease Burden	Treatment and Prevention
Yellow Fever	While yellow fever is primarily maintained within the sylvatic cycle, an urban cycle exists where the virus is transmitted between humans primarily by the *Aedes aegypti* mosquito. Most infected persons are asymptomatic or exhibit mild symptoms, with only a small proportion developing severe symptoms. Of whom, half of those with severe symptoms were reported to die within seven to ten days (World Health Organization, 2023d). The estimated human case fatality rate for severe cases is 39% (Servadio, Muñoz-Zanzi, & Convertino, 2021). While Singapore is free from yellow fever, there are concerns of risk of importation and transmission due to global travel and the presence of *Aedes* spp. mosquitoes in Singapore.	Yellow fever virus is primarily maintained in African and South American non-human primate populations and is spread by *Aedes* spp. or *Haemagogus* spp. and *Sabethes* spp. mosquitoes within the sylvatic cycle. No Yellow fever cases have been reported in Singapore or in the region. But if yellow fever is introduced to Singapore, there are potential risk of transmission from human cases to local macaques due to the presence of *Aedes* spp. mosquitoes, with the possibility of establishing a sylvatic cycle in the local macaque population (Miot et al. 2020).	Effective vaccine (17D attenuated vaccine) is available for human and non-human primate use (de Miranda et al., 2022). There is no specific treatment for yellow fever, and treatment is mainly supportive in humans (World Health Organisation, 2023). Elimination of potential breeding sites and vector control measures (e.g., space spraying and release of male *Wolbachia Aedes* mosquitoes) can be employed for disease prevention and outbreak response.
Leptospirosis	Of an estimated 1 million cases reported globally annually, 60,000 cases result in deaths, with case fatality of about 6% (Centers for Disease Control and Prevention, 2018).	All mammals (except rodents) are vulnerable to pathogenic *Leptospira* serovars to varying degrees (Petrakovsky, 2021). The mortality rate in dogs was estimated at 34% in Malaysia (Rahman et al., 2021). A survey of rodent-borne pathogens revealed the circulation of *Leptospira* spp. in Singapore (Griffiths et al., 2022).	Vaccine is commercially available for animals but not for humans (Barazzone et al., 2021). Leptospirosis is typically treated with antibiotics, such as doxycycline or penicillin, which should be given early in the course of the disease. Intravenous antibiotics may be required for patients with more severe symptoms (Centers for Disease Control and Prevention, 2015b).

PARTICIPATING ORGANIZATIONS

- Ministry of Health (MOH)
- National Environment Agency (NEA)
- National Parks Board (NParks)
- Singapore's National Water Agency (PUB)
- Singapore Food Agency (SFA)
- Ministry of National Development (MND)
- Ministry of Sustainability and the Environment (MSE)
- Mandai Wildlife Group (MWG)
- National University Hospital (NUH)
- National Public Health Laboratory (NPHL)
- Duke-NUS Medical School (Duke NUS)
- National University of Singapore (NUS)
  - Department of Civil and Environmental Engineering
  - Saw Swee Hock School of Public Health
- Nanyang Technological University (NTU)
  - Singapore Centre for Environmental Life Sciences Engineering
- U.S. Centers for Disease Control and Prevention (CDC)

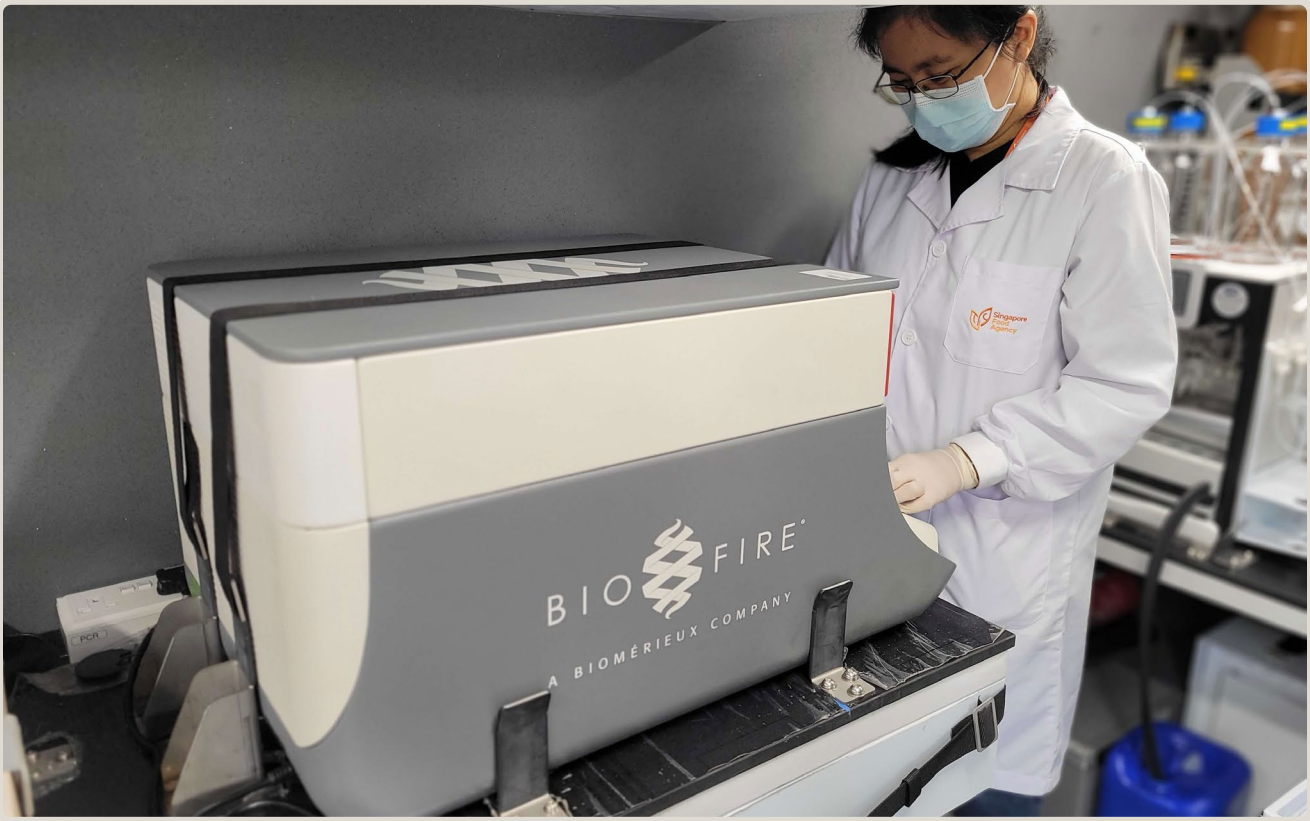


Photo 4. Laboratory staff operating diagnostic equipment.

INTRODUCTION

Zoonotic diseases are diseases that are spread between animals and people. Most known human infectious diseases and about three-quarters of newly emerging infections originated from animals. Zoonotic diseases can impact society in three main ways. Specifically, they:

- Threaten the health of animals resulting in illness, loss of productivity, and death.
- Threaten the livelihood of populations dependent on livestock as a major source of income.
- Threaten the health of people, possibly causing illness and death, that result in significant social and economic losses.

To best address zoonotic disease threats, a One Health approach is needed. This refers to a collaborative, multisectoral, and transdisciplinary approach—stakeholders working at local, regional, national, and global levels—with the goal of achieving optimal health outcomes with recognitions towards the interconnectedness between people, animals, plants, and their shared environment.

Population and Geography

Singapore is a city-state in Southeast Asia. Situated one degree north of the equator, Singapore resides within a region of perpetual summer and high rainfall. The current population of Singapore is estimated at over 5.92 million in 2023 and with a population density of 8,058 per sq. km, it is one of the most densely populated countries in the world. Despite being highly urbanised and having a small land area of 735.2km^2, Singapore is home to a rich diversity of flora and fauna.

Singapore as an International Travel Hub

Singapore's vision to become a leading, vibrant hub for tourism, business, and trade yields significant passenger traffic through its shores. Globalisation, climate change and massive urbanisation accelerate the spread of contagious diseases in a highly connected world. This has been exemplified in the SARS and COVID-19 pandemics where air travel and the movement of people internationally became a gateway through which infectious disease spread. Singapore's status as a major transportation, trans-shipment and travel hub makes it particularly vulnerable to the importation of infectious diseases.

Singapore—A City in Nature

Singapore aspires to be a "City in Nature" through the culmination of over five decades of planting effort to improve the greenery, parks, and landscape. Currently, over 40% of the Singapore's land is covered in green space, with a tree canopy percentage of almost 30%, making it one of the greenest cities in the world. This unique aspiration envisions a city where biodiversity thrives alongside our urban ecosystems, fostering a harmonious coexistence between the residents and nature. The "City in Nature" concept not only strives to enhance the aesthetic appeal of the city but also seek to address environmental challenges such as air quality improvement, mitigating climate change impacts, and bolstering the resilience of its ecosystems. As Singapore expands its green spaces and continues its efforts to conserve biodiversity in urban landscapes, interactions between humans and wildlife will inevitably intensify and could increase the likelihood of zoonotic disease spillover events.

Singapore's Food and Water Story

Singapore has limited land resources for farming. To ensure food supply resilience, Singapore imports more than 90% of its food from over 180 countries and regions as part of its source diversification strategy. This reduces the risk of reliance on any single food supply source. While the strategy has served Singapore well, disruptions in food supply will inevitably arise from time to time due to factors such as climate change,

volatility in crop yields, geopolitical developments, and global pandemics. As such, Singapore also has a "Grow Local" strategy which helps lessen the impact of supply disruptions by allowing more time for activation of alternative sources. As part of the 30 by 30 vision, Singapore is working to build the capability and capacity of the agri-food industry to sustainably produce 30% of the country's nutritional needs locally by 2030. However, running intensive farms within an urban environment has its own challenges, including management of farm pollutants and animal waste, minimising the environmental footprint, and preventing the spread of zoonotic diseases.

Water demand in Singapore is currently about 430 million gallons a day, with the domestic sectors accounting for 45% and the remaining utilized by the non-domestic sectors. By 2065, Singapore's total water demand could almost double, with the non-domestic sector accounting for about 60%. Over the years, Singapore has built a robust and diversified supply of water known as the "Four National Taps": water from local catchment, imported water, NEWater, and desalinated water. The demand for water is expected to continue increasing with population and economic growths. Hence, it will be important to understand the impacts of emerging waterborne zoonotic diseases on drinking and recreational water safety to better manage potential health threats.

Biosurveillance in Singapore

Singapore has implemented a comprehensive biosurveillance strategy across pre-border, border, and post-border stages to protect against potential zoonotic disease threats. Pre-border surveillance includes monitoring global disease outbreaks and emerging pathogens to identify potential introduction risks, as well as ensuring that all imported animals, food, and products meet Singapore's import health requirements before entering the country. At Singapore's border, measures to screen incoming travellers and imported animals for symptoms of infectious diseases are in place. Additionally, there are robust quarantine requirements for at-risk individuals and animals to curb further transmission within the country.

Lastly, there are post-border surveillance mechanisms among the human population and specific areas (such as, animal establishments, and nature areas) for zoonotic disease signals. Laboratory testing and diagnostic capabilities are also utilized to confirm and trace the pathogens responsible for outbreaks.

Photo 5. Lush jungle of Pulau Ubin Island, Singapore.

Singapore also conducts wastewater testing at more than 500 sites across Singapore. Wastewater-based epidemiology is a complementary and non-intrusive approach which could help to facilitate early detection of cases and serve as an indication of the prevailing infection rate, providing situational awareness of the spread of new variants or diseases in the community. Diseases which could be monitored include COVID-19, Zika virus, and anti-microbial resistance, among others. Overall, Singapore's multifaceted biosurveillance strategy helps to safeguard public health against potential zoonotic disease threats.

One Health in Singapore

Established in 2012, the One Health Framework in Singapore serves as an important platform for multisectoral collaborative efforts to combat threats at the human-animal-environment interface. This allows Singapore to effectively address public health concerns and to prevent, prepare against, respond to and learn from public health threats. The One Health framework comprises five agencies in Singapore—the Ministry of Health (MOH), Singapore Food Agency (SFA), National Parks Board (NParks), National Environment Agency (NEA) and PUB, Singapore's National Water Agency. The goal of the One Health framework is to learn, prevent, prepare, and respond to cross-sectoral public health threats using an integrated and collaborative One Health approach.

The main body of One Health-Singapore is the inter-agency One Health Coordinating Committee (OHCC), which provides strategic direction and sets priorities on One Health issues in Singapore. The OHCC champions inter-agency coordination and collaboration on One Health issues, including the progress and effectiveness of the One Health action plans and serves as the platform to resolve any interagency One Health issues which cannot be resolved at the working level.

The inter-agency One Health Working Group (OHWG) formulates, coordinates, implement and review programmes, for the priorities identified. Sub-working groups or project teams are established as and when necessary, to focus on specific areas of One Health issues.

Key priority areas and examples of One Health collaboration in Singapore include:

- **Development of national One Health strategies and programmes** (e.g., launch of the five-year National Strategic Action Plan on Antimicrobial Resistance (AMR) on 1 November 2017 to strengthen Singapore's efforts to combat the growing threat of AMR)
- **Peacetime development of joint protocols to improve coordinated public health responses** (e.g., joint response protocol for foodborne outbreaks and monkeypox, and contingency planning for yellow fever, avian influenza and rabies.)
- **Improved data sharing mechanisms among One Health agencies** (e.g., sharing of information for foodborne and zoonotic diseases e.g. GBS, typhoid and leptospirosis)
- **Capacity Building in the area of public health and field epidemiology** (e.g., Joint development of field epidemiology training courses)

Photo 6. Key participants comprising the voting members
(seated from the left: A/Prof. Jeffery Cutter (MOH), Prof. Vernon Lee (MOH), Dr Judith Wong (NEA), Dr Wilson Tan (NEA), Dr Chang Siow Foong (NParks), Dr Chua Tze Hoong (NParks), Ms. Grace Goryoka (CDC), Dr Sarah Teng (PUB), Dr Chang Siao Yun (PUB), Dr Leong Hon Keong (SFA), and Dr Astrid Yeo (SFA)), external facilitators from CDC, and advisors from One Health agencies and external institutions (IHLs and wildlife/public health institutes).

To address zoonotic disease challenges in Singapore, a One Health Zoonotic Disease Prioritization (OHZDP) workshop was held from 19th to 21st April 2023 in HortPark, Singapore. The purpose of this workshop was to prioritize zoonotic disease of greatest concern to Singapore using a multisectoral, One Health approach with inputs from representatives of public, animal and environmental health sectors and other relevant partners. A total of 88 participants across the One Health agencies and external institutions (i.e. U.S. Centers for Disease Control and Prevention (CDC), Institutes of Higher Learning (IHLs), and relevant wildlife and public health institutes, participated in the three-day workshop (Photo 6).

The workshop goals were to guide the One Health agencies through a multisectoral, One Health approach to:

1. Prioritize zoonotic diseases of greatest concern for Singapore; and
2. Develop next steps and action plans to address the priority zoonotic diseases in collaboration with five agencies under Singapore's One Health framework.

Photo 7. Laboratory staff examining a specimen.

WORKSHOP METHODS

The One Health Zoonotic Disease Prioritization (OHZDP) Process uses a mixed methods prioritization process developed by the U.S. Centers for Disease Control and Prevention's (CDC) One Health Office. The methods have been previously described in detail (Appendix A). Preparation for the workshop began in November 2022; a core planning team consisting of key points of contacts from each One Health agency was established. During the planning process, an initial list of 49 zoonotic diseases was developed by the core planning team through a series of internal discussions and consultations within each agency. The initial list included zoonotic diseases from human or animal reportable disease lists (Appendix B). Additionally, a zoonotic disease was included if it was known to be spread or had the potential to be spread between humans and animals of concern for Singapore. Extensive literature review on the initial list of 49 zoonotic diseases was also conducted by the core planning team. Specifically, disease-specific information on the transmission, severity, pandemic and epidemic potential, economic impact, prevention and control, and environmental impact for the country, region, and globally were collected. These references were compiled and shared with the workshop participants to be used during the evaluation and prioritization process.

During the three-day workshop, participants had the opportunity to review and finalize the zoonotic disease list to focus on for prioritization. All the zoonotic diseases from the initial list were considered during the workshop. The following steps took place over the three days:

- Voting members developed five criteria for ranking the 49 zoonotic diseases.
- One categorical question was developed for each criterion through group discussion. Questions had ordinal, binomial or multinomial answers.
- Voting members individually ranked the relative importance of each criterion.
- Each voting member's ranking was entered into the OHZDP Tool and a group weight for each criterion was calculated using the Analytic Hierarchy Process.
- Facilitators and participants answered each question for each zoonotic disease using data identified from the literature review, as well as information from other relevant websites (i.e., WHO, WOAH, ProMED) or subject matter expertise. If information for a particular zoonotic disease was not available for Singapore, data from the region or globally were used.
- After scoring all diseases, a decision tree analysis was used to determine the ranked zoonotic disease list. Each weighted criterion was applied across each question's answers for each disease. The scores across all five questions for each zoonotic disease were summed. The maximum score was used to normalize the raw scores across all zoonotic diseases, giving the most important zoonotic disease a normalized score of 1. See Appendix B for a complete listing of normalized scores for all considered zoonotic diseases.
- Workshop participants then utilized the ranked OHZDP list (with raw and normalised scores presented) to conduct discussions among the voting members. A consensus was reached to finalize the top five priority zoonotic diseases for One Health collaboration in Singapore, and ten other zoonotic diseases of importance to be monitored closely for significant developments were identified.
- The final list of priority zoonotic diseases and diseases of concern were endorsed by the One Health Coordinating Committee (OHCC) members, which included Director-Generals from the One Health agencies.
- Participants discussed and developed next steps and action plans to address the priority diseases.

Photo 8. Voting members reaching a consensus during the criteria and question development stage of the OHZDP process.

CRITERIA AND QUESTIONS DEVELOPED

The criteria for ranking the zoonotic diseases listed in this table are in descending order of importance based on their weight determined by the voting members' confidential votes. A description of how the questions assessed the criteria are listed below. Further details of the criteria, questions, answer choices, definitions, and assumptions are included in Appendix C.

Table 2. Finalized ranked criteria and questions calculated based on voting members' confidential votes in Singapore during the One Health Zoonotic Disease Prioritization workshop conducted April 19–21, 2023.

Rank	Criteria	Weight	Question Description
1	**Criterion B:** Epidemic/ Pandemic/ Epizootic potential (inc. transmission potential)	0.32	What is the location, recency, and type of outbreak/ epidemic/ epizootic for the zoonotic disease?
2	**Criterion A:** Disease severity (inc. mortality & morbidity)	0.31	How severe is the disease in human and animal population (sum of points in animal and human populations)?
3	**Criterion C:** Exposure risk (environmental persistence and likelihood of disease introduction)	0.17	(a) Is the infectious agent/pathogen currently present in Singapore? AND (b) Can there be sustained community transmission?
4	**Criterion E:** Socioeconomic impact and food security/safety	0.14	Does the zoonotic disease impact the following key sectors? • Economy • Food security • Food safety • Social/cultural • Biodiversity
5	**Criterion D:** One Health Collaboration	0.06	Is there more than one agency in Singapore that plans for and/or performs these activities for the zoonotic disease?

Photo 9. Voting members reaching a consensus during the criteria and question development stage of the OHZDP process.

Photo 10. Group of Lesser Dog-faced Fruit Bats, (*Cyneropterus brachyotis*) in the Sungei Buloh Wetland Reserve, Singapore.

PRIORITY ZOONOTIC DISEASE LIST FOR SINGAPORE

The five priority zoonotic diseases identified for multisectoral, One Health collaboration for Singapore are:

- Avian Influenza
- Coronavirus Disease 2019 (COVID-19)
- Salmonellosis (Non-typhoidal)
- Yellow Fever
- Leptospirosis

Singapore also identified ten other zoonotic diseases for close monitoring for One Health collaboration. These diseases are Nipah Virus Disease, Rabies, Japanese Encephalitis, Dengue, Zika, Hantavirus Disease, Campylobacteriosis, Hepatitis E, Severe Acute Respiratory Syndrome (SARS), and Middle Eastern Respiratory Syndrome (MERS).

Table 3. Description of the five priority zoonotic diseases characteristics under each criterion.

The criteria are ordered based on their weights which are indicated in parentheses in the header while the raw scores under each criterion for each disease are indicated in the table.

Prioritized zoonotic disease	**Avian Influenza**
Criteria B (0.32): Epidemic/Pandemic/Epizootic potential (inc. transmission potential)	Raw score: 0.32 Avian influenza A viruses may be transmitted from infected birds to other animals, and potentially to humans, either directly from infected birds or from avian influenza A virus-contaminated environments, or through an intermediate host, such as another animal (Swayne & Brown, 2021). Direct infection can occur from exposure to saliva, mucous, or faeces from infected birds. Although human to human transmission is rare, human infections can occur when enough virus gets into a person's eyes, nose, or mouth, or is inhaled (Centers for Disease Control and Prevention, 2022a). The primary risk factor for avian influenza A infection in humans has been direct contact with live or dead infected poultry. A few cases have resulted from consumption of uncooked poultry products, or close contact with other human cases (Swayne, 2023). Seemingly, an infection by the H5N1 strain can also be caused by the consumption of processed poultry-based foods (e.g., pet food), which resulted in the death of at least one shelter cat in Korea (Yonhap, 2023).
Criteria A (0.31): Disease severity (inc. mortality & morbidity)	Raw score: 0.39 Human infection with influenza A (H5N1) viruses can cause severe disease with high mortality rate (World Health Organization, 2023c). Depending on the strain, the mortality rate varies but it was reported that the case fatality rate for the H5N1 strain that is circulating currently is 56% (World Health Organization, 2023a). With regards to animal-related morbidity and mortality, there have been varied responses with severe mortality (and outbreaks) occurring mostly in aquatic and domesticated poultry species; Highly Pathogenic Avian Influenza (HPAI) infections can cause diseases that affect multiple internal organs with up to 100% mortality in chickens, often within 48 hours. Low pathogenic avian influenza (LPAI) can have less severe morbidity but can mutate into HPAI in poultry (Centers for Disease Control and Prevention, 2022a). More recently, spillover from avian to mammalian species have also been reported in 10 countries across three continents (Kuiken, Fouchier, & Koopmans, 2023), which are synonymous with unusual wild bird die-offs (World Health Organization, 2023c).
Criteria C (0.17): Exposure risk (environmental persistence and likelihood of disease introduction)	Raw score: 0.06 Despite the seemingly low likelihood of incursion into Singapore, there have been reports of HPAI outbreaks within neighbouring countries such as Malaysia and Indonesia, where Singapore sources its poultry products from (Food and Agriculture Organization of the United Nations, 2023a). As a result, people who are in close and repeated contact with infected birds or reside within potentially contaminated environments are at risk at acquiring avian influenza (World Organisation for Animal Health, 2023b). In addition, Singapore is located along the East Asian-Australasian Flyway and Central Asian Flyway which poses a potential risk of disease incursion due to the migratory flight movement of infectious passerine and water birds.

Prioritized zoonotic disease	Avian Influenza
Criteria E (0.14): Socioeconomic impact and food security/safety	Raw score: 0.18 Owing to the susceptibility of poultry to avian influenza, this disease can result in severe disruption to poultry and egg production, especially at the immediate/early phase of the outbreak, with the loss of local shell egg production. It will take time to activate business continuity plans and buffer with alternative sources/supply till recovery of local production (American Veterinary Medical Association, n.d.).
Criteria D (0.08): One Health Collaboration	Raw score: 0.08 More than one agency in Singapore that plans/performs Surveillance, Prevention, and Control.

Prioritized zoonotic disease	Coronavirus Disease 2019 (COVID-19)
Criteria B (0.32): Epidemic/Pandemic/Epizootic potential (inc. transmission potential)	Raw score: 0.42 SARS-CoV-2 is mainly transmitted from human to human and the primary mode of transmission is through the respiratory droplets of infected persons when in close contact, or via contact with surfaces or objects contaminated by the virus (World Health Organisation, 2020). On 11 March 2020, WHO declared COVID-19 a pandemic. As of 27 Aug 2023, there have been 770,085,713 confirmed cases of COVID-19, including 6,956,173 deaths (World Health Organisation, 2023b). In animals, SARS-CoV-2 can be transmitted from an infected animal to another given prolonged close contact. Multiple animal species have tested positive for COVID-19 (e.g., from Canidae, Cebidae, Cercopithecidae, Cervidae, Cricetidae, Felidae, Hominidae, Hyaenidae, Mustelidae, Procionidae, Viverridae, Hippopotamidae families) (Food and Agriculture Organization of the United Nations, 2023b). However, there have been no documented cases of COVID-19 in horses or livestock species, and there is no evidence that humans represent a risk of infection to farm animals (College of Veterinary Medicine, 2021).
Criteria A (0.31): Disease severity (inc. mortality & morbidity)	Raw score: 0.08 There are over 6 million human deaths recorded worldwide (as of 27 Aug 2023) with a case fatality rate of 1.2% in humans (ASEAN BioDiaspora Virtual Center, 2023). Case fatality rate increases by 360 times in those aged 85 and above compared with young adults aged 18 to 29 (Ahmad, Cisewski, Xu, & Anderson, 2023). Severe COVID-19 can manifest as pneumonia, acute respiratory syndrome, and multiple organ dysfunction (Zaim, Chong, Sankaranarayanan, & Harky, 2020). For some, symptoms can persist after COVID-19 recovery and can sometimes result in disability (Centers for Disease Control and Prevention, 2023b). Animal deaths due to COVID-19 have been reported, with some species (i.e., minks) being more vulnerable with high mortality rates of 35–55% (Eckstrand et al., 2021).
Criteria C (0.17): Exposure risk (environmental persistence and likelihood of disease introduction)	Raw score: 0.23 SARS-CoV-2 is highly capable of human transmission, including frequent asymptomatic transmission and amplification through superspreader events. (Centers for Disease Control and Prevention, 2022c). Exposure occurs in three principal ways: (1) inhalation of very fine respiratory droplets and aerosol particles, (2) deposition of respiratory droplets and particles on exposed mucous membranes in the mouth, nose, or eye by direct splashes and sprays, and (3) touching mucous membranes with hands that have been soiled either directly by virus-containing respiratory fluids or indirectly by touching surfaces with virus on them (Centers for Disease Control and Prevention, 2022b).
Criteria E (0.14): Socioeconomic impact and food security/safety	Raw score: 0.11 Border closures, lockdowns, and travel restrictions disrupted Singapore's economy and the social life of Singaporeans (Daly et al., 2021). While the mitigating measures helped to control the SARS-CoV-2 transmission in Singapore, it impacted multiple industries and sectors, including but not limited to public health, construction, tourism, food security, and aviation. In 2020, Singapore's economy shrank by 4.1%, its worst full-year recession since independence (Ministry of Finance, 2022).
Criteria D (0.08): One Health Collaboration	Raw score: 0.08 More than one agency in Singapore that plans/performs Surveillance, Prevention, and Control.

Prioritized zoonotic disease	Salmonellosis (Non-typhoidal)
Criteria B (0.32): Epidemic/Pandemic/Epizootic potential (inc. transmission potential)	Raw score: 0.42 The annual global incidence of non-typhoidal salmonellosis in humans was estimated to be 93.8 million cases (Majowicz et al., 2010). Human to human transmission of salmonellosis can occur particularly through the faecal-oral route, however it is not typically sustained (Centers for Disease Control and Prevention, 2023c). The bacteria are carried asymptomatically in many animals and shed through faeces. It can then be easily transmitted through contaminated food, water, or environment (World Health Organization, 2018). Asymptomatic infections are prevalent in poultry, swine, reptiles, and amphibians, especially where intensive animal husbandry is practiced due to contamination of water and feed by infected rodents and wild birds (Grünberg, 2022).
Criteria A (0.31): Disease severity (inc. mortality & morbidity)	Raw score: 0.08 Non-typhoidal Salmonella infections can range from mild self-limited gastroenteritis to more severe systemic disease, and can affect different systems of the body, with a mean all-age case fatality of 14.5% (Stanaway et al., 2019). Infants had the highest rate of hospitalization and the highest rate of death, while elderly individuals and those with compromised immune systems also had increased rates of severe illness and death. It is estimated that non-typhoidal Salmonella causes 155,000 deaths worldwide each year (Majowicz et al., 2010). Enteric infection can be associated with septicaemia and high mortality rates in young animals, with mortality rates ranging from 17–60%, depending on species (Hoelzer, Moreno Switt, & Wiedmann, 2011).
Criteria C (0.17): Exposure risk (environmental persistence and likelihood of disease introduction)	Raw score: 0.23 *Salmonella* spp. have been found to survive in the environment for a long period of time (~18–20 weeks) due to its ability to produce biofilm (Dantas et al., 2020), and can persist for several months to years depending on the specific strain and environmental conditions (Brandl, 2006). Southeast Asia, with 11 different countries, stands third as a super region for the global burden of Salmonella induced gastroenteritis (Patra, Mohakud, Panda, Sahu, & Suar, 2021).
Criteria E (0.14): Socioeconomic impact and food security/safety	Raw score: 0.07 In Singapore, non-typhoidal salmonellosis is a leading cause of foodborne diseases. Over the decade since the disease had been made notifiable in 2008, the incidence of non-typhoidal salmonellosis has increased. An example of it causing socioeconomic impact in Singapore was when imported eggs from Malaysia were recalled by the Singapore Food Agency (SFA) after it detected the presence of Salmonella enteritidis (Baharudin, 2021).
Criteria D (0.08): One Health Collaboration	Raw score: 0.08 More than one agency in Singapore that plans/performs Surveillance, Prevention, and Control.

Prioritized zoonotic disease	Yellow Fever
Criteria B (0.32): Epidemic/Pandemic/Epizootic potential (inc. transmission potential)	Raw score: 0.32 Yellow fever virus is transmitted to people primarily through the bite of infected Aedes or Haemagogus species mosquitoes. Mosquitoes acquire the virus by feeding on infected (human or non-human) primates and then transmit the virus to other (human or non-human) primates. People infected with yellow fever virus are viraemic shortly before the onset of fever and up to 5 days after onset (Centers for Disease Control and Prevention, 2023d).
Criteria A (0.31): Disease severity (inc. mortality & morbidity)	Raw score: 0.23 As of 2023, 34 countries in Africa and 13 countries in Central and South America are either endemic for or have regions that are endemic for yellow fever (World Health Organization, 2023d). Though most of the infected persons are asymptomatic or have only mild illness, a small proportion of infected persons can develop severe symptoms and half of those with severe symptoms die within seven to ten days (World Health Organization, 2019). Although deaths of non-human primates have been recorded amongst certain non-human primates (e.g., Howler monkeys; Fernandes et al., 2017), animal-related morbidities and/or mortalities associated with this disease has not yet been reported within the region. The estimated case fatality rate for severe cases in humans is 39% (Servadio et al., 2021).

Prioritized zoonotic disease	Yellow Fever
Criteria C (0.17): Exposure risk (environmental persistence and likelihood of disease introduction)	Raw score: 0.11 While Singapore is free from yellow fever, the primary vector for yellow fever transmission, i.e., Aedes aegypti, is one of the most common mosquitoes in Singapore (Tan, Chan, & Lim, 2018) and they are highly competent in transmitting the yellow fever virus of the West-African genotype (Lataillade et al., 2020). As a result, the potential and risk of A. aegypti transmitting the disease to human populations can be high (Lataillade et al., 2020). That said, the susceptibility of the yellow fever virus in Old World non-human primate populations within the Southeast Asian (e.g., long-tailed macaques) region remains understudied.
Criteria E (0.14): Socioeconomic impact and food security/safety	Raw score: 0.11 Food security and safety is not affected because the disease is not known to affect any livestock. Global economic burden of yellow fever in 2019 was 109,000 severe cases and 51,000 deaths per year (Gaythorpe et al., 2021).
Criteria D (0.08): One Health Collaboration	Raw score: 0.08 More than one agency in Singapore that plans/performs Surveillance, Prevention, and Control.

Prioritized zoonotic disease	Leptospirosis
Criteria B (0.32): Epidemic/Pandemic/Epizootic potential (inc. transmission potential)	Raw score: 0.32 Leptospira are maintained in nature through chronic renal infection of carrier animals—commonly rats, dogs, cattle, horses, sheep, goats, and pigs. Human infection occurs through direct contact with the body fluids (except saliva) of the infected animals or indirectly through the environment. However, human to human transmission is rare (Centers for Disease Control and Prevention, 2015a).
Criteria A (0.31): Disease severity (inc. mortality & morbidity)	Raw score: 0.15 Leptospirosis was estimated to cause 1.03 million cases and 58,900 deaths in humans each year (Costa et al., 2015). Overall case fatality rate in humans is estimated to be 1–5% but varies with the form of the disease, the health and age and availability of medical care (Spickler & Leedom Larson, 2013a). The case fatality rate of canine leptospirosis was estimated at 34% in Malaysia (Rahman et al., 2021). Locally, an outbreak in 2016 resulted in the death of 15 dogs in a day-care centre (AVA, 2016) and sporadic cases of leptospirosis are reported annually in Singapore.
Criteria C (0.17): Exposure risk (environmental persistence and likelihood of disease introduction)	Raw score: 0.23 Chronic carriers may shed these leptospira for months or years. Moreover, leptospira spp. are extremely persistent and can survive in water and/or soil for up to 14+ weeks (Bierque, Thibeaux, Girault, Soupé-Gilbert, & Goarant, 2020). *Leptospira* spp. are present in an estimated 42.4% of the rodent population in Singapore (Griffiths et al., 2022).
Criteria E (0.14): Socioeconomic impact and food security/safety	Raw score: 0.04 The global estimated burden of leptospirosis is approximately 2.90 million Disability Adjusted Life Years (DALYs) lost per annum (1.25–4.54) from the approximately 1.03 million annual cases reported previously (Torgerson et al., 2015).
Criteria D (0.08): One Health Collaboration	Raw score: 0.08 More than one agency in Singapore that plans/performs Surveillance, Prevention, and Control.

NEXT STEPS AND ACTION PLANS

Following the finalization of the prioritized zoonotic diseases, participants discussed and developed next steps and action plans to address the priority zoonotic diseases in collaboration with other One Health agencies. A summary of the recommendations was organised into four thematic areas as follows:

Thematic area 1: One Health Coordination and Workforce

Goal:

To promote and enhance synergies between multisectoral and transdisciplinary collaboration, through a One Health approach

Next steps:

- Take stock of existing cross-sectoral global and regional initiatives around One Health, identify gaps and advise on synergies and overlaps, and support coordination. This will be taken in reference to the Quadripartite One Health Joint Plan of Action (OH JPA).
- Form, where necessary, technical work groups and project teams to develop action plans to prevent the risk of potential outbreaks of the priority diseases.
- Table the work group updates and resourcing needs at the One Health Directorate level meetings

Photo 11: Identifying key areas for multisectoral and transdisciplinary collaboration around One Health with reference to the six action tracks from the Quadripartite One Health Joint Plan of Action (OH JPA) (FAO, UNEP, WHO & WOAH, 2022).

Thematic area 2: Communications and Outreach

Goal:

To increase public awareness of One Health

Next steps:

- Organize scientific symposiums/seminars on One Health
- Push out public communications on One Health (e.g., on World One Health Day)
- Enhance awareness of the One Health Approach among the public

Thematic area 3: Preparedness and Response Planning

Goal:

To strengthen One Health collaboration and response

Next steps:

- Establish a One Health network of contacts for alert and activation of response measures
- Review existing One Health response framework and table-top exercises (TTXs), and identify gaps
- Develop and strengthen existing One Health preparedness and response framework (i.e., involvement of more agencies)
- Plan and conduct joint One Health TTX for priority diseases identified during the workshop
- Capability development (e.g., joint training, Field Epidemiology Training Programme)

Thematic area 4: Laboratory and Surveillance Capacity and Capabilities

Goal:

To develop a framework for joint-surveillance and identify the capabilities of various agencies to better plan for joint surveillance

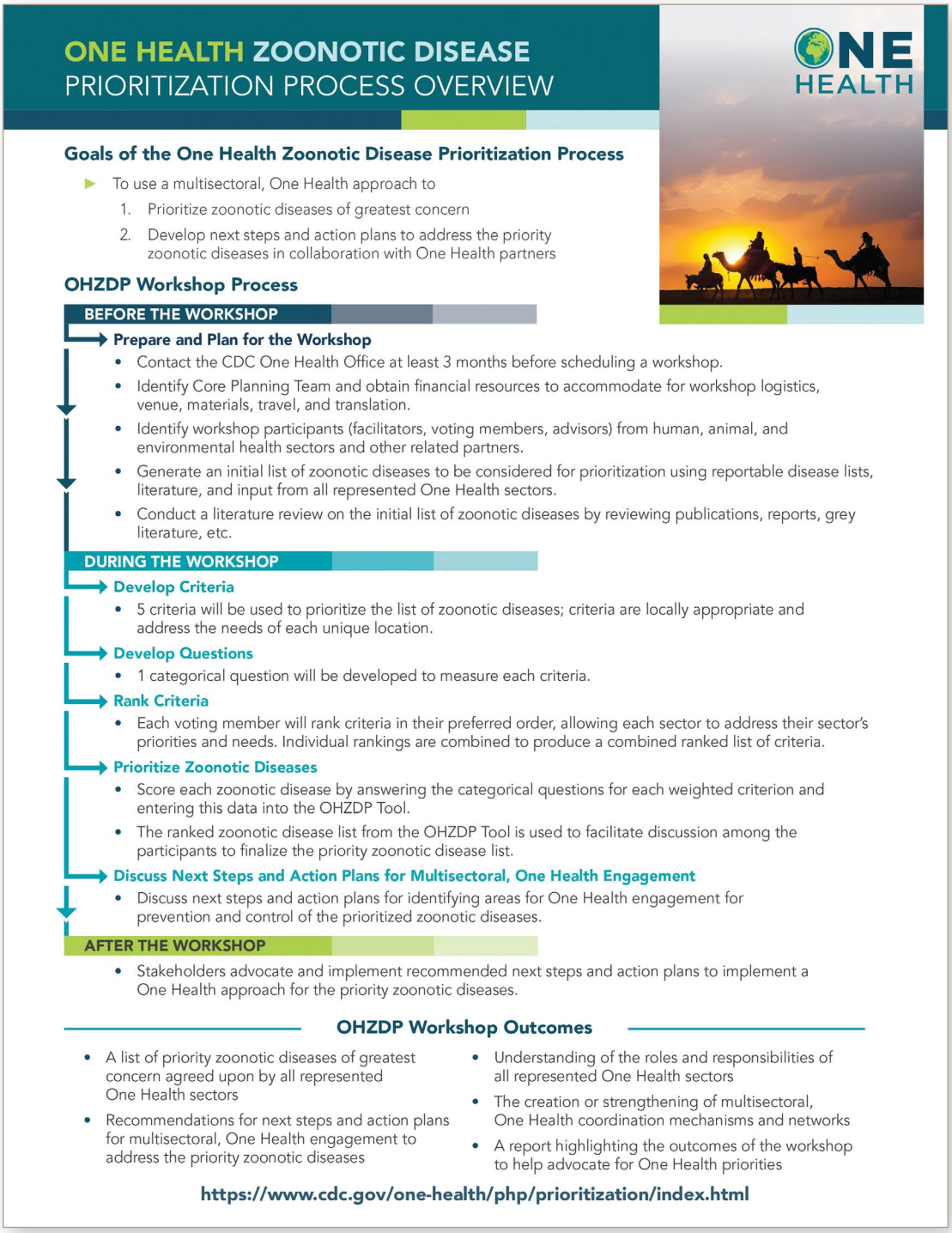
Next steps:

- Stock-take, identify gaps, and review joint-surveillance capacity and capabilities
- Stock-take, identify gaps, and review existing platforms/mechanisms/protocols (if any) for data sharing across the agencies
- Develop frameworks (if lacking) and strengthen existing joint-surveillance capacity and capabilities in (1) field surveillance, and (2) horizon scanning
- Conduct gap or resource analysis to identify, review and update the existing list of diseases that each agency is working on, and determine the purpose for existing disease monitoring programmes

In summary, through a multisectoral, One Health collaborative effort, Singapore has identified a priority list of zoonotic diseases for Singapore and developed next steps and action plans to address these zoonotic diseases. This enables the alignment of One Health agencies to collaborate and manage the zoonotic disease threats more effectively, as well as enhancing existing national health programmes for humans and animals in Singapore.

APPENDIX A: Overview of the One Health Zoonotic Disease Prioritization Process

U.S. Centers for Disease Control and Prevention: Overview of the One Health Zoonotic Disease Prioritization Workshop https://www.cdc.gov/one-health/php/prioritization/



ONE HEALTH ZOONOTIC DISEASE PRIORITIZATION PROCESS OVERVIEW

Goals of the One Health Zoonotic Disease Prioritization Process

- To use a multisectoral, One Health approach to
  1. Prioritize zoonotic diseases of greatest concern
  2. Develop next steps and action plans to address the priority zoonotic diseases in collaboration with One Health partners

OHZDP Workshop Process

BEFORE THE WORKSHOP

Prepare and Plan for the Workshop

- Contact the CDC One Health Office at least 3 months before scheduling a workshop.
- Identify Core Planning Team and obtain financial resources to accommodate for workshop logistics, venue, materials, travel, and translation.
- Identify workshop participants (facilitators, voting members, advisors) from human, animal, and environmental health sectors and other related partners.
- Generate an initial list of zoonotic diseases to be considered for prioritization using reportable disease lists, literature, and input from all represented One Health sectors.
- Conduct a literature review on the initial list of zoonotic diseases by reviewing publications, reports, grey literature, etc.

DURING THE WORKSHOP

Develop Criteria

- 5 criteria will be used to prioritize the list of zoonotic diseases; criteria are locally appropriate and address the needs of each unique location.

Develop Questions

- 1 categorical question will be developed to measure each criteria.

Rank Criteria

- Each voting member will rank criteria in their preferred order, allowing each sector to address their sector's priorities and needs. Individual rankings are combined to produce a combined ranked list of criteria.

Prioritize Zoonotic Diseases

- Score each zoonotic disease by answering the categorical questions for each weighted criterion and entering this data into the OHZDP Tool.
- The ranked zoonotic disease list from the OHZDP Tool is used to facilitate discussion among the participants to finalize the priority zoonotic disease list.

Discuss Next Steps and Action Plans for Multisectoral, One Health Engagement

- Discuss next steps and action plans for identifying areas for One Health engagement for prevention and control of the prioritized zoonotic diseases.

AFTER THE WORKSHOP

- Stakeholders advocate and implement recommended next steps and action plans to implement a One Health approach for the priority zoonotic diseases.

OHZDP Workshop Outcomes

- A list of priority zoonotic diseases of greatest concern agreed upon by all represented One Health sectors
- Recommendations for next steps and action plans for multisectoral, One Health engagement to address the priority zoonotic diseases
- Understanding of the roles and responsibilities of all represented One Health sectors
- The creation or strengthening of multisectoral, One Health coordination mechanisms and networks
- A report highlighting the outcomes of the workshop to help advocate for One Health priorities

https://www.cdc.gov/one-health/php/prioritization/index.html

APPENDIX B: Ranked Zoonotic Disease List in Singapore from the One Health Zoonotic Prioritization Tool

Finalized list of the 49 zoonotic diseases and their normalised rank (rounded).

Note: The five prioritized zoonotic diseases identified for One Health collaboration during the workshop are bolded while the other zoonotic diseases of importance to be monitored closely are indicated with an asterisk(*).

List	Zoonotic disease name	Etiological agent	Normalised rank
1	*Nipah	Nipah henipavirus (NiV)	1.000
2	**Avian Influenza**	**Influenza A Virus**	**0.999**
3	Mpox	Orthopoxviruses (OPV): Monkeypox virus	0.926
4	**Coronavirus Disease 2019 (COVID-19)**	**SARS-CoV-2**	**0.899**
5	*Rabies	Lyssaviruses	0.896
6	**Salmonellosis (Non typhoidal)**	***Salmonella* spp.**	**0.865**
7	*Campylobacteriosis	*Campylobacter jejuni* and *C. coli*	0.845
8	Listeriosis	*Listeria monocytogenes*	0.844
9	Plague	*Yersinia pestis*	0.841
10	**Yellow Fever**	***Flavivirus* spp.**	**0.835**
11	*Hepatitis E	Hepatitis E virus	0.825
12	*Japanese Encephalitis (JE)	Japanese Encephalitis Virus	0.822
13	Anthrax	*Bacillus anthracis*	0.820
14	Vibriosis	*Vibrio parahaemolyticus, V. vulnificus*, and *V. alginolyticus*	0.809
15	**Leptospirosis**	***Leptospira* spp.**	**0.802**
16	*Hantavirus Disease	Hantaviruses (e.g., Saaremaa virus, Hantaan virus, Seoul virus, Puumala virus, Dobrava virus)	0.802
17	Group B Streptococcus	Group B Streptococcus	0.796
18	Toxoplasmosis	*Toxoplasma gondii*	0.774
19	Brucellosis	*Brucella* spp. (*Brucella canis, B. arbortus, B. suis,* and *B. melitensis*)	0.760
20	Melioidosis	*Burkholderia pseudomallei* (Gram negative bacillus)	0.754
21	West Nile Fever	West Nile Virus	0.745
22	Zoonotic Malaria	*Plasmodium knowlesi*, *P. cynomolgi*, *P. inui, P. fieldi*, and *P. coatney*	0.734
23	*Dengue Fever	Dengue Virus	0.726
24	*Zika Fever	Zika Virus	0.725
25	Bovine spongiform Encephalopathy	Prions	0.716
26	Zoonotic Tuberculosis	*Mycobacterium bovis*	0.705
27	Pathogenic E. coli	*Escherichia coli* O157 (EHEC); ETEC, EPEC, EAEC, EIEC, DAEC, VTEC	0.705
28	Shigellosis	*Shigella* spp.	0.705

List	Zoonotic disease name	Etiological agent	Normalised rank
29	*Middle East Respiratory Syndrome (MERS)	MERS-CoV	0.704
30	Chlamydia	*Chlamydia psittaci*	0.686
31	Chikungunya	Chikungunya virus	0.678
32	Newcastle Disease	Avian Paramyxovirus Type 1 (APMV-1), also known as Newcastle Disease Virus (NDV)	0.677
33	Cryptosporidiosis	*Cryptosporidium* spp.	0.670
34	Marburg Virus Disease	Marburg virus	0.670
35	Cysticercosis	Tapeworms (Taenia spp.)	0.665
36	Simian B virus infection	Herpesvirus simiae (B virus)	0.657
37	*Severe Acute Respiratory Syndrome (SARS)	SARS-CoV-1	0.656
38	Trypanosomiasis	*Trypanosoma* spp.	0.650
39	Lassa Fever	Lassa virus	0.650
40	Crimean-congo haemorrhagic fever	Arboviruses belonging to the genus Orthonairovirus in the family Nairoviridae	0.650
41	Murine Typhus	*Rickettsia typhi*	0.630
42	Q fever	*Coxiella burnetii*	0.609
43	Ebola	Ebolavirus	0.606
44	Trichinellosis	Nematodes (roundworms) of the genus *Trichinella*	0.593
45	Leishmaniasis	*Leishmania* spp.	0.546
46	Lyme Disease	*Borrelia* spp.	0.498
47	Charpare haemorrhagic fever (CHHF)	Charpare virus	0.442
48	Lujo Haemorrhagic Fever	Lujo virus	0.442
49	Yersiniosis	*Yersinia enterocolitica*	0.429

APPENDIX C: Criteria and Questions Utilized to Determine the Ranked Outcomes of the One Health Zoonotic Disease Prioritization Process in Singapore

Criteria A. Disease severity (inc. mortality & morbidity)

Question: How severe is the zoonotic disease? (Add up points in both columns as follows)?

Human population	Animal population
High mortality AND high morbidity = 3 points	High mortality AND high morbidity = 3 points
Low mortality AND high morbidity = 2 points High mortality AND low morbidity = 2 points	Low mortality AND high morbidity = 2 points High mortality AND low morbidity = 2 points
Low mortality AND low morbidity = 1 point	Low mortality AND low morbidity = 1 point

Answers:

Human population	Animal population
High mortality AND high morbidity = 3 points	High mortality AND high morbidity = 3 points
Low mortality AND high morbidity = 2 points High mortality AND low morbidity = 2 points	Low mortality AND high morbidity = 2 points High mortality AND low morbidity = 2 points
Low mortality AND low morbidity = 1 point	Low mortality AND low morbidity = 1 point

Assumptions: Mortality and morbidity is observed in spite of readily available vaccines/treatments; worst case scenario was considered

Definitions:

Human population	Animal population
High mortality = case fatality >5%	High mortality = case fatality >3%
High morbidity = >5% ICU admission OR significant long term sequelae (e.g. birth defects, amputation)	High morbidity = >3% animals infected were sick enough to require treatment OR euthanasia

Criteria B. Epidemic/pandemic/epizootic potential (inc. transmission potential)

Question: What is the location, recency, and type of outbreak/ epidemic/ epizootic for the zoonotic disease?

Answers:

- ☐ 9 points (4)
- ☐ 7–8 points (3)
- ☐ 5–6 points (2)
- ☐ 3–4 points (1)

Assumptions:

- *Singapore's definition of outbreak for the disease. If unavailable, refer to global definition or subject-matter-experts' opinion.*
- *Defaults to the highest score in each category.*

Definitions:

Scoring matrix	3 points	2 points	1 point
Location	Singapore	Asia	Rest of the world
Human recency	< 1 year or endemic	1 to 10 years	> 10 years
Animal recency	< 1 year or endemic	1 to 10 years	> 10 years

Criteria C. Exposure risk (environmental persistence and likelihood of disease introduction)

Question:

a) Is the infectious agent/pathogen currently present in Singapore? AND
b) Can there be sustained community transmission?

Answers:

- ☐ *(a) Yes + (b) Yes (4)*
- ☐ *(a) Yes + (b) No (3)*
- ☐ *(a) No + (b) Yes (2)*
- ☐ *(a) No + (b) No (1)*

Assumptions/Definitions:

(a) Accounts for existing prevention and control; Present and transmission in humans, animals, or environment (i.e. non-experimental/laboratory settings).

(b) Community transmission through humans or vectors or food-borne or environment.

Criteria D. Socio-economic impact and food security/safety

Question: Does the zoonotic disease impact the following key sectors?

- **Economy**
- **Food security**
- **Food safety**
- **Social/cultural**
- **Biodiversity**

Answers:

- ☐ All of the above (5)
- ☐ 4 sectors (4)
- ☐ 3 sectors (3)
- ☐ 1–2 sectors (2)
- ☐ None (1)

Assumptions/Definitions:

- *Economy: trade and tourism*
- *Food security: availability, accessibility, and affordability*
- *Food safety: does the disease cause food-borne illnesses?*
- *Social/cultural: movement, public acceptance, and public response*
- *Biodiversity: wildlife impact*

Criteria E. One Health Collaboration

Question: Is there more than one agency in Singapore that plans for and/or performs these activities for the zoonotic disease?

- **Surveillance**
- **Prevention**
- **Control**

Answers:

- ☐ None (1)
- ☐ 1 out of 3 (2)
- ☐ 2 out of 3 (3)
- ☐ 3 out of 3 (4)

Assumptions/Definitions:

- *Agencies include the One Health agencies: MOH, NEA, NParks, SFA, and PUB.*
- *Surveillance includes event-based, indicator-based, and lab-based surveillance.*
- *Prevention includes vaccine and non-pharmaceutical interventions, quarantine, etc.*
- *Control includes medical interventions, environmental sanitation, vector control, addressing social determinants (e.g., education and campaigns), good hygiene practices, contingency plans, etc.*

Photo 12. Arial view of Singapore Marina.

APPENDIX D: One Health Zoonotic Disease Prioritization Workshop Participants for Singapore

Core Planning Team

Name	Agencies/Ministries	Designation
Mr Sylvester Lee	Ministry of Health (MOH)	Senior Public Health Officer (Surveillance, Epidemiology & Response), Communicable Diseases Division
Dr Chua Hui Zi	Ministry of Health (MOH)	Public Health Officer (Surveillance, Epidemiology & Response), Communicable Diseases Division
Ms Toh Yi Shuen, Abigail	Ministry of Health (MOH)	Public Health Officer (Public Health Intelligence), Epidemiology & Disease Control Division
Ms Diong Hui Yee	Ministry of Health (MOH)	Public Health Officer, Communicable Diseases Policy & Preparedness Office
Mr Pang Hao Yang	National Environment Agency (NEA)	Senior Research Officer, Environmental Epidemiology & Toxicology Division, Environmental Health Institute
Mr Ding Huicong	National Environment Agency (NEA)	Research Officer, Vector Biology & Control Division, Environmental Health Institute
Ms Germaine Ng	National Environment Agency (NEA)	Research Officer, Vector Biology & Control Division, Environmental Health Institute
Ms Hillary Yee	National Environment Agency (NEA)	Senior Research Officer, Vector Biology & Control Division, Environmental Health Institute
Dr Kelvin Lim	National Parks Board (NParks)	Director, Biorisk and Biosurveillance; and Director, Science and Technology Planning
Ms Wendy Sng	National Parks Board (NParks)	Deputy Director, Biorisk and Biosurveillance
Dr Kelvin Ho	National Parks Board (NParks)	Deputy Director, Biorisk and Biosurveillance; and Deputy Director, Science and Technology Planning
Dr Lim Hwee Ping	National Parks Board (NParks)	Senior Veterinarian, Biorisk and Biosurveillance
Dr Heng Zhan Pei	National Parks Board (NParks)	Senior Veterinarian, Biorisk and Biosurveillance
Dr Lim Bock Hing Rayson	National Parks Board (NParks)	Senior Scientist, Biorisk and Biosurveillance
Dr Cai Panqin	Singapore Food Agency (SFA)	Deputy Director, Regulatory Standards & Veterinary Office
Ms Lina Sabrina	Singapore Food Agency (SFA)	Manager, Regulatory Standards & Veterinary Office
Dr Elaine Quek	PUB, Singapore (PUB)	Deputy Director, Water Quality Department
Dr Chen Xiu Ling	PUB, Singapore (PUB)	Senior Biologist, Water Quality Department
Ms Grace Goryoka	U.S. Centers for Disease Control and Prevention (CDC)	Public Health Advisor, One Health Office
Ms Hayley Belles	U.S. Centers for Disease Control and Prevention (CDC)	Health Scientist, One Health Office
Dr Italo Zecca	U.S. Centers for Disease Control and Prevention (CDC)	Epidemiologist, One Health Office

Voting Members

Name	Agencies/Ministries	Designation
Dr Chua Tze Hoong	National Parks Board (NParks)	Group Director, Veterinary Health
Dr Chang Siow Foong	National Parks Board (NParks)	Group Director, Professional & Scientific Services; and Group Director, Community Animal Management
Dr Wilson Tan	National Environment Agency (NEA)	Director, Vector Biology & Control Division, Environmental Health Institute
Dr Judith Wong	National Environment Agency (NEA)	Director, Microbiology and Molecular Epidemiology Division, Environmental Health Institute
Dr Astrid Yeo	Singapore Food Agency (SFA)	Senior Director, Regulatory Standards & Veterinary Office
Dr Leong Hon Keong	Singapore Food Agency (SFA)	Senior Advisor, CEO Office
Prof. Vernon Lee	Ministry of Health (MOH)	Senior Director, Communicable Diseases Division
A/P Jeffery Cutter	Ministry of Health (MOH)	Senior Consultant, Public Health Group
Dr Sarah Teng	PUB, Singapore (PUB)	Director, Water Quality Department
Dr Chang Siao Yun	PUB, Singapore (PUB)	Senior Assistant Director, Quality Assurance and Inspectorate, Water Quality Department

External Advisors

Name	Agencies/Ministries	Designation
A/P Alex Cook	Saw Swee Hock School of Public Health—NUS (SSHSPH-NUS)	Vice Dean (Research)
Dr Cheng Wen Haur	Mandai Wildlife Group (MWG)	Deputy CEO and Chief Life Sciences Officer
A/P Hsu Li Yang	Saw Swee Hock School of Public Health—NUS (SSHSPH-NUS)	Vice Dean, Global Health & Programme Leader of Infectious Diseases
Dr Nancy Tee	National University Hospital & National Public Health Laboratory	Senior Consultant, Department of Laboratory Medicine
A/P Karina Gin	Department of Civil and Environmental Engineering—NUS (CDE-NUS)	Deputy Head (Research)
Prof. Gavin Smith	Duke-NUS Medical School	Programme Director, Emerging Infectious Diseases Programme
Prof. Stefan Wuertz	Singapore Centre for Environmental Life Sciences Engineering—Nanyang Technological University	Research Director for Environmental Engineering

Internal Advisors

Name	Agencies/Ministries	Designation
Ms Lalitha Kurupatham	Ministry of Health (MOH)	Deputy Director (Surveillance & Response), Communicable Diseases Division
Dr Sim Shuzhen	National Environment Agency (NEA)	Director, Environmental Epidemiology & Toxicology Division, Environmental Health Institute
Dr Chong Chee Seng	National Environment Agency (NEA)	Deputy Director, Vector Biology & Control Division, Environmental Health Institute
Dr Chanditha Hapuarachchi	National Environment Agency (NEA)	Principal Scientist, Microbiology and Molecular Epidemiology Division, Environmental Health Institute
Dr Setoh Yin Xiang	National Environment Agency (NEA)	Senior Scientist, Microbiology and Molecular Epidemiology Division, Environmental Health Institute
Dr Sophie Octavia	National Environment Agency (NEA)	Senior Scientist, Microbiology and Molecular Epidemiology Division, Environmental Health Institute
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Dr Charlene Judith Fernandez	National Parks Board (NParks)	Director, Centre for Animal & Veterinary Sciences
Dr Kelvin Lim	National Parks Board (NParks)	Director, Biorisk and Biosurveillance; and Director, Science and Technology Planning
Ms Wendy Sng	National Parks Board (NParks)	Deputy Director, Biorisk and Biosurveillance
Dr Jan Yong	National Parks Board (NParks)	Deputy Director, Animal & Veterinary Programme Office
Dr Ong Jie Ying	PUB, Singapore (PUB)	Senior Microbiologist, Water Quality Department
Dr Cheong Wan Shoo	PUB, Singapore (PUB)	Assistant Director, Water Quality Department
A/P Aung Kyaw Thu	Singapore Food Agency (SFA)	Branch Head, National Centre for Food Science, Exposure & Data Science
Dr Lim Yen Ching	Singapore Food Agency (SFA)	Senior Scientist, National Centre for Food Science, Exposure & Data Science
Mr Edward Lee	Singapore Food Agency (SFA)	Senior Scientist, National Centre for Food Science
Dr Stacy Khaw	Singapore Food Agency (SFA)	Manager, Livestock & Food Fish Farms Team

Observers/Particpants

Name	Agencies/Ministries	Designation
Mr Pream Raj	Ministry of Health (MOH)	Senior Assistant Director (Surveillance Epidemiology & Response), Communicable Diseases Division
Ms Poh Cuiqin	Ministry of Health (MOH)	Assistant Director (Surveillance Epidemiology & Response), Communicable Diseases Division
Ms Georgina Lim	Ministry of Health (MOH)	Assistant Director, Communicable Disease Policy & Preparedness Office
Mr Chan Guanhao	Ministry of Health (MOH)	Senior Public Health Officer, Epidemiology & Disease Control
Dr Diana Chee	National Parks Board (NParks)	Director, Animal & Veterinary Programme Office
Dr Ian Liang	National Parks Board (NParks)	Veterinarian, Centre for Animal Rehabilitation
Dr Brian Tan	National Parks Board (NParks)	Deputy Director, Centre for Animal & Veterinary Sciences
Dr Lin Anhui	National Parks Board (NParks)	Acting Director, Animal Population Management
Mr Joshua Teoh	National Parks Board (NParks)	Director, Investigations & Community Animal Management Operations
Mr Poh Yew Kwang	National Parks Board (NParks)	Director, Compliance Management
Mr Wang Ming Yuan	National Parks Board (NParks)	Director, Licensing
Dr Anna Wong	National Parks Board (NParks)	Director, Wildlife Trade
Mr How Choon Beng	National Parks Board (NParks)	Director, Wildlife Management & Outreach
Ms Yang Shufen	National Parks Board (NParks)	Director, Sungei Buloh
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Photo 13. A golden-backed weaver (*Ploceus jacksoni*) builds a nest in Singapore.

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Photo 14. Stork Billed Kingfisher (*Pelargopsis capensis*) in a tropical garden in Singapore.

Photo 15. Crab-eating macaques (*Macaca fascicularis*) sitting on a rock in a wooded area of Singapore.

http://www.cdc.gov/onehealth