Wild animal and zoonotic disease risk management and regulation in China: Examining gaps and One Health opportunities in scope, mandates, and monitoring systems

Hongying Li\textsuperscript{a,d}, Yufei Chen\textsuperscript{b}, Catherine C. Machalaba\textsuperscript{a}, Hao Tang\textsuperscript{c}, Aleksei A. Chmura\textsuperscript{a}, Mark D. Fielder\textsuperscript{d}, Peter Daszak\textsuperscript{a,*}

\textsuperscript{a} EcoHealth Alliance, New York, NY, United States of America
\textsuperscript{b} School of Veterinary Science, Massey University, Palmerston North, New Zealand
\textsuperscript{c} School of Veterinary Medicine, College of Science, Health, Engineering and Education, Murdoch University, Murdoch, WA, Australia
\textsuperscript{d} School of Life Sciences, Faculty of Science, Engineering and Computing, Kingston University, London, United Kingdom

\begin{abstract}
Emerging diseases of zoonotic origin such as COVID-19 are a continuing public health threat in China that lead to a significant socioeconomic burden. This study reviewed the current laws and regulations, government reports and policy documents, and existing literature on zoonotic disease preparedness and prevention across the forestry, agriculture, and public health authorities in China, to articulate the current landscape of potential risks, existing mandates, and gaps. A total of 55 known zoonotic diseases (59 pathogens) are routinely monitored under a multi-sectoral system among humans and domestic and wild animals in China. These diseases have been detected in wild mammals, birds, reptiles, amphibians, and fish or other aquatic animals, the majority of which are transmitted between humans and animals via direct or indirect contact and vectors. However, this current monitoring system covers a limited scope of disease threats and animal host species, warranting expanded review for sources of disease and pathogen with zoonotic potential. In addition, the governance of wild animal protection and utilization and limited knowledge about wild animal trade value chains present challenges for zoonotic disease risk assessment and monitoring, and affect the completeness of mandates and enforcement. A coordinated and collaborative mechanism among different departments is required for the effective monitoring and management of disease emergence and transmission risks in the animal value chains. Moreover, pathogen surveillance among wild animal hosts and human populations outside of the routine monitoring system will fill the data gaps and improve our understanding of future emerging zoonotic threats to achieve disease prevention. The findings and recommendations will advance One Health collaboration across government and non-government stakeholders to optimize monitoring and surveillance, risk management, and emergency responses to known and novel zoonotic threats, and support COVID-19 recovery efforts.
\end{abstract}

1. Introduction

1.1. Impacts of emerging and re-emerging zoonotic diseases

Zoonotic diseases have been featured throughout human history, accounting for more than 60% of the known human infectious diseases, and are associated with environmental conditions and human activities interacting with animals. A review reported that approximately 70% of the emerging zoonotic disease events detected during 1940–2006 were originated from wild animals [1]. In China, a number of infectious diseases known or strongly suspected to have zoonotic origins have emerged or re-emerged over the past two decades, leading to local outbreaks and pandemics [2]. These include Severe Acute Respiratory Syndrome (SARS), Highly Pathogenic Avian Influenza (HPAI) H5N1, H7N9 Influenza, and Coronavirus disease 2019 (COVID-19) as a significant threat to the health security in China and elsewhere in the world [3–8].

The impacts of emerging zoonotic diseases extend far beyond disease burden, with demonstrated socioeconomic consequences for multiple sectors at the country, regional, and global levels when the diseases...
spread through international travel [9,10]. As a result of the country-wide lockdown for COVID-19, China's gross domestic product (GDP) in the first quarter of 2020 decreased by 6.8% as compared with the first quarter of 2019, being the first reported economic constriction in China since 1976 [11]. The predicted impact of COVID-19 on the global travel and tourism sector is approximately 100.8 million job losses and a loss of $2.7 trillion contributing to global GDP in 2020 [12]. Many other indirect impacts from COVID-19 on the environment, such as illegal poaching or deforestation, and on human populations including education and psychological effects, have been reported, although they are seldom evaluated in economic terms [13,14].

1.2. Utilization of wild animals as a key risk pathway

As the impacts are multi-sectoral, the proactive management of disease threats will require new approaches for governments, communities, and the private sector to identify and address the key risk pathways. Among many of the human activities driving emerging zoonotic infections, utilization of wild animals for commercial trade, farming, and captivity in China represents the most direct interface and a systematic pattern of interactions between human and wild animal, posing a significant risk of zoonotic spillover from wild animal to domestic animal and human [15–17]. While the connections between wild animals in markets and the initial outbreaks of SARS and COVID-19 are still under active scientific research, the animal origin of SARS-CoV-1 and SARS-CoV-2 and the presence of live animals in the local markets that were linked to early human cases further emphasize the need to assess the disease risk in wild animal utilization practices [18–20]. Therefore, understanding existing policies, mandates, and systems around these at-risk activities in China is essential to characterize the risk pathway, assess zoonotic risk, identify key stakeholders, and develop mitigation strategies.

To strengthen prevention and preparedness measures, many countries are currently examining enhancements to their regulations, institutional mandates, and operations [21]. Given China's importance as a consumer and producer of wild animal products and the fact that it possesses a rapid development trajectory with increasing investment in agriculture and forestry, and being a world leader in emerging zoonotic disease research, we review current systems in place for zoonotic disease monitoring in humans and animals in China; analyze the species coverage against known zoonotic disease sources; present areas of focus for further attention. The prevention and preparedness measures for zoonotic diseases vary in different situations, this article primarily focuses on the systems in place to regulate at-risk human-animal interactions in wild animal trade and captive-breeding relevant to forestry, agriculture, and public health sectors.

2. Review methods and data

This study reviewed the current laws and regulations, government reports and policy documents, and existing literature on zoonotic disease preparedness and prevention across the forestry, agriculture, and public health authorities in China to identify areas of coverage and gaps. Specifically, we reviewed: i) Relevant policies implemented at the national level in response to COVID-19 in China; ii) China's wild animal management and governance structure; and iii) China's zoonotic disease management system. Information was sourced from government reports and websites and peer-reviewed literature, using a One Health lens to provide an overview of the current systems related to the assessment, monitoring, and management of zoonotic diseases and disease emergence risks (Supplementary Material I).

3. Results

3.1. Collaboration across sectors for management of COVID-19

The initial response to, and control of, COVID-19 in China illustrated a collaborative effort of multiple authorities (Fig. 1). In addition to the work of public health and human medicine, six departments, agriculture, forestry, market regulation, public security, customs, and transport, were involved in the regulation of the value chain and activities for wild animal trade [22–28]. A decision was made by the Standing Committee of the National People's Congress in February 2020 to prohibit wild animal consumption [29], followed by the amendment of the National Catalogue of Livestock and Poultry Genetic Resources by the agriculture department to define the legality of which animals can be consumed [30]. Moreover, the Animal Epidemic Prevention Law has been amended and released on January 23, 2021 [31], and the national list of endangered and protected species has been revised in February 2021 with additional 517 species added to the list [32]. These actions simultaneously highlighted existing gaps and fragmentation in the governance of zoonotic disease risk at the human-animal interfaces, which requires considerable coordination and communication to ensure cohesive and effective management among different sectors.

3.2. Wild animal management and governance structure

3.2.1. Governance of wild animal protection

The Wild Animal Protection Law (WAPL) was enacted in 1988 as the major state law to protect wild animals in China. A list of endangered and protected species was formulated in accordance with the provisions [33]. The WAPL is enforced by both the forestry and fisheries departments, which oversee the terrestrial and aquatic wild animals, respectively, according to the administrative regulations on the protection of terrestrial and aquatic wild animals. Similarly, the capture and breeding of wild terrestrial and aquatic animals are under separate management by the forestry and fisheries departments, respectively, with developed lists of captive-bred endangered and protected terrestrial and aquatic wild animals [34–36] and established technical standards and normative documents for farming activities. Moreover, a list of state-protected terrestrial wild animals with important ecological, scientific, and social values (3-Value) [37] has been formulated by the forestry department, which places under protection species that are not already covered by the list of endangered and protected species. Joint efforts are exerted by other government authorities of environment and ecology, development and reform, customs, and additional laws to protect endangered wild animals from being hunted (stated in the Criminal Law) and manage the access of wild animals or animal products to the market (provided by the Administrative License Law) (Supplementary Materials II). (Fig. 2).

3.2.2. Management of wild animal utilization

With decades of practice, the wild animal industry in China has developed to meet the local and global demand for animal products (e.g. fur), medicines, pets, food, and research. Approximately 2371 animal species or subspecies are documented as medicinal animals in the Annals of Chinese Medicinal Animals [38]; 18 animal species are listed as Class I or Class II wild medicinal species under state protection [39]; and 103 animal species are included in the Pharmacopoeia of the People's Republic of China (2010 version) [40,41]. Wild animal farming, product processing, trade, and tourism have significantly contributed to the national economy, particularly for the economic development of rural areas, generating more than $75 billion in economic output and providing employment for 14 million people in 2016 [42]. It is challenging to estimate the volume of captive and traded wild animals in China, owing to a lack of centralized tracking. Existing data from the literature show that there were at least 517 mammal, reptile, amphibian, and bird species from 114 families belonging to 33 orders being traded...
or kept in captivity for commercial purposes during 1996–2017 (Supplementary Materials III). These numbers reveal only the tip of the iceberg of wild animal utilization in China without including aquatic animals and other animals for which data are insufficient.

Managing the utilization of wild animals in relation to the practices of hunting, farming, processing, transport, and sale in local markets is the responsibility of multiple departments (Fig. 3). Even though there are a series of checks and barriers, most wild animals can enter the value chain with appropriate permits regardless of their protection status [43]. Wild animals or their products can reach consumers directly from the wild or farms, or most commonly through a wholesale or retail point. Quarantine is required for transporting and trading wild animals at markets, but the procedures are insufficiently enforced, compounded by the involvement of multiple stakeholders including middlemen, processors, and abattoirs in the value chain [44]. Additionally, international value chains have been established to meet global demand. For example, China produced roughly 50% of the world's fur pelts in 2014 [45], farms in China are the leading suppliers of non-human primates.
and reduction among wild animals. Overlapping or separate management by the forestry and agriculture departments undermines the responsibility and accountability in enforcement, neglecting the management of many reptile and amphibian species [48, 51]. The same situation is true for animal species that are not clearly defined as domestic or wild due to the long captive-breeding histories (e.g., deer, mink, and fox), leading to ambiguities in the management between the forestry and agriculture departments [44]. Amendments have been made to the relevant laws in China as the initial step to address these challenges in the management system [30, 52, 53], but incorporating these changes into the disease monitoring system among wild animals requires more enabling mechanisms and coordination of mandates.

3.2.5. Understanding the wild animal trade value chains

Limited understanding of the wild animal trade value chains (Fig. 3) in China is one of the greatest challenges in the risk assessment of zoonotic transmission and disease emergence at the wild-life–livestock–human interface, particularly in the peri-domestic or domestic setting. There are few published studies documenting the value chains of farming and trading wild animals, and as a result, very little is known about how wild animals are produced and traded or their interactions with domestic animals and humans before reaching consumers, or which populations are involved along the value chains and how they operate and interact with wild-sourced stock, which is further compounded by the vague definitions of “wild animal” and “farmed wild animal” in Chinese regulations across different authorities [54]. Given the high volume of wild animal farming and consumption in China, such information will be important for understanding the epidemiological, economic, and social aspects of zoonotic disease transmission risks. A solid understanding of wild animal trade value chains not only allows for the evaluation of potential pathogen transmission pathways and critical control points in risk assessment but also helps to form practical risk mitigation measures that are viewed as economically viable and socially acceptable by stakeholders.

3.3. Zoonotic disease management system

3.3.1. Cross-sectoral management of zoonotic disease in human, domestic and wild animal

Zoonotic diseases in China have been primarily monitored and regulated by the human health and veterinary departments. A list of notifiable human infectious diseases has been established for monitoring and reporting under the Law of Prevention and Treatment of Infectious Diseases [55]. Similarly, the veterinary department under the Ministry of Agriculture and Rural Affairs has developed a list of animal epidemic diseases for regular monitoring and reporting, and measures for the administration, investigation, evaluation, and contingency plans of animal epidemics [56–64]. Technical guidance or standard documents for specific animal epidemics are also developed and distributed by the veterinary department on a regular basis [65, 66]. In 2009, the Health and Agriculture Ministries collaboratively issued a list of zoonotic infectious diseases [67, 68]. These schemes together serve as part of the national emergency response system.

A wild animal epidemic and epidemic source monitoring center was founded under the forestry department in 2005. It has developed into a wide network that consists of national (305), provincial (918), and city/county-level monitoring stations, and 2000 institutions for an online reporting system [69]. This system is centered around terrestrial wild animals, while disease monitoring for aquatic animals is implemented by the agriculture department. In 2013, the administrative measures for monitoring and controlling epidemics and epidemic sources for terrestrial wild animals was enacted by the forestry department to outline the procedure and accountability for terrestrial wild animal disease monitoring, reporting, and response. Several rules and normative documents were issued by the forestry department including the lists of wildlife epidemics for monitoring and technique standards for wildlife disease investigation and wild animal captive breeding [70–75]. The China National Biodiversity Conservation Strategy and Action Plan (2011–2030) has set goals to conduct a nationwide assessment of wild species and reduction among wild animals. Overlapping or separate management by the forestry and agriculture departments undermines the responsibility and accountability in enforcement, neglecting the management of many reptile and amphibian species [48, 51]. The same situation is true for animal species that are not clearly defined as domestic or wild due to the long captive-breeding histories (e.g., deer, mink, and fox), leading to ambiguities in the management between the forestry and agriculture departments [44]. Amendments have been made to the relevant laws in China as the initial step to address these challenges in the management system [30, 52, 53], but incorporating these changes into the disease monitoring system among wild animals requires more enabling mechanisms and coordination of mandates.

3.2.5. Understanding the wild animal trade value chains

Limited understanding of the wild animal trade value chains (Fig. 3) in China is one of the greatest challenges in the risk assessment of zoonotic transmission and disease emergence at the wild-life–livestock–human interface, particularly in the peri-domestic or domestic setting. There are few published studies documenting the value chains of farming and trading wild animals, and as a result, very little is known about how wild animals are produced and traded or their interactions with domestic animals and humans before reaching consumers, or which populations are involved along the value chains and how they operate and interact with wild-sourced stock, which is further compounded by the vague definitions of “wild animal” and “farmed wild animal” in Chinese regulations across different authorities [54]. Given the high volume of wild animal farming and consumption in China, such information will be important for understanding the epidemiological, economic, and social aspects of zoonotic disease transmission risks. A solid understanding of wild animal trade value chains not only allows for the evaluation of potential pathogen transmission pathways and critical control points in risk assessment but also helps to form practical risk mitigation measures that are viewed as economically viable and socially acceptable by stakeholders.

3.3. Zoonotic disease management system

3.3.1. Cross-sectoral management of zoonotic disease in human, domestic and wild animal

Zoonotic diseases in China have been primarily monitored and regulated by the human health and veterinary departments. A list of notifiable human infectious diseases has been established for monitoring and reporting under the Law of Prevention and Treatment of Infectious Diseases [55]. Similarly, the veterinary department under the Ministry of Agriculture and Rural Affairs has developed a list of animal epidemic diseases for regular monitoring and reporting, and measures for the administration, investigation, evaluation, and contingency plans of animal epidemics [56–64]. Technical guidance or standard documents for specific animal epidemics are also developed and distributed by the veterinary department on a regular basis [65, 66]. In 2009, the Health and Agriculture Ministries collaboratively issued a list of zoonotic infectious diseases [67, 68]. These schemes together serve as part of the national emergency response system.

A wild animal epidemic and epidemic source monitoring center was founded under the forestry department in 2005. It has developed into a wide network that consists of national (305), provincial (918), and city/county-level monitoring stations, and 2000 institutions for an online reporting system [69]. This system is centered around terrestrial wild animals, while disease monitoring for aquatic animals is implemented by the agriculture department. In 2013, the administrative measures for monitoring and controlling epidemics and epidemic sources for terrestrial wild animals was enacted by the forestry department to outline the procedure and accountability for terrestrial wild animal disease monitoring, reporting, and response. Several rules and normative documents were issued by the forestry department including the lists of wildlife epidemics for monitoring and technique standards for wildlife disease investigation and wild animal captive breeding [70–75]. The China National Biodiversity Conservation Strategy and Action Plan (2011–2030) has set goals to conduct a nationwide assessment of wild animal species and reduction among wild animals. Overlapping or separate management by the forestry and agriculture departments undermines the responsibility and accountability in enforcement, neglecting the management of many reptile and amphibian species [48, 51]. The same situation is true for animal species that are not clearly defined as domestic or wild due to the long captive-breeding histories (e.g., deer, mink, and fox), leading to ambiguities in the management between the forestry and agriculture departments [44]. Amendments have been made to the relevant laws in China as the initial step to address these challenges in the management system [30, 52, 53], but incorporating these changes into the disease monitoring system among wild animals requires more enabling mechanisms and coordination of mandates.

3.2.5. Understanding the wild animal trade value chains

Limited understanding of the wild animal trade value chains (Fig. 3) in China is one of the greatest challenges in the risk assessment of zoonotic transmission and disease emergence at the wild-life–livestock–human interface, particularly in the peri-domestic or domestic setting. There are few published studies documenting the value chains of farming and trading wild animals, and as a result, very little is known about how wild animals are produced and traded or their interactions with domestic animals and humans before reaching consumers, or which populations are involved along the value chains and how they operate and interact with wild-sourced stock, which is further compounded by the vague definitions of “wild animal” and “farmed wild animal” in Chinese regulations across different authorities [54]. Given the high volume of wild animal farming and consumption in China, such information will be important for understanding the epidemiological, economic, and social aspects of zoonotic disease transmission risks. A solid understanding of wild animal trade value chains not only allows for the evaluation of potential pathogen transmission pathways and critical control points in risk assessment but also helps to form practical risk mitigation measures that are viewed as economically viable and socially acceptable by stakeholders.

3.3. Zoonotic disease management system

3.3.1. Cross-sectoral management of zoonotic disease in human, domestic and wild animal

Zoonotic diseases in China have been primarily monitored and regulated by the human health and veterinary departments. A list of notifiable human infectious diseases has been established for monitoring and reporting under the Law of Prevention and Treatment of Infectious Diseases [55]. Similarly, the veterinary department under the Ministry of Agriculture and Rural Affairs has developed a list of animal epidemic diseases for regular monitoring and reporting, and measures for the administration, investigation, evaluation, and contingency plans of animal epidemics [56–64]. Technical guidance or standard documents for specific animal epidemics are also developed and distributed by the veterinary department on a regular basis [65, 66]. In 2009, the Health and Agriculture Ministries collaboratively issued a list of zoonotic infectious diseases [67, 68]. These schemes together serve as part of the national emergency response system.

A wild animal epidemic and epidemic source monitoring center was founded under the forestry department in 2005. It has developed into a wide network that consists of national (305), provincial (918), and city/county-level monitoring stations, and 2000 institutions for an online reporting system [69]. This system is centered around terrestrial wild animals, while disease monitoring for aquatic animals is implemented by the agriculture department. In 2013, the administrative measures for monitoring and controlling epidemics and epidemic sources for terrestrial wild animals was enacted by the forestry department to outline the procedure and accountability for terrestrial wild animal disease monitoring, reporting, and response. Several rules and normative documents were issued by the forestry department including the lists of wildlife epidemics for monitoring and technique standards for wildlife disease investigation and wild animal captive breeding [70–75]. The China National Biodiversity Conservation Strategy and Action Plan (2011–2030) has set goals to conduct a nationwide assessment of wild animal species and reduction among wild animals. Overlapping or separate management by the forestry and agriculture departments undermines the responsibility and accountability in enforcement, neglecting the management of many reptile and amphibian species [48, 51]. The same situation is true for animal species that are not clearly defined as domestic or wild due to the long captive-breeding histories (e.g., deer, mink, and fox), leading to ambiguities in the management between the forestry and agriculture departments [44]. Amendments have been made to the relevant laws in China as the initial step to address these challenges in the management system [30, 52, 53], but incorporating these changes into the disease monitoring system among wild animals requires more enabling mechanisms and coordination of mandates.

3.2.5. Understanding the wild animal trade value chains

Limited understanding of the wild animal trade value chains (Fig. 3) in China is one of the greatest challenges in the risk assessment of zoonotic transmission and disease emergence at the wild-life–livestock–human interface, particularly in the peri-domestic or domestic setting. There are few published studies documenting the value chains of farming and trading wild animals, and as a result, very little is known about how wild animals are produced and traded or their interactions with domestic animals and humans before reaching consumers, or which populations are involved along the value chains and how they operate and interact with wild-sourced stock, which is further compounded by the vague definitions of “wild animal” and “farmed wild animal” in Chinese regulations across different authorities [54]. Given the high volume of wild animal farming and consumption in China, such information will be important for understanding the epidemiological, economic, and social aspects of zoonotic disease transmission risks. A solid understanding of wild animal trade value chains not only allows for the evaluation of potential pathogen transmission pathways and critical control points in risk assessment but also helps to form practical risk mitigation measures that are viewed as economically viable and socially acceptable by stakeholders.
animal diseases to build a database for preventing and controlling ani-
mal epidemics [76]. (Fig. 4; Supplementary Materials II).

Among these multiple systems, 55 zoonotic diseases (59 disease
agents) are under regular monitoring in China by the human health (43),
agriculture (29), and forestry (7) departments. More than half of these
diseases (35 disease agents) are endemic in human populations in China,
seven have caused local outbreaks over the past 20 years, and five have
been linked to imported cases (Table 1).

3.3.2. Wild animal hosts and the transmission routes of monitored zoonotic
diseases

Analysis of the potential wild animal hosts for the 59 zoonotic dis-
ease agents monitored in China shows that wild animals in the class
Mammalia are potential hosts for 71% of the agents, followed by the
classes Aves (17), Reptilia (5), and Amphibia (2). Many monitored
zoonotic agents are associated with wild animals in the orders Carnivora
(20), Artiodactyla (18), and Rodentia (15), bats (order Chiroptera) are
hosts of 13 monitored zoonotic agents and known as reservoirs for SARS-
related coronaviruses. In addition, fish and other aquatic animals, are
potential hosts for 10 zoonotic agents under monitoring (Table 2).

These monitored disease agents vary in their transmission routes and
zoonotic risks from causing endemics to be only linked to single or rare
spillover events thus far. Diseases such as anthrax and tularemia can be
transmitted from animals to humans through multiple routes, ranging
from direct contact with infected animals to food- or waterborne expo-
sures, while rabies and leishmaniasis are known to have a single route of
transmission. More than half of the monitored zoonotic diseases (32) are
associated with direct or indirect contact with animal hosts, and 17 are
transmitted via vectors. Among the five zoonotic diseases that are
currently reported as imported cases, four are vector-borne diseases with
the potential of local emergence affected by climate conditions and the
presence of competent arthropod vector species in China. The role of
wild animals may not be significant for some diseases if the transmission
cycle between humans and arthropods sustains the pathogen within
human populations (e.g., lymphatic filariasis), or the pathogens have
been readily spread within the humans without an animal host (e.g.,
HIV/AIDS, SARS) (Table 2).

3.3.3. Limited scope of zoonotic disease monitoring

Many wild animals as hosts of zoonotic pathogens are being traded
and kept in captivity in China, including rats or other small rodent
species as primary hosts for several zoonotic infections. The practices of
capturing, transporting, handling, or processing wild animals, including
holding animals in markets and farms, create routes for zoonotic path-
ogens transmission and provide chances for pathogen evolution and
amplification. Meanwhile, many other zoonotic diseases with increasing
human cases in China, and emerging zoonotic diseases of public health
concerns occurring in other Asian countries in recent years are not
systematically monitored [77–80]. The lack of investigation on the
source of reported disease incidence also limits our understanding of the
zoonotic transmission routes to identify the animal origins for better risk
assessment and monitoring. Therefore, the number of zoonotic diseases
with endemic risks in China and the wide range of wild animal host
species require an expanded review and scope of the monitoring system
regarding the pathogens, wild animal species, and at-risk human
populations.

4. Discussion

The present review indicates that there are existing scope and op-
erations in China for wild animal management and zoonotic disease risk
monitoring. However, the coverage of diseases or pathogens with zoo-
notic risk, as well as the management of potential wild animal hosts to
prevent disease emergence, are limited in the current system. Proactive
screening of zoonotic diseases or emerging pathogens with zoonotic
potential in wild animal populations is often overlooked by the system;
instead, it relies heavily on the research community that would require
additional mechanisms for integration into government monitoring and
policy. The gaps in the completeness of mandates and enforcement
about wild animal management in the at-risk scenarios of wild animal
utilization remain a concern for emerging zoonotic disease prevention
and preparedness. The lack of a cohesive strategy has resulted in data
gaps that make it challenging to precisely identify the practices and
aspects of disease risks in the wildlife animal trade value chains. A more
coordinated governance structure and regulation system are needed for
the systematic assessment and management of zoonotic disease emer-
gence risks in China.

4.1. Coordinated and collaborative disease monitoring

In line with China's recent investment in epidemic preparedness [81], which emphasizes a One Health approach to zoonotic and other
Table 1
Zoonotic disease classification and monitoring under the human health, agriculture, and forestry departments in China [92-136].

| Disease or disease agent | Type of pathogen | Epidemiological occurrence of human case in China | Monitoring & reporting regulations | Class I, II, III animal epidemic diseases | Zoonotic infectious diseases | Prioritized wildlife epidemics and resources for monitoring | Hazardness classification of terrestrial wildlife-borne infectious diseases | OIE-listed diseases 2020 |
|--------------------------|------------------|--------------------------------------------------|-----------------------------------|-----------------------------------------|----------------------------|-----------------------------------------------------------|---------------------------------------------------------------|--------------------------|
| Cholera                  | Bacteria         | Sporadic                                         | A                                 |                                         |                           |                                                           |                                                                |                          |
| Plague                   | Bacteria         | Endemic/sporadic                                 | B                                 |                                         |                           |                                                           |                                                                |                          |
| Avian influenza A (H7N9) | Virus            | Endemic/re-emerging                               | II                                | X                                       |                           |                                                           | B                               |                          |
| Highly pathogenic avian influenza (H5N1) | Virus | Outbreak/no case reported since 2017 | B | I | X | X | A | X |
| Acquired immunodeficiency syndrome (AIDS) | Virus | Endemic | B |
| Rabies                   | Virus            | Endemic                                          | B                                 |                                         |                           |                                                           |                                                                |                          |
| Brucellosis              | Bacteria         | Endemic                                          | B                                 |                                         |                           |                                                           |                                                                |                          |
| Bovine tuberculosis      | Bacteria         | Sporadic                                         | B                                 |                                         |                           |                                                           |                                                                |                          |
| Antrax                   | Bacteria         | Endemic                                          | B                                 |                                         |                           |                                                           |                                                                |                          |
| Leptospirosis            | Bacteria         | Sporadic                                         | B                                 |                                         |                           |                                                           |                                                                |                          |
| Schistosomiasis japonica | Parasite         | Endemic                                          | B                                 |                                         |                           |                                                           |                                                                |                          |
| Japanese encephalitis    | Parasite         | Endemic                                          | B                                 |                                         |                           |                                                           |                                                                |                          |
| Hemorrhagic fever with renal syndrome (HFRS) (bantiviruses) | Virus | Endemic/sporadic | B | III | X |
| Severe acute respiratory syndrome (SARS) | Virus | Outbreak, 2002-2003 | B |
| Dengue fever             | Virus            | Endemic                                          | B                                 |                                         |                           |                                                           |                                                                |                          |
| Hepatitis E              | Virus            | Endemic                                          | B                                 |                                         |                           |                                                           |                                                                |                          |
| Coronavirus disease 2019 (COVID-19) | Virus | Outbreak, 2019-present | B |
| Zoonotic malaria (Plasmodium knowlesi) | Parasite | Endemic | B |
| Kicchinoscosis           | Parasite         | Endemic                                          | C                                 |                                         |                           |                                                           |                                                                |                          |
| Colibacillosis: E. coli (O157:H7) (STEC) (infectious diarrhea) | Bacteria | Endemic | C | II | X | |
| Nontyphoidal Salmonella infections (infectious diarrhea) | Bacteria | Endemic | C | II | X |
| Rotavirus disease (infectious diarrhea) | Virus | Endemic | C |
| Giardiasis (infectious diarrhea) | Parasite | Endemic | C |
| Yersiniosis (infectious diarrhea) | Bacteria | Endemic | C |
| Cryptosporidiosis (infectious diarrhea) | Parasite | Endemic | C |
| Lymphatic filariasis       | Parasite         | Eliminated                                        | C                                 |                                         |                           |                                                           |                                                                |                          |
| Leishmaniasis: cutaneous and visceral (Kala-azar) | Parasite | Endemic | C | III | X | B | X |
| Epidemic typhus          | Bacteria         | Endemic                                          | C                                 |                                         |                           |                                                           |                                                                |                          |
| Scrub typhus             | Bacteria         | Endemic                                          | C                                 |                                         |                           |                                                           |                                                                |                          |
| Leprosy                  | Bacteria         | Endemic/sporadic                                 | C                                 |                                         |                           |                                                           |                                                                |                          |
| Chagas disease           | Parasite         | No                                               | Others                            |                                         |                           |                                                           |                                                                |                          |
| Lassa fever              | Virus            | No                                               | Others                            |                                         |                           |                                                           |                                                                |                          |
| Yellow fever             | Virus            | Imported cases                                   | Others                            |                                         |                           |                                                           |                                                                |                          |
| Ebola hemorrhagic fever  | Virus            | No                                               | Others                            |                                         |                           |                                                           |                                                                |                          |
| Zika virus               | Virus            | Imported cases                                   | Others                            |                                         |                           |                                                           |                                                                |                          |
| Angiostrongyliasis        | Parasite         | Endemic/emerging                                 | Others                            |                                         |                           |                                                           |                                                                |                          |
| Middle East respiratory syndrome (MERS) | Virus | Imported case, 2015 | Others |
| Rift Valley fever        | Virus            | Imported case, 2016                              | Others                            |                                         |                           |                                                           |                                                                |                          |
| Marburg hemorrhagic fever | Virus | No | Others |
| Chikungunya              | Virus            | Imported cases/outbreaks, 2010, 2017              | Others                            |                                         |                           |                                                           |                                                                |                          |
| Amoebiasis               | Parasite         | Endemic                                          | Others                            |                                         |                           |                                                           |                                                                |                          |
| Gnathostomiasis          | Parasite         | Endemic                                          | Others                            |                                         |                           |                                                           |                                                                |                          |

(continued on next page)
emerging health threats, a highly coordinated and collaborative mechanism among different departments is required for effective monitoring of, and response to, disease emergence and transmission risks in animal value chains. Design and implementation of this envisioned system offer an opportunity to fill knowledge gaps about risks throughout the value chain for risk reduction, which is expected to improve the utility of the monitoring system in wild animals as a sentinel to identify potential zoonotic disease risks and prevent disease introduction into domestic animals and human populations. One practical application will be the design of a flow of information, as part of the monitoring system, from wild animal monitoring to trigger real-time risk alerts for human health, agriculture, and forestry authorities (and potentially others as needed, such as commerce or customs) to guide implementation of risk reduction strategies. As an existing example, the influenza monitoring and surveillance network established in China across human hospitals, the conservation community, and poultry and livestock industries demonstrated the feasibility of a cross-sectoral system to take joint responsibility for disease monitoring and biosecurity in markets and natural habitats to protect human and wild domestic animal health [82,83]. Meanwhile, a centralized information system and the clearly defined responsibility and accountability of different authorities will lay the foundation for effective coordination and collaboration to improve wild animal management and disease monitoring in China.

4.2. Integrated surveillance and zoonotic risk analysis

Building on China’s existing monitoring system for zoonotic diseases and pathogens, potential enhancements should be considered to shed light on relevant animal populations, dynamics between host species and microbes, and at-risk human activities to guide cost-effective monitoring and surveillance. While some wild animal species of relevance are overseen by the forestry authority, wild animals in peri-domestic or captive breeding settings should be emphasized given the high potential for inter-species contact and the fundamental changes in ecological and evolutionary dynamics in these settings. Beyond disease monitoring, upstream surveillance of potential zoonotic pathogens among wild animal hosts and at-risk human populations is a proactive approach for disease risk assessment and prevention if paired with follow-up risk reduction actions. Surveillance will advance our knowledge of other pathogens present in wild animal populations in China with zoonotic risk but outside the current monitoring and reporting system. Such work has elucidated the reservoir species for several high-consequence pathogens, such as SARS-CoV [84], and may help to elucidate the origins of SARS-CoV-2. It will also provide serological or molecular evidence indicating early spillover events and information on the animal host distribution and zoonotic transmission routes, which are valuable for assessing the potential of disease emergence and guiding targeted risk monitoring and mitigation efforts [85,86].

Results from both disease monitoring and pathogen surveillance in wild animals and human populations should be considered in the ongoing risk analysis procedures and the refinement of animal protection listings and regulations. In addition to the potential human health impact, socioeconomic impacts associated with the restriction of trade, human and animal movement, and animal-based food production are important determinants of the prioritization of disease monitoring and surveillance efforts to best inform mitigation options [87]. Recognizing the growing infectious disease threat as a result of globalized trade and travel, authorities must also strengthen the quarantine of potential pathogen animal hosts at the borders [88]. Given China’s strong history of research on emerging pathogens, as well as decisive whole-of-society action to monitor and reduce HPAI risks, alignment of surveillance activities to guide additional research questions (e.g., specific reservoir species) can help efficiently fill the gaps to improve the understanding and future control and prevention of emerging pandemic threats and zoonotic diseases existing outside of the routine monitoring system.

Table 1 (continued)

| Disease or disease agent | Type of pathogen | Epidemiological occurrence of human case in China | Monitoring & reporting regulations | Prioritized wildlife epidemics and resources for monitoring | Hazard classification of terrestrial wildlife-borne infectious diseases | OIE-listed diseases 2020 |
|--------------------------|------------------|-----------------------------------------------|-----------------------------------|----------------------------------------------------------|---------------------------------------------------------------|------------------------|
| West Nile fever          | Virus            | Endemic/sporadic/emerging                     | Others                            | X                                                        | A                                                              | X                      |
| Norovirus                | Virus            | Endemic/outbreaks                             | Others                            | X                                                        |                                                                | X                      |
| Glanders/malleus         | Bacteria         | No                                            | Others                            | II X                                                     | B                                                              | X                      |
| Melioidosis              | Bacteria         | Endemic                                      | Others                            | III X                                                    | B                                                              | X                      |
| Streptococcus suis       | Bacteria         | Sporadic/outbreak, 2005                       | Others                            | II X                                                     |                                                                |                        |
| Transmissible spongiform encephalopathies (TSE) | Prion | No                                            | I X                               |                                                        | A                                                              | X                      |
| Toxoplasmosis            | Parasite         | Endemic                                      | II X                               | B                                                        |                                                                |                        |
| Trichinellosis/trichinosis | Parasite       | Endemic                                      | II X                               | B                                                        |                                                                | X                      |
| Cysticercosis            | Parasite         | Endemic                                      | II X                               | B                                                        |                                                                | X                      |
| Tularemia (rabbit fever) | Bacteria         | Sporadic                                     | II X                               | B                                                        |                                                                | X                      |
| Liver flukes (foodborne trematodiasis) | Parasite | Endemic                                      | III X                             |                                                        |                                                                |                        |
| Q fever                  | Bacteria         | Sporadic                                     | III X                             | B                                                        |                                                                | X                      |
| Foot-and-mouth disease (FMD) | Virus | Sporadic                                     | I                                 |                                                        | A                                                              | X                      |
| Listeriosis              | Bacteria         | Endemic/outbreaks                             | III X                             | B                                                        |                                                                |                        |
| Actinomycosis            | Bacteria         | Sporadic                                     | III X                             | B                                                        |                                                                |                        |
| Eperythrozoonosis        | Bacteria         | Endemic/emerging                             | III                               | A                                                        |                                                                | C                      |

Note: Epidemiologic Occurrence of Human Case in China: The epidemiological occurrence of human cases for each disease was classified as “Sporadic” when a disease occurs on occasion, singly, or as scattered instances; “Endemic” when a disease constantly present in the human population; “Outbreak” when a disease has led to many cases in a given area in a short time period; “Emerging” or “Re-emerging” when a disease that was increasing in incidence or spreading to new geographic areas; “Imported cases”; or combination of them. Pathogen isolated from animal hosts or serological evidence among human populations are not counted as occurrence. Lymphatic Filariasis was eliminated in China in 2007, and Malaria was eliminated in China in 2021.
| Disease or disease agent | Type of pathogen | (potential) Wild animal host | (potential) Domestic animal host | Major animal-human transmission route | Vector | Human-to-human transmission |
|--------------------------|------------------|-----------------------------|---------------------------------|-------------------------------------|--------|-----------------------------|
| Cholera                  | Bacteria         | Shellfish, fish, waterfowl incl. waders, egrets, herons, cormorants, pelicans, gulls | Farmed aquatic animals | Waterborne Foodborne | NA | Yes (fecal-oral) |
| Plague                   | Bacteria         | Marmots, rodents, wild carnivores, wild cloven-hoofed mammals | Rodents | Direct contact | Vector | Yes (direct contact) |
| Avian Influenza A (H7N9) | Virus            | Bar-headed geese, swans and other migratory or non-migratory birds of Anatidae | Poultry | Direct contact | Indirect contact | NA | Limited |
| Highly pathogenic avian influenza (H5N1) | Virus | Bar-headed geese, swans and other migratory or non-migratory birds of Anatidae | Poultry | Direct contact | Indirect Contact | NA | Limited |
| Acquired immunodeficiency syndrome (AIDS) | Virus | Great apes, monkeys (Hominidae, Cercopithecidae) | | Direct contact | | Yes (direct contact) |
| Rabies                   | Virus            | Bats, Carnivora esp. wolves, jackals, foxes, badgers | Domestic dogs | Direct contact | | NA | No |
| Brucellosis              | Bacteria         | Bison, deer, wild boar, and other marine mammals | Sheep, goats, cattle, swine, domestic dogs | Direct contact | Indirect Contact | NA | Rare |
| Bovine tuberculosis      | Bacteria         | Cloven-hoofed mammals and non-human primates (wildlife reservoirs in certain countries incl. badgers, deer) | Cattle | Direct contact | | NA | Rare |
| Anthrax                  | Bacteria         | Herbivorous mammals (primary), birds | Cattle, sheep, horse, swine | Direct contact | Indirect contact | NA | Rare |
| Leptospirosis            | Bacteria         | Rodents (pathogen isolated from 67 animal species in China) | Rodents, swine, cattle, dogs | Direct contact | Foodborne | Direct contact | NA | No |
| Schistosomiasis japonica | Parasite         | Rodents, carnivores, freshwater snails | Cattle, buffalos | Waterborne | Waterborne | NA | No |
| Japanese encephalitis (epidemic encephalitis B) | Virus | Waterfowls, bats, great apes, monkeys | Swine | | Vector | Mosquitoes (Culex spp.) | No |
| Avian tuberculosis       | Bacteria         | Wild birds | Poultry and captive birds, swine, cattle | Indirect contact (occasional) | | NA | Unconfirmed |
| Hemorrhagic fever with renal syndrome (HFRS) (hantavirus) | Virus | Rodents (primary) | | Direct contact | Indirect contact | NA | No |
| Severe acute respiratory syndrome (SARS) | Virus | Bats, civets, raccoon dogs | | Indirect contact | | | Yes (direct contact) |
| Dengue fever             | Virus            | Non-human primates | Domestic dogs | Vector (rare) | | | | |
| Hepatitis E              | Virus            | Wild boars (primary), deer, rabbits, mongooses | Swine (primary) | Direct contact | Foodborne | Waterborne | NA | Yes (fetal-oral) |
| Coronavirus disease 2019 (COVID-19) | Virus | Bats, pangolins, minks, tigers, lions | Domestic cats, macaques (experimental) | | Known | | | Yes (fetal-oral) |
| Zoonotic malaria (Plasmodium knowlesi) | Parasite | Non-human primates | | Vector | | Mosquitoes (Anopheles spp.) | No |
| Echinococcosis           | Parasite         | Foxen, wolves and other Canidae, small rodents, other mammals | Domestic dogs | Direct contact | Foodborne | Waterborne | NA | No |
| Colibacillosis: E. coli (O157:H7) ( STEC) (infectious diarrhea) | Bacteria         | Rodents, birds, deer (found in a wide range of wild mammals and birds) | Cattle, sheep, goats, chicken, rabbits | Direct contact | Foodborne | Waterborne | NA | Yes (fetal-oral) |
| Nontyphoidal salmonella infections (infectious diarrhea) | Bacteria         | Wild mammals, birds, reptiles, amphibians | Poultry, swine, cattle, pets incl. cats, dogs, reptiles, amphibians, birds | Direct contact | Foodborne | Waterborne | NA | Yes (fetal-oral) |
| Rotavirus disease (infectious diarrhea) | Virus | Wild mammals, birds | Young calves and piglets, foals | Direct contact | Foodborne | | | Yes (fetal-oral) |
| Giardiasis (infectious diarrhea) | Parasite | Non-human primates, rodents, wild boars | Cattle, goats, cats, dogs, swine, farmed raccoon dogs, deer, horses, donkeys | Direct contact | Foodborne | | | Yes (fetal-oral) |
| Yersiniosis (infectious diarrhea) | Bacteria | Rodents, hares, birds, reptiles, aquatic animals | Swine, dogs, cats, sheep | Foodborne (primary) | Direct contact | | | | |
| Cryptosporidiosis (infectious diarrhea) | Parasite | Wide range of wild mammals | Cattle, sheep, cats, dogs | Direct contact | Foodborne | | | | |

(continued on next page)
| Disease or disease agent        | Type of pathogen | (potential) Wild animal host                                      | (potential) Domestic animal host | Major animal-human transmission route | Vector | Human-to-human transmission |
|--------------------------------|------------------|------------------------------------------------------------------|----------------------------------|--------------------------------------|--------|-----------------------------|
| Lymphatic filariasis           | Parasite         | Felines, non-human primates (no reservoir hosts in China)         | Domestic dogs (primary), cats,   | Vector (rare)                        | Mosquitoes (Aedes spp., Culex spp., Anopheles spp.) | Yes (vector presence) |
| Leishmaniasis: cutaneous and visceral (kala-azar) | Parasite         | Canines, hares, rodents                                           | Domestic dogs, cats,             | Vector                              | Sandflies (Phlebotomus spp.) | Yes (vector presence) |
| Epidemic typhus                | Bacteria         | Flying squirrels (Glaucomys volans) (rare)                       | Domestic dogs, cats,             | Vector                              | Human body lice (Pediculus humanus corporis) | Yes (vector presence) |
| Scrub typhus                   | Bacteria         | Wild rodents (genus Rattus)                                       | Domestic dogs, cats,             | Vector                              | Larval mites ( trombiculid)     | No |
| Leprosy                        | Bacteria         | Nine-banded armadillo (Dasyus novemcinctus), chimpanzee, non-human primates | Domestic dogs, cats,             | Direct contact (rare)               | NA     | Yes                         |
| Yellow fever                   | Virus            | Non-human primates                                               | Domestic dogs, cats,             | Direct contact                      | Mosquitoes (Aedes spp., Hemagogus spp.) | Yes (vector presence) |
| Ebola hemorrhagic fever        | Virus            | Non-human primates, fruit bats, antelope, porcupines             | Domestic dogs, cats,             | Direct contact                      | NA     | Yes (vector presence)       |
| Zika virus                     | Virus            | Non-human primates                                               | Domestic dogs, cats,             | Direct contact                      | NA     | Yes (vector presence)       |
| Angiostrongylisiasis           | Parasite         | Rodents, freshwater snails                                       | Freshwater shrimp, prawns, crabs, frogs, Dromedary camels | Vector                              | Foodborne | No |
| Middle East respiratory syndrome (MERS) | Virus           | Bats                                                             | Domestic dogs, cats,             | Direct contact (rare)               | NA     | Yes (vector presence)       |
| Rift Valley fever              | Virus            | Wild ruminants                                                   | Domestic dogs, cats,             | Vector                              | Mosquitoes (Aedes spp. & Culex spp.) | No |
| Marburg hemorrhagic fever      | Virus            | African fruit bat, non-human primates                            | Domestic dogs, cats,             | Direct contact                      | NA     | Yes (vector presence)       |
| Chikungunya                    | Virus            | Non-human primates, bats, palm squirrel                          | Domestic dogs, cats,             | Direct contact                      | NA     | Yes (vector presence)       |
| Amoebiasis                     | Parasite         | Non-human primates                                               | Domestic dogs, cats,             | Vector                              | Foodborne | No |
| Gnavathomiasis                 | Parasite         | Wild canines, felines, fish, eels, other aquatic animals         | Domestic dogs, cats,             | Vector                              | Foodborne | NA |
| West Nile fever                | Virus            | Migratory and non-migratory birds of Passeriformes, Corvidae (found in a wide range of vertebrates) | Poultry                          | Vector (primary)                    | Mosquitoes (Culex spp.)         | No |
| Norovirus                      | Virus            | Wild birds, rodents, bats, marine mammals                        | Domestic horses, mules, donkeys   | Direct contact (rare)               | NA     | Rare                        |
| Glanders/malleus               | Bacteria         | Wild equids, camels, wild carnivores, rodents                    | Domestic horses, mules, donkeys   | Direct contact                      | NA     | Rare                        |
| Melioidosis                    | Bacteria         | Non-human primates, rodents, dolphins and other captive marine mammals (found in a wide range of mammals, birds, reptiles) | Swine                            | Unknown, potential reverse zoonosis | NA     | Yes (direct contact)       |
| Streptococcus suis             | Bacteria         | Wild boars                                                       | Swine                            | Direct contact                      | NA     | No                          |
| Transmissible spongiform encephalopathies (TSE) | Prion           | Cervidae, Felidae, mustelida                                     | Swine                            | Direct contact                      | NA     | No                          |
| Toxoplasmosis                  | Parasite         | Felidae (primary), bats, birds, farmed sila deer, minks have been found infected in China | Swine, chicken, sheep, cattle, cats, dogs | Direct contact                      | NA     | No                          |
| Trichinellosis/trichinosis     | Parasite         | Wild carnivores, rodents Over 15 wild/domestic species can be infected in China | Swine and domestic dogs          | Direct contact                      | NA     | No                          |
| Cysticercosis                  | Parasite         | Wild boars                                                       | Swine                            | Direct contact                      | NA     | Yes (fecal-oral)            |
| Tularemia (rabbit fever)       | Bacteria         | Hares, rodents, hedgehogs, canids, felids, mustelids, deer, fish, crayfish | Domestic rabbits, dogs, cats      | Direct contact                      | NA     | No                          |
| Liver flukes (foodborne trematodiases) | Parasite       | Fish-eating mammals, aquatic animals incl. fish & crustaceans Freshwater snails | Domestic dogs, cats              | Direct contact                      | NA     | No                          |
| Q Fever                        | Bacteria         | Rodents, birds, hares, other mammals and arthropods              | Cattle, sheep, goats, cats, dogs  | Direct contact                      | NA     | Yes (vector presence)       |
| Viral                          | Virus            | African buffalos                                                 | Cattle, sheep, goats, cats, dogs  | Direct contact                      | NA     | No                          |

(continued on next page)
further investigation. For the majority of diseases, the role of listed potential wild animal hosts in the transmission of pathogen to humans and/or domestic animals will require investments in training and education across multiple disciplines and indirect impacts of known and novel disease threats can help to target entry points for intervention and identify areas where stopgap measures may be rapidly needed as part of COVID-19 recovery. The gaps identified in the existing landscape of policy responses, animal management, and disease and pathogen monitoring provide a basis for authorities to review their mandates and systems and contribute to an overall national strategy. A One Health platform supported by multiple sectors to provide insight and coordination for disease emergencies and routine operations has the potential to substantially address these gaps.

### Authors’ contributions

All authors contributed equally to the development of this study. H.L. & P.D. contributed to the conception and design of the study. H.L., Y.C., and C.C.M. conducted review and analysis of literature and policy information. H.L. and C.C.M. developed the first draft of the paper. P.D., H.T., A.A.C., and M.D.F. advised on manuscript writing and reviewed the paper. All authors read and approved the final manuscript.

### Funding

This work was supported by the National Institute of Allergy and Infectious Diseases of the National Institutes of Health (Award No. R01AI110964). All work conducted by EcoHealth Alliance staff after April 24th, 2020 was also supported by generous funding from The Samuel Freeman Charitable Trust, Pamela Thye, The Wallace Fund, The Whitehead Foundation, and an anonymous Donor c/o Schwab Charitable.

### Declaration of Competing Interest

The authors declare there is no conflict of interest.

### Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2021.100301.

### References

[1] K.E. Jones, N.G. Patel, M.A. Levy, A. Storeygard, D. Balk, J.L. Gittleman, et al., Global trends in emerging infectious diseases, Nature 451 (7181) (2008) 990.
[66] The Ministry of Agriculture and Rural Affairs of the PRC, Emergence Implementation Plan to Respond to the Africa Swine Fever, 2020, 2020 Version.
[67] The National Health Commission of the PRC, Infectious Disease Prevention and Control Action Plan (2011-2020), China National Environmental Science Press, Beijing, 2011.
[68] The State Forestry and Grassland Administration of the PRC, General Technical Rules for Prevention and Control Terrestrial Wildlife-Borne Infectious Diseases in Zoo, 2019.
[69] The State Forestry and Grassland Administration of the PRC, Monitoring Technical Norms for Terrestrial Wildlife-Borne Infectious Diseases, 2014.
[70] The State Forestry and Grassland Administration of the PRC, List of Prioritized Animal Epidemics and Epidemic Sources, 2005.
[71] The State Forestry and Grassland Administration of the PRC, Classification and Codes for Epidemic Diseases in Terrestrial Wildlife, 2011.
[72] The State Forestry and Grassland Administration of the PRC, General Technical Rules for Prevention and Control Terrestrial Wildlife-Borne Infectious Diseases in Zoo, 2019.
[73] The State Forestry and Grassland Administration of the PRC, Hazardness Classification of Terrestrial Wildlife-Borne Infectious Diseases, 2014.
[74] The State Forestry and Grassland Administration of the PRC, Prioritizing zoonoses: a proposed one health tool for collaborative decision-making, PloS ONE 9 (10) (2014) 1-9.
[75] V.P. Hsu, M.J. Hossain, U.D. Parashar, M.M. Ali, T.G. Ksiazek, I. Kuzmin, et al., High index of suspicion for brucellosis in a highly cosmopolitan city in southern China, Zhonghua liuxing bingxue zazhi 39 (8) (2018) 1036–1040.
[76] C. Xu, F. Havers, L. Wang, T. Chen, J. Shi, D. Wang, et al., Monitoring avian influenza A (H7N9) virus through national influenza-like illness surveillance, China, Emerg. Infect. Dis. 19 (8) (2013) 1289.
[77] W. Li, Z. Shi, M. Yu, W. Ren, C. Smith, J.H. Epstein, et al., Bats are natural reservoirs of SARS-like coronaviruses, Science 310 (5748) (2006) 676–679.
[78] H. Li, E. Mendelsohn, C. Zong, W. Zhang, E. Hagan, N. Wang, et al., Human animal interactions and bat coronavirus spillover potential among rural residents in Southern China, Biosaf. Health 1 (2) (2019) 84–90.
[79] A. Wang, S.Y. Li, X.L. Yang, H.M. Huang, Y.J. Zhang, H. Guo, et al., Serological evidence of bat SARS-related coronavirus infection in humans, China, Virol. Sin. 33 (1) (2018) 104–107.
[80] A.H.l Havelaar, F. Van Rosse, C. Bucura, M.A. Toetenel, J.A. Haagsma, D. Kurovicka, et al., Prioritizing emerging zoonoses in the Netherlands, PloS ONE 5 (11) (2010).
[81] C.L. Rist, C.S. Arriola, C. Rubin, Prioritizing zoonoses: a proposed one health tool for collaborative decision-making, PloS ONE 9 (10) (2014).
[82] M. Emerink, Coronavirus Rips through Dutch Mink Farms, Triggering Culls, Science 370 (6518) (2020) 1-2.
[83] Z. Zhang, Y. Fang, Y. Wang, C. Cohen, D. Yu, Z. Chen, et al., Distribution of tick-borne encephalitis in mainland China, Ticks Tick-Borne Dis. 8 (4) (2017) 766–775.
[84] Y. Hu, M.P. Ward, C. Xia, L. Li, R. Li, S. Lynn, et al., Monitoring schistosomiasis risk in East China over space and time using a Bayesian hierarchical modeling approach, Sci. Rep. 6 (1) (2016) 1-9.
[85] Z. Zhang, Y. Chen, Food safety in China, J. Epidemiol. Commun. Health 67 (6) (2013) 428–432.
[86] Y. Hu, S. Gao, W. Liu, Y. Gao, S. Li, Y. Bi, MERS in South Korea and China: a potential outbreak threat? Lancet 385 (9985) (2015) 2349–2350.
[87] S. Lai, Z. Huang, H. Zhou, K.L. Anders, T.A. Perkins, W. Yin, et al., The changing epidemiology of dengue in China, 1990-2014: a descriptive analysis of 25 years of nationwide surveillance data, BMC Med. 13 (1) (2015) 100.
[88] Z. Tao, G. Liu, M. Wang, H. Wang, X. Lin, S. Song, et al., Molecular epidemiology of Japanese encephalitis virus in mosquitoes during an outbreak in China, 2013, Sci. Rep. 4 (2014) 4911.
[89] X. Lu, X. Li, Z. Mo, F. Jin, B. Wang, J. Huang, et al., Chikungunya emergency in China: microevolution and genetic analysis for a local outbreak, Virus Genes 48 (1) (2014) 15–22.
[90] L. Qiao, L. Cao, X.-Q. Zhu, Major emerging and re-emerging zoonoses in China: a matter of global health and socioeconomic development for 1.3 billion, Int. J. Infect. Dis. 25 (2014) 65–72.
[91] B. Cai, The epidemic status and strategy for prevention and control of brucellosis in China, Chin. J. Prev. Med. 48 (12) (2014) 1035–1038.
[92] Y. Wu, Y. Chen, Food safety in China, J. Epidemiol. Commun. Health. 67 (6) (2013) 478–479.
[93] X.-B. Wu, R.-H. Na, S.-S. Wei, J.-S. Zhu, H.-J. Peng, Distribution of tick-borne encephalitis in mainland China, Ticks Tick-Borne Dis. 8 (4) (2017) 766–775.
[94] Y. Hu, S. Gao, W. Liu, Y. Gao, S. Li, Y. Bi, MERS in South Korea and China: a potential outbreak threat? Lancet 385 (9985) (2015) 2349–2350.
[95] S. Lai, Z. Huang, H. Zhou, K.L. Anders, T.A. Perkins, W. Yin, et al., The changing epidemiology of dengue in China, 1990-2014: a descriptive analysis of 25 years of nationwide surveillance data, BMC Med. 13 (1) (2015) 100.
[96] Z. Tao, G. Liu, M. Wang, H. Wang, X. Lin, S. Song, et al., Molecular epidemiology of Japanese encephalitis virus in mosquitoes during an outbreak in China, 2013, Sci. Rep. 4 (2014) 4911.
[97] X. Lu, X. Li, Z. Mo, F. Jin, B. Wang, J. Huang, et al., Chikungunya emergency in China: microevolution and genetic analysis for a local outbreak, Virus Genes 48 (1) (2014) 15–22.
[98] L. Qiao, L. Cao, X.-Q. Zhu, Major emerging and re-emerging zoonoses in China: a matter of global health and socioeconomic development for 1.3 billion, Int. J. Infect. Dis. 25 (2014) 65–72.
[99] B. Cai, The epidemic status and strategy for prevention and control of brucellosis in China, Chin. J. Prev. Med. 48 (12) (2014) 1035–1038.
[100] Y. Wu, Y. Chen, Food safety in China, J. Epidemiol. Commun. Health. 67 (6) (2013) 478–479.
[101] X.-B. Wu, R.-H. Na, S.-S. Wei, J.-S. Zhu, H.-J. Peng, Distribution of tick-borne encephalitis in mainland China, Ticks Tick-Borne Dis. 8 (4) (2017) 766–775.
[102] D.-S. Huang, P. Guan, W. Liu, T.-F. Shen, H.-L. Liu, S. Cao, et al., Infection rate of Eperythrozoon spp. in Chinese population: a systematic review and meta-analysis, Sci Rep. 6 (1) (2016) 1-5.
[103] Y. Hu, S. Gao, W. Liu, Y. Gao, S. Li, Y. Bi, MERS in South Korea and China: a potential outbreak threat? Lancet 385 (9985) (2015) 2349–2350.
[104] S. Lai, Z. Huang, H. Zhou, K.L. Anders, T.A. Perkins, W. Yin, et al., The changing epidemiology of dengue in China, 1990-2014: a descriptive analysis of 25 years of nationwide surveillance data, BMC Med. 13 (1) (2015) 100.
[105] L. Qiao, L. Cao, X.-Q. Zhu, Major emerging and re-emerging zoonoses in China: a matter of global health and socioeconomic development for 1.3 billion, Int. J. Infect. Dis. 25 (2014) 65–72.
[106] B. Cai, The epidemic status and strategy for prevention and control of brucellosis in China, Chin. J. Prev. Med. 48 (12) (2014) 1035–1038.
H. Zhu, J. Li, H. Zheng, Human natural infection of Plasmodium knowlesi, Zhongguo jisheng chong xue yu ji sheng chong bing za zhi— Chin. J. Parasitol. Parasit. Dis. 24 (1) (2006), 70–1.

L. Zhang, X. Fu, J. He, Analysis on the epidemic characteristics of typhus from 1994–2003 in China, China Prev. Med. 6 (5) (2005).

M. Liu, P. Boitrait, Trichinosis in China: epidemiology and control, Trends Parasitol. 18 (12) (2002) 553–556.

R. Luo, J. Xie, Y. Chen, S. Yang, Report of one human case of foot and mouth disease (in Chinese), New Med. 30 (3) (1999) 159.

World Organisation for Animal Health, Infectious SARS-COV-2 in Animals, June 2020, Accessed on 01 June 2020, https://www.oie.int/fileadmin/Home/en/g/Our_scientific_expertise/docs/pdf/COV-19_A_Factsheet_SARS-COV-2.pdf.

The World Health Organization, Emergencies and Diseases, Accessed on May 20, 2020, https://www.who.int/emergencies/diseases/en/.

US Centers for Disease Control and Prevention, Zoonotic Diseases, Accessed on May 10, 2020, https://www.cdc.gov/onehealth/basics/zoonotic-diseases.html.

World Organisation for Animal Health, GLANDERS. Aetiology Epidemiology Diagnosis Prevention and Control References, Accessed on 01 May 2020, http://www.oie.int/fileadmin/Home/eng/AnimalHealth_in_the_World/docs/pdf/Disease_cards/GLANDERS.pdf.