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EDITORIAL

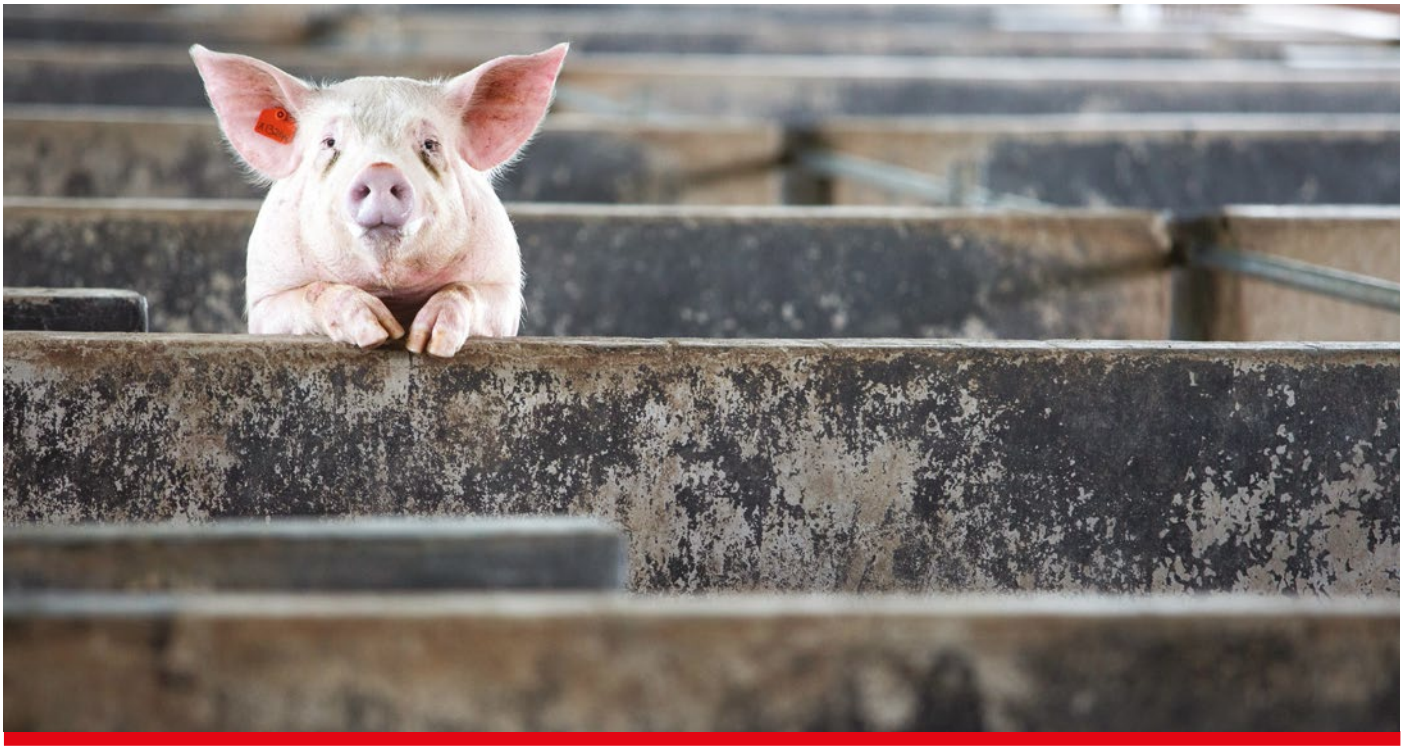
Emergence and spread of transboundary animal and zoonotic diseases continue to threaten the lives and livelihoods of people worldwide

Contributor: Subhash Morzaria

I am honoured to be invited by the Food and Agriculture Organization of the United Nations (FAO) to write an editorial for this issue of *EMPRES-Animal Health 360*. The world is deeply preoccupied in tackling the ongoing COVID-19 pandemic, the first of this magnitude in this century, which is continuing to cause the loss of human lives, disrupt normal human activity and cost trillions of US dollars to the global economy. COVID-19 yet again underscores that infectious diseases can emerge anytime, anywhere, with unpredictable consequences. In this regard, the current issue of *EMPRES-Animal Health 360* is a timely reminder that there are still many other existing and emerging infectious diseases, both of humans and livestock, that present a constant threat to the lives and livelihoods of people, particularly the most vulnerable in low- and middle-income countries.

This issue of *EMPRES-Animal Health 360* addresses important aspects of three high-impact transboundary animal diseases: zoonotic avian influenza, and non-zoonotic African swine fever (ASF) of pigs and the vector-borne lumpy skin disease of cattle and water buffalo. All of these diseases have a viral aetiology, and have rapidly spread worldwide from their points of origin, across borders, regions and continents. In most of the newly infected countries these diseases have become endemic soon after their incursion, and continue to remain a threat to humans and their livestock in infected and non-infected countries. Their negative social and economic impacts are a major concern to the global community as they thwart development efforts to improve economies, reduce poverty, enhance livelihoods, and improve food safety and security, particularly in the global South.

While classical avian influenza due to H5N1 still remains entrenched in several countries in Africa, Asia and Europe, where it causes regular outbreaks affecting poultry production, the major concern in recent years has been the continued genetic drift and recombination events, resulting in the emergence of a number of haemagglutinin (HA) clades and subtypes, which are not only impacting on the poultry industry but also continue to pose a risk of a human pandemic. Of particular interest are the predominant HA clade 2.3.4.4b and the emergence of a broad range of H5Nx subtypes such as H5N1, H5N3, H5N4, H5N5, H5N6 and H5N8 that have become widely distributed in Africa, Asia, Europe and North America. The existence of hugely diverse genetic populations in birds will further perpetuate the emergence of new genetic variants, and presents a significant challenge to the effective control and prevention of avian influenza worldwide. FAO, the World Organisation for Animal Health (WOAH), the World Health Organization (WHO), the European Union and several other organizations and governments



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Quarantine and movement-control measures during an ASF outbreak response are essential.

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Simple, practical and feasible biosecurity standards for small- and medium-scale poultry farming.

have raised the alert about the increasing risk of new introductions of H5Nx, and the need for more intense monitoring and characterization of viruses from poultry, wild birds and humans to ascertain that the current vaccines are compatible with circulating strains, and also better define emerging risks from these viruses. The current trend in the epidemiology of the influenza A viruses calls for a revival of a more coordinated and concerted global effort to contain their impacts.

ASF, a highly fatal disease, is another serious emerging problem with its spread to Asia, Europe and the Russian Federation. It continues to have a significant impact on global food security, particularly following its first detection in China and then its rapid spread in several other countries in East, Southeast and South Asia. More recent detection of the virus in the Dominican Republic and Haiti in 2021 is extremely worrisome for the Americas, as the virus has the potential to decimate the pig industry in the continent. Without the availability of licensed vaccines, the future thrust for control and eradication must be focused on high sanitary standards, biosecurity in farms and along value chains, early detection, culling, and management of disease in wild boars. All of these are challenging when in many parts of the world 60–70 percent of the pig production is in the hands of smallholder communities where veterinary services are woefully underfunded. Undoubtedly, the availability of safe and efficacious vaccines against ASF would be a tremendous boost to the global pig industry.

Like ASF, lumpy skin disease has been recently introduced in Asia, affecting cattle and water buffalo. Although its impact on cattle and water buffalo is not as dramatic as that of ASF on pigs, its spread has resulted in production losses, particularly in South Asia where large ruminants play an important role in the livelihoods of poor people.

The vulnerability of many uninfected countries to new disease incursions, rapid spread and entrenchment is very much linked to the nature of livestock systems that have poor biosecurity at the farm level and along the food chain, and the failure of veterinary services to provide adequate extension services for early detection and response.

> “Outbreak investigation to inform evidence-based disease control, and promoting One Health actions to improve the efficiency of disease prevention”

The issue also illustrates how FAO is helping its Member Nations to build capacities to address these diseases, including initiatives such as the Surveillance Evaluation Tool, Virtual Learning Centers with cascade training linked to outbreak investigation to inform evidence-based disease control, and promoting One Health actions to improve the efficiency of disease prevention and control at country level. It is also pleasing to see that FAO’s Emergency Prevention System Global Animal Disease Information System (EMPRES-i) has finally been revamped. Now referred to as EMPRES-i+, it has a number of new features that include improved data quality, advanced analytics and visualization tools, and interoperability with data platforms from other health and environmental sectors.

The issue is a great reflection of a range of contributions that FAO makes in improving the control of high-impact transboundary animal and zoonotic diseases, working in close collaboration with other international agencies such as WOAH, WHO, regional organizations and government partners. 360

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PERSPECTIVE

Avian influenza: information must improve effective interventions

Contributors: Les Sims, Sophie von Dobschuetz, Dirk Pfeiffer, Tim Harder, Guillaume Fournié, Arnaud Bataille, Folorunso Fasina, Beatriz Martínez-López and Joanne Taylor[1]

BACKGROUND

Avian influenza (AI) emerged as a serious zoonotic and potential pandemic threat in 1997, when a fatal disease associated with a novel H5N1 highly pathogenic avian influenza (HPAI) virus occurred in poultry and humans in Hong Kong Special Administrative Region. Related H5N1 viruses, within the so-called goose/GD/1-96-lineage (Gs/GD/96-lineage), continued to circulate and evolve in China before spilling over to other parts of East and Southeast Asia in 2003/04, causing disease in poultry and, occasionally, in humans. In 2005–2007 a strain of H5N1 HPAI (clade[2] 2.2) virus spread to Africa, Central Asia, East Asia, Europe, the Near East, the Russian Federation and South Asia, causing unprecedented losses for the poultry sector and threatening livelihoods in many low- and lower-middle-income countries. Gs/GD/96-lineage H5 HPAI viruses continued to evolve, and from 2013 onwards one particular lineage of H5 HPAI virus (clade 2.3.4.4) diversified to produce different subtypes (e.g. H5N2, H5N6, H5N8) as a result of reassortment between poultry and wild bird influenza viruses. Other intercontinental waves of infection have occurred subsequently with related viruses, including H5N8/H5N2 HPAI in 2014/15 (clade 2.3.4.4c) that spread to North America and caused the largest HPAI epidemic in the history of the United States of America.

The latest, ongoing, intercontinental wave commenced in 2016 and resulted in another H5Nx virus within clade 2.3.4.4 (2.3.4.4b)[1] spreading from western China to Africa, including, for the first time, eastern and southern Africa; Central Asia; East Asia; Europe; the Near East; and South Asia (FAO 2017, 2018). Subsequent waves of infection with related clade 2.3.4.4b viruses have occurred, with repeated waves of infection across Eurasia in 2019/20 and 2020/21, and new incursions into Africa and the Americas involving countries that had never reported HPAI[3] (OFFLU, 2021).

H5Nx viruses within the Gs/GD/96-lineage continue to circulate and remain endemic in poultry in a number of countries and subregions, including China, parts of South and Southeast Asia, Egypt, and Nigeria. Occasional human clinical cases occurred as a result of exposure to infected poultry or their products, with most reported from China. Indeed, an apparent increase in zoonotic human cases, associated with clade 2.3.4.4b H5N6 viruses, was reported in China between June and October 2021. This was preceded by human infections in Nigeria and the southern Russian Federation with related H5N8 viruses. Nonetheless, there has been no evidence of sustained human-to-human transmission of Gs/GD/96-lineage H5Nx viruses to date.

In 2013, a low pathogenicity (LP, for chickens) AI virus emerged in eastern China (influenza A(H7N9)), that showed a higher capacity to infect and produce disease in humans than the Gs/GD H5Nx viruses, resulting in a greater number of human clinical cases. Human infection is primarily caused by exposure to infected poultry or poultry products. Influenza A(H7N9) was initially found in live bird markets (LBM) in Shanghai, China, and most human cases had a link to these markets, reflecting events that occurred in 1997 when Gs/GD/96-lineage H5N1 emerged as a serious zoonotic threat. In late 2016, a highly pathogenic (to chickens) strain of this H7N9 virus emerged and was detected widely in farms across China. The emergence of this virus coincided with a marked increase in human cases in the so-called fifth wave of cases, although the majority of these were still caused by the low pathogenicity form of the virus. Nevertheless, the HPAI strain of H7N9 virus has some features that appear to make it a greater threat to humans than other zoonotic AI viruses (Sun *et al.*, 2018). Measures introduced in China in 2017/18, including vaccination of poultry, have markedly reduced the quantities of circulating viruses and, as a result, the number of human cases has fallen dramatically (Wu *et al.*, 2019). These viruses continue to circulate and evolve; however, only one human case (in 2019) has been reported since the poultry have been vaccinated. Changes to the viruses may have reduced their capacity to infect mammals (Yin *et al.*, 2021), while some strains from southern China appear to be able to overcome immunity generated by vaccines currently in use (Chen *et al.*, 2021).

CONTENTS

[1] OFFLU Applied Epidemiology Group.

[2] A formal system of clade nomenclature has been established for HA sequences of highly pathogenic H5 viruses belonging to the Goose/Guangdong/96 lineage (see, for example, Smith *et al.*, 2015).

[3] Algeria, Botswana, Estonia, Latvia, Lesotho, Mali, Mauritania and Senegal reported HPAI for the first time (see FAO, 2022).

Genetic diversity and evolution of AI viruses

AI subtypes (e.g. H5N1, H7N9, H9N2) are defined by their haemagglutinin (HA) and neuraminidase (NA) glycoproteins, encoded by the HA and NA genes. The genome of influenza A viruses consists of eight unique segments of single-stranded negative sense RNA, which encode at least 11 proteins. The HA and NA are present on the outer surface of the virus, and the HA in particular stimulates a strain-specific protective humoral immune response in infected animals. Immunity to the HA protein is a particularly strong driver of evolution of influenza viruses.

AI evolution is dynamic as these viruses frequently undergo genetic changes, either through gene mutation or following reassortment, the latter resulting from gene exchange between two influenza viruses infecting the same cell. In this way, the same subtype can evolve into different strains that may have very different characteristics. Even different subtypes can emerge through reassortment (e.g. H5N6 from H5N1).

The HA genes of the highly pathogenic H5 AI viruses belonging to the Gs/GD/96-lineage – named after the first detection of this virus strain in a goose in Guangdong, China – have circulated and evolved since 1996. A formal system of nomenclature was established to divide genetically similar viruses within this lineage into groups, referred to as clades (e.g. clade 2.3.2.1c). Genetic evolution has also been demonstrated for H9 and H7 virus HA proteins, but official, standardized nomenclature systems for these clades are yet to be established.

Despite active surveillance efforts, and the detection of the virus overseas in illegally imported meat, there is no evidence to show that H7N9 has become established in birds in other countries (Shibata *et al*., 2018; Sun *et al*., 2018).

As with the Gs/GD/96-lineage H5 viruses, sustained human-to-human transmission of H7N9 viruses has not occurred. H7N9 viruses have evolved into different lineages and some novel HPAI strains have acquired different NA genes (e.g. H7N2) which experimentally are more infectious (and lethal) for ducks than the original 2013 viruses (Shi *et al*., 2018).

Other zoonotic AI viruses have also emerged over the past 20 years but have not caused as many severe human infections. H9N2 subtype viruses[4] are widespread and endemic to many countries in Asia (mainly Y280 lineage and some G1 lineage) as well as the Near East and North Africa (G1 lineage) (Nagy *et al*., 2017). While they can infect humans, they rarely produce severe disease.

We now have over 20 years of experience in the control and prevention of zoonotic AI, which has been supported by considerable research and disease investigations to understand the epidemiology of these viruses. As a consequence, the knowledge base on these viruses and the diseases they cause has grown substantially.

Risk assessments and modelling of introduction and transmission of AI viruses within poultry populations, undertaken to guide control and preventive programmes and to assist in forecasting, have utilized this information. However, these studies have also identified that our knowledge base is still incomplete and/or based on biased information, which often results in high levels of uncertainty that limit its utility for decision-making and modelling. Without accurate and timely information provided by countries, model outputs can sometimes be misleading. In addition, production systems and viruses change over time which means that it is important to recognize that models and risk assessments need to be updated and revised regularly to remain useful for decision-makers devising disease control programmes.

The information base on AI is far better than it has ever been. Nevertheless, there are still important gaps in both data and knowledge. In this review we highlight some of the important gaps that we believe should be addressed through targeted research and thorough epidemiological case investigations.

SOME IMPORTANT KNOWLEDGE GAPS

SUSCEPTIBLE ANIMAL HOSTS

Wild birds and the wild bird/poultry interface

Wild waterbirds of the orders *Anseriformes* and *Charadriiformes* are the main natural hosts of low pathogenicity AI viruses (Venkatesh *et al*., 2018). HPAI viruses were rarely detected in wild birds until events from 2002 onwards, when Gs/GD/96-lineage H5N1 viruses infected a range of wild and captive bird species, causing disease and death in some instances (Ellis *et al*., 2004).

The evidence supporting the role of wild birds in the long-distance transmission of some Gs/GD/96-lineage H5Nx HPAI viruses is now strong, based on information gathered from intra- and intercontinental waves of transmission and viral genetic data (Bouwstra *et al*., 2015; Hill *et al*., 2015; Global Consortium for H5N8 and Related Influenza Viruses, 2016; Pohlmann *et al*., 2017; Lee *et al*., 2018; Marchenko *et al*., 2018; van den Brand *et al*., 2018). This information has been used in forecasting (FAO, 2016). Detection of a novel clade of virus in wild birds in western China or southern Siberia is now

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Farmer tending to her ducks in Viet Nam.

[4] Several H9N2 lineages have been identified. WHO refers to the G1 lineage for viruses with a direct link back to the A/quail/Hong Kong/G1/97 H9N2 virus HA gene, and the Y280 lineage for viruses with a direct link back to the Duck/Hong Kong/Y280/97 H9N2 virus HA gene. The latter viruses are also referred to in some publications as BJ94 lineage and G9 lineage.

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Bung Boraphet Water Bird National Park is the largest wetland in the freshwater swamp category of Thailand. It is a habitat for many bird species (both migratory and residential), and one of Southeast Asia's premier birding destinations.

regarded as an alert for likely intercontinental spread, but it is still not possible to forecast the extent and exact geographical range of transmission.

Knowledge on the exact mechanisms and drivers of long-distance spread of Gs/GD/96-lineage H5Nx viruses by wild birds and the species (or combinations of species) involved, remains weak. Experimental infections of wild birds have demonstrated differences in virus behaviour and host response, depending on the strain of virus and the host (Spackman *et al*., 2017; van den Brand *et al*., 2018). In some cases, infection is subclinical (Hall *et al*., 2021). Effects on migratory fitness costs and pre-existing population immunity have been subject to some studies with other AI viruses (van Dijk *et al*., 2014; Hoye *et al*., 2016). Other work tracking migratory and nomadic species has also been conducted (Zhang *et al*., 2011; Bengtsson *et al*., 2014; Kang *et al*., 2016; Lee *et al*., 2020). Recent reports of active surveillance have also provided information on the likely species involved (Gobbo *et al*., 2021). These studies have greatly improved knowledge on species or combinations of species potentially involved in long-distance spread of the virus, but gaps remain, including limited surveillance in areas where wild *Anatidae* congregate in summer (Verhagen *et al*., 2021).

Until recently, no evidence existed for long-term persistence of specific strains of Gs/GD/96-lineage H5Nx HPAI viruses in wild bird populations. For example, wild bird infections with clade 2.2 virus were only recorded in Europe between late 2005 and early 2009, and no new cases of clade 2.3.4.4c H5Nx viruses in wild birds have been detected in North America since 2016 after the 2014/15 outbreak. The reasons for this are not well understood and warrant further study. However, events in the current intercontinental wave that commenced in 2016/17 provide additional information. The virus is still being detected in wild birds in Europe and Asia during summer and late 2021, with spillover to domestic poultry occurring in the autumn of 2021. It is not known if this represents an independent cycle of infection maintained in wild birds since 2016, or whether it involves the reinfection of wild birds by viruses maintained in poultry populations as has been proposed (Lewis *et al*., 2021).

While it is not exactly clear how and where novel Gs/GD/96-lineage viruses become established in wild birds, the sharing of habitats between domestic and wild waterfowl in China provides ample opportunity for transmission in both directions (Prosser *et al*., 2016). Production systems conducive for contact with wild birds, in particular integrated duck and rice farming systems, appear to be important. Events in recent years suggest a need to examine other parts of Eurasia where Gs/GD/96-lineage viruses remain endemic in poultry populations (Verhagen *et al*., 2021).

East Asia has been the source of the parent strain of all Gs/GD/96-lineage H5Nx AI viruses that have been involved in intercontinental spread. It is noteworthy that viruses originating in East Asia, regardless of their route of introduction, are now endemic in geographically distant poultry populations (e.g. clade 2.2 and derivatives in Egypt and clade 2.3.2.1c in Nigeria). However, once established in these locations endemically for several years, they did not spread to other continents. This may have changed with clade 2.3.4.4b viruses. Considerable reassortment has occurred between Gs/GD/96-lineage H5Nx viruses and wild bird AI viruses. The geographical site(s) and habitats where reassortments occur have not been established, but molecular dating of 2016 H5N8 reassorted viruses in the Netherlands suggests reassortment occurred earlier than the first introduction into Europe (Beerens *et al*., 2017).

Exact transmission pathways between wild birds and poultry are not always determined in epidemiological investigations of outbreaks (Grear *et al*., 2018), but a range of pathways have been identified (Verhagen *et al*., 2021).

To date, there is no evidence to support wild bird involvement in transmission of influenza A(H7N9). The detection of reassorted strains in domestic ducks (Shi *et al*., 2018) may represent an important event in the natural history of these viruses, as much as the host shift for Gs/GD/96-lineage H5N1 HPAI viruses in the early 2000s to infect domestic ducks is regarded as an important turning point in the evolution of these viruses (Sims *et al*., 2005). The role (if any) of wild birds in the long-distance transmission of H9N2 viruses found in poultry across Asia, the Near East and North and West Africa remains undetermined.

Questions have been raised as to whether songbirds have a significant role in the genesis and transmission of zoonotic AI viruses from birds to humans. Infection has been detected with Gs/GD/96-lineage H5Nx viruses in a wide range of species (Bodewes and Kuiken, 2018). The experimental infection of finches, sparrows and parakeets with influenza A(H7N9) was successful (Jones *et al*., 2014).

GAPS

- What are the drivers of intercontinental spread of novel Gs/GD/96-lineage H5Nx viruses by wild birds?
- Which species, or combinations of species, are involved in intercontinental spread?
- Do any strains of Gs/GD/96-lineage highly pathogenic (for poultry) H5Nx viruses persist in wild bird populations for as much as one year or more?
- What biological and environmental factors affect the persistence of HPAI viruses in wild birds and in environments?
- What are the principal transmission pathways between wild birds and poultry, in both directions?
- What is the extent of infection of potentially zoonotic H7Nx viruses in domestic ducks in China?

Domestic poultry

Domestic ducks play a key role in maintaining Gs/GD/96-lineage H5Nx HPAI viruses. The course of infection in individual birds and its outcome have been studied, and both seem to depend on the viral strain and the age of ducks at the time of infection. Long-term carriers in individual ducks have not been identified, with the longest period of virus shedding following experimental infection being 17 days (Hulse-Post *et al*., 2005). Little is known about the course/duration of infection with these viruses on a flock basis, including the duration of protection from acquired immunity or the role played by virus in the environment in which they are reared, such as ponds, lakes and paddy fields. These are critical gaps in understanding the behaviour of these viruses in the field. As discussed previously, the detection of H7 viruses derived from Chinese influenza A(H7N9) in ducks warrants close attention.

Some breeds of chicken appear to be intrinsically more resistant to AI than others, based on experimental studies and/or survival during outbreaks (Lee *et al*., 2016). The mechanisms for such resistance are poorly understood, but research to identify relevant genetic factors is ongoing (Drobik-Czwarno *et al*., 2018). In addition, certain Gs/GD/96-lineage H5Nx viruses have caused less severe disease in chickens than others.

Quail have been highlighted as potentially important in influenza epidemiology (Xu *et al*., 2007) but the precise role they play in the genesis of novel AI viruses or transmission is unclear, given that they usually account for a small fraction of overall poultry populations and are generally present in very low numbers in LBM.

GAPS

- What are the infection dynamics of Gs/GD/96-lineage H5nx HPAI viruses in duck flocks?
- What is the duration of immunity in ducks following natural exposure?
- What is the epidemiological significance of novel H7Nx HPAI viruses detected in 2017 in ducks in China?
- What role do variations in the host genetics of chickens play in the epidemiology of the disease?
- What is the role of quail under field conditions in the genesis and transmission of Gs/GD/96-lineage H5nx HPAI viruses?

Courtesy of Alaska Region U.S. Fish & Wildlife Service / Kristine Sowl

Red fox near Kinzarof Lagoon, Izembek National Wildlife Refuge.

Other hosts

The role of mammals in the epidemiology of AI, and their likely role in the emergence of a human pandemic influenza virus from an avian virus, is also incompletely characterized. It has been hypothesized that pigs may be required as "mixing vessels" to produce a human pandemic influenza virus, given they have receptors for, and can be infected with, both avian and human influenza strains. At least three factors appear to be important in determining whether an AI virus could become a human pandemic virus: (i) the capacity to bind efficiently to mammalian upper airway receptors; (ii) optimal pH for membrane fusion; and (iii) high polymerase activity (Herfst *et al*., 2018). Some of these changes can occur when mammals, including humans and ferrets, are infected, but have also emerged independently in avian viruses (Sun *et al*., 2018). Pigs have been reportedly infected sporadically with H9N2 and other AI viruses, but experimental serial passage of one strain of H9N2 virus in pigs could not be sustained by the tenth passage (Mancera Gracia *et al*., 2017). Factors that limit sustained transmission in this case are not well defined. Airborne transmission between mammals can occur under experimental conditions in ferrets, after reassortment with mammalian influenza viruses (Cáceres, Rajao and Peres, 2021).

We do not yet know the role played by domestic pets, rodents or other urban and peri-urban mammals in transmission or maintenance of zoonotic AI viruses. Both experimental and natural infection of these mammals have been reported.

GAPS

- What role do mammals have in the transmission cycle of zoonotic AI viruses?
- What role are they likely to play in the development of a human pandemic influenza virus (if any)?

ENDEMICITY

A number of countries have remained endemically infected with Gs/GD/96-lineage H5Nx HPAI virus since the first incursion/emergence. Most of these countries, including Bangladesh, Egypt, Indonesia, Myanmar, Nigeria and Viet Nam, have been subject to reincursions. Endemicity can only occur if there are sufficient hosts or an environmental niche in which the virus can survive. In tropical countries it is unlikely that virus would persist for a prolonged period in the environment, given the very hot conditions that would customarily lead to virus inactivation. Yet AI viruses have persisted in a number of tropical areas, suggesting that they must have sufficient exposed, susceptible avian hosts to allow virus persistence at the population level (see earlier for more information on avian hosts).

The broad factors that are predictive of endemicity once the virus is introduced to an area or country have been described (FAO, 2011), but there is insufficient understanding of the contribution of each factor. In general, the two main factors are: (i) the nature of the poultry production system (very large

numbers of poultry reared by a variety of farm types and traded in conditions of suboptimal biosecurity, and in some places large numbers of extensively reared ducks); and (ii) the capacity of veterinary services for early detection of all cases of infection and for taking appropriate and timely follow-up action. This is further complicated by a reluctance by some farmers to report disease. Other factors have also been considered in modelling studies. Some have attempted to compare the relative importance of large- and small-scale production (Wibawa *et al*., 2018), but these studies are constrained in most countries by an absence of reliable data and the existence of very complex production and marketing chains that are not entirely segregated by farm type or marketing system.

GAPS

What is the relative importance of the various factors linked to endemicity?

What is the best way to capture factors associated with endemicity in risk assessments and modelling?

Are there other factors, that have not yet been identified, which are involved in the endemicity of zoonotic AI viruses?

What are the relative contributions of different production and marketing systems in the maintenance and onward transmission of zoonotic AI viruses?

MODES OF TRANSMISSION

The information available on the modes of transmission of virus into poultry flocks and even between birds is limited. The most important factors in local AI virus spread are direct and indirect (e.g. via contaminated feed or surface water) contact with infected birds, and human activities in which objects such as clothes, boots, equipment or vehicles are contaminated and can transport viruses among premises. It is noteworthy that influenza A(H7N9) has not been detected outside of China in poultry or wild birds, despite considerable active surveillance in high-risk countries. It is not clear why spread beyond China has not occurred, given that cross-border trade in poultry from China has continued (often informally). The reasons for this warrant additional investigation.

Airborne transmission

Evidence is building that airborne transmission may play a role in the spread of AI viruses within poultry populations (i.e. flocks on a farm or poultry in a market) and even between such populations (i.e. between farms) (Zhao *et al*., 2019). For example, short-distance transmission has been established in a mock live bird slaughter area (Bertran *et al*., 2017), and virus has been detected in the air inside and outside affected farms and in LBM (Torremorell *et al*., 2016; Zhou *et al*., 2016). In many AI outbreaks, "local transmission" has occurred in an area from 500 m to 1 km around affected farms, but the exact mode of spread was not determined. The relative importance of airborne transmission compared to other modes of spread is yet to be established.

Notably, all of the important zoonotic AI viruses are shed via the respiratory route in greater quantities than the faecal route by chickens (Gs/DGD/96-lineage H5Nx, H7N9, H9N2). The significance of this finding in regard to the importance of aerogenous transmission warrants further investigation.

GAPS

What is the relative contribution of each of the different modes of AI introduction into farms and transmission between birds?

Vaccination and other forms of immunity

Vaccination against AI usually increases resistance of poultry to infection, prevents clinical signs and reduces virus shedding. At the population level, ideally, vaccination will reduce the effective reproductive number R (that is, the expected number of new infectious hosts that one infectious host will produce during its period of infectiousness in a large population) to less than 1, thereby ultimately leading to extinction of the virus, but only if adequate vaccination coverage is achieved. However, the extent of the reduction in R depends on a number of factors, including pre-existing diseases that modify immune responses post-vaccination, the antigenic match between the vaccine and field strain and whether sufficient doses of vaccine are administered to individual birds. Modelling these various factors can be complex, especially across large poultry populations with different farm and species types as well as varying vaccination programmes.

In many places where vaccination is used as an aid to prevent AI, information on the proportion of the population vaccinated is incomplete and information on post-vaccination monitoring (if it is done) is not published. Systems for measuring cell-mediated immunity in vaccinated birds, especially for those given vector vaccines, are poorly developed, yet it is likely to be an important element in the overall immune response and levels of protection. In the case of H7N9 viruses, antigenic change in viruses reduced the capacity of viruses to infect mammals despite increasing susceptibility of vaccinated chickens to infection (Chang *et al*., 2020). These factors, in turn, influence the utility of outputs generated by risk assessments and modelling.

Antigenic variant viruses have emerged in a number of countries where vaccine is used, but they can also arise in unvaccinated populations (Wang *et al*., 2014). The extent to which vaccination versus infection in unvaccinated hosts contributes to this process of emergence of new antigenic variants is another knowledge gap. Experimental studies demonstrate that antigenic variants can be selected in partially immune chickens, but in a number of countries the same vaccine antigen has been used for a number of years. In several countries, mismatches between vaccine antigens and circulating virus strains have occurred. In addition, often only part of the target population is fully vaccinated. Virus continues to circulate in these places, but despite this only small number of outbreaks are reported in some of these countries. Questions have been raised as to the contribution of poorly matched vaccines to apparent low numbers of reported outbreaks.

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Veterinarians administering free vaccines to chickens to prevent another outbreak of the H5N1 virus at one of the many vaccination points set up by the Vietnamese Government.

GAPS

- More reliable reporting of proportion vaccinated for different poultry populations, as well as results from post-vaccination monitoring, must be encouraged.
- Systems for measuring cell-mediated immunity in vaccinated birds must be developed.
- What is the relative contribution of vaccination as selection pressure on antigenic variants?
- What effect does vaccination have in preventing disease in places where there is antigenic mismatch and incomplete vaccination coverage of target populations?

INFORMATION FROM EPIDEMIOLOGICAL INVESTIGATIONS, INCLUDING SURVEILLANCE

Epidemiological investigations of outbreaks

Comprehensive epidemiological data are available from outbreaks in high-income countries, e.g. Canada in 2014, (Xu *et al*., 2016) and the Midwest of the United States of America in 2015 (United States Department of Agriculture Animal and Plant Health Inspection Service, 2015), but there are very few of such quality from outbreaks in low- and lower-middle-income countries. Since poultry production systems and therefore the epidemiological context are very different in these countries, this information is critical, especially when outbreaks occur in new, previously unaffected locations.

> “Improved disease outbreak investigations generating good quality epidemiological data are urgently required, especially in low- and lower-middle-income countries”

Surveillance systems and data (and politics)

Active and passive surveillance for AI is carried out in most countries, generating substantial amounts of data. These data are collected by animal health and human health authorities, as well as by university researchers. However, only a small proportion of the generated data are made available outside the countries where the work is implemented. In addition, detailed information about the surveillance systems, their performance characteristics and associated biases is often not available.

Passive surveillance systems are known to perform poorly in terms of sensitivity and timeliness in many parts of the world (especially low- and lower-middle-income countries) and, as a result, maps of outbreaks tend to highlight areas, or farming systems, associated with better reporting systems. This introduces a significant bias that needs to be acknowledged explicitly when utilizing such data for risk assessment and modelling purposes.

Active surveillance for AI in endemically infected regions has focused on LBM because this is a more cost-effective approach for collecting samples from the poultry population in a particular catchment area. Due to the amplification of virus in such markets, the probability of finding virus is increased as compared to logistically much more difficult and more costly surveys conducted on randomly sampled farms and their birds.

Techniques for collecting surveillance samples are not standardized, making comparisons difficult, in addition to the marked differences between markets where much of the surveillance takes place. In many cases, it is not possible from published information to determine how samples were collected or which types of samples were positive (Hood *et al*., 2021).

GAPS

- The availability of AI surveillance data to the global community in a timely fashion must be encouraged.
- Development of standardized techniques, protocols and data-collection forms for collecting and reporting surveillance data which are agreed to be used by the international community must be encouraged.

Viruses and their genetic sequences

There are large gaps in information on presently circulating virus strains, and often considerable delays in obtaining and releasing these data. For example, from September 2017 to July 2018 no new H7N9 genetic sequence information was provided to public genome databases, even though the viruses were still circulating. Sequences from that time period were eventually submitted in 2019 and 2020 (see Influenza Research Database, 2022).

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Sampling chicken and ducks during active surveillance in Cambodia.

Genetic information is crucial for epidemiological studies to establish likely links between affected premises. This has been used to good effect in a number of outbreaks, but depends on timely availability of sequence data from each affected farm (Xu *et al*., 2016; Lee *et al*., 2018).

It is important to recognize, however, that genetic sequencing information available through public databases is not based on random sampling processes from an underlying population. Inferences that are to be drawn from any analyses using these data need to take account of the potential impact of this bias. The metadata submitted along with genetic sequences should include some key epidemiological information about the sampled population and context of sampling, allowing users to appreciate the nature of potential selection biases. This would allow genome sequencing data to be analysed and interpreted alongside outbreak data in a more meaningful way. Whole genome sequencing provides much more valuable information than the sequencing of single genes (Verhagen *et al*., 2021).

GAPS

- The timely submission of sequences accompanied by appropriate metadata that is explicit about the representativeness or selection bias must be encouraged.
- Awareness of the correct use and limitations of genetic analyses when making epidemiological inferences must be emphasized.
- Whole genome sequencing must be aimed for where possible.

PRODUCTION SYSTEMS AND VALUE CHAINS

The structure of production, distribution and processing systems (also referred to as value chains) has a major influence on the spread of AI viruses. It shapes poultry population dynamics and the frequency and intensity of potential infectious contacts (both direct and indirect) between poultry populations.

Considerable information has been gathered on value chains that demonstrate their complexity and changing nature. Value chain studies have been promoted as an important prerequisite for being able to conduct meaningful risk assessments, but in many cases this information is coarse, based on expert opinion and collated at an aggregated level, and provides only basic data about the structure of at-risk populations, such as censuses of poultry farms and LBM. Often data gathered are either out of date or of poor quality, or the required data are not available at all. For example, gathering accurate data on the extent and nature of informal trade, both in-country and across borders, remains a challenge. There is also no simple way to categorize LBM, given the very wide range of management systems in place. Value chains can also change rapidly in response to alterations in economic conditions or in the face of measures implemented to control disease.

In cases where the data are reliable, information on sources of birds for live poultry markets is valuable in determining the likely threat of introduction of an AI virus by incoming birds or fomites. For example, all birds going to Hong Kong LBM are vaccinated against H5 and H7 AI viruses, and all or a sample are tested for antibodies before being dispatched from farms. In addition, no live ducks, geese or quail can be sold in these markets. However, even in this controlled environment the exact contribution of each of these measures to risk reduction has not been determined.

The role of co-circulation of different viruses in a production system, together with the use of vaccines, on detection of infection warrants further investigation (Moyen *et al*., 2021; Ripa *et al*., 2021). Work is progressing in this area (see, for example, work being conducted via the One Health Poultry Hub in a number of countries), but the difficulties in ensuring information remains relevant has been demonstrated during the COVID-19 pandemic, during which significant changes occurred in value chains as a result of restrictions imposed on slaughter plants due to disease outbreaks.

The continuously increasing demand for poultry meat, particularly in the context of economic development, provides incentives for increasing production, which can result in value chain structures that greatly increase (e.g. weak farm and market biosecurity) or, in some cases, reduce (e.g. well-managed compartments) the opportunity for the spread and endemicity of AI viruses.

GAPS

Understanding of value chains and their role in virus spread must be improved, taking account of the social, cultural and economic factors that shape them.

Evidence-based approaches for structural change of value chains must be developed, that result in a reduced risk of virus spread, amplification and endemicity, based on measures that appear to have been successful elsewhere.

Farm-level biosecurity

Most commercial farms have some deficiencies in their biosecurity, even in high-income countries, and these often only become apparent during infectious disease outbreaks. In addition, many birds are produced under conditions of minimal biosecurity, such as ducks on ponds and rice fields or backyard poultry. Systems for assessing biosecurity exist (see, for example, Biocheck.UGent, 2022), but these are not necessarily applicable to small-scale production systems. The drivers and barriers of uptake of biosecurity measures need to be well understood given the observed low uptake of measures (Rimi *et al*., 2019; Høg *et al*., 2021).

GAPS

A system must be developed for assessing biosecurity, considering location, facilities and management procedures suitable for smaller scale producers.

Acceptable and sustainable interventions for progressive biosecurity improvements must be developed that are based on sound anthropological understanding of the social, economic and cultural factors influencing farmers' behaviours.

Live bird markets and traders

Much work has been done on LBM, but information on the effectiveness of control measures is generally poor or uses proxy viruses (e.g. levels of H9N2 instead of H5 Gs/GD/96-lineage viruses) to measure improvements (Kung *et al*., 2003). Measures in LBM are of limited value if they result in behavioural adaptations that transfer disease risk to other nodes of the value chains, e.g. if no overnight keeping in markets is allowed, but live birds are just removed to somewhere else, such as to traders' yards. There is limited knowledge and understanding of the way in which the social, economic and cultural contexts experienced by poultry production and market stakeholders limit behavioural changes, such as uptake of improved biosecurity practices in LBM (Høg *et al*., 2019, 2021).

While the circulation and amplification of AI viruses in LBM, or through the chain of transactions from farms to LBM, is documented, the contribution of LBM and traders in introducing the infection back to farms is unclear.

GAPS

Recommendations must be developed for acceptable and sustainable interventions that are based on sound anthropological understandings of the social, economic and cultural factors influencing traders' and LBM workers' behaviours.

Are LBM, through traders' movements, a source of infection for upstream poultry farms?

A view inside a commercial chicken farm holding 5 000 layer hens. The flock has been successfully protected from bird flu through good hygiene and good farming practices.

CLIMATE

AI demonstrates considerable seasonal variation, with peak periods usually occurring during the winter, or in association with migration periods of wild birds. However, seasonal AI patterns have also been described in some places with little seasonal climatic variation, e.g. southern Viet Nam, suggesting other factors are also important such as variations in production and trade to meet demand (Delabouglise *et al*., 2017). Effects of humidity on virus survival and transmission have been investigated for human influenza, but few studies were performed on links between absolute humidity and transmission in poultry.

Climate change could result in modifications to wild bird migration, but these effects have not been explored in detail.

GAPS

The relative contribution of climatic and economic factors to seasonal changes in viral dynamics at local, regional and global levels must be investigated.

The potential impact of climate change on AI virus dynamics at local, regional and global levels must be explored.

What role does humidity play in AI virus survival and does absolute humidity influence transmission in poultry?

VALIDATION, REVISION AND BIAS IN EPIDEMIOLOGICAL MODELS AND RISK ASSESSMENTS

Many studies modelling AI have been published, for predictive or analytical purposes, and using dynamic and statistical modelling approaches (Stegeman *et al*., 2011). These include models that examine likely effects of surveillance and control measures (Savill *et al*., 2006; Fournie *et al*., 2013; Hill *et al*., 2018; Mellor *et al*., 2018; Younjung *et al*., 2018; Vergne *et al*., 2019), the risk factors that facilitate transmission or persistence of virus (including identification of niches that would be suitable for transmission if the virus were to gain entry) (Paul *et al*., 2014), the structure of live poultry trading networks (Moyen *et al*., 2021) and information on transmission parameters (van der Goot *et al*., 2005; Willgert *et al*., 2020). Gaps in information that can affect these studies have been reviewed (Gilbert and Pfeiffer, 2012).

In addition, a large number of risk assessments have been conducted that attempt to answer specific questions about the likelihood of future events and the identification of suitable areas with respect to AI transmission (e.g. Belkhiria *et al*., 2016; Dhingra *et al*., 2016).

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Live chicken for sale at a live bird market.

There is a need for researchers developing theoretical models based on published knowledge or primary or secondary data to more explicitly discuss and emphasize the hypotheses and assumptions on which the models rely, as well as the uncertainty and biases associated with the knowledge and data, and the impact that this will have had on the model outputs. Models aimed at examining control measures need to take into account that published data on most avian outbreaks in Asia is biased, due to late detection and unreported persistence of virus prior to formal reports. Weaknesses in surveillance systems, both active and passive, need to be recognized, especially when there are strong disincentives for disease reporting that are likely to lead to bias. They also need to consider a wider range of preventive measures, including pre-emptive vaccination, rather than reactive measures, especially in places where these viruses remain endemic. If field data exist that challenge the conclusions of the model, then these also needs to be considered and models be revised accordingly.

It is important to regularly review and revise risk assessments, to see whether the conclusions and assumptions at the time of the assessment remained valid and to take into account new information that has become available. It is also essential to be explicit about the uncertainty of model and risk assessment outputs, and to discuss the impact of different sources of bias.

GAPS

The emphasis on effective communication of uncertainty (including bias) associated with epidemiological models and risk assessments must be increased.

CONCLUSIONS

This review highlights some of the areas where improved data collection and reporting would facilitate risk assessments, modelling and forecasting. The quality of information has improved over the past 20 years, but under-reporting is still occurring and has to be taken into account. Gs/GD/96-lineage H5Nx viruses will remain endemic to a number of countries and subregions, and spillover events to other parts of the world will recur. Good information is now available on the agroecological and socioeconomic factors that allow these viruses to remain endemic, as well as geographical areas where these viruses are likely to find suitable ecological niches. Repeated invasions of virus into Europe in the recent past suggest that this will occur again with a novel strain of virus, unless changes occur in East Asia to prevent their emergence. However, we are still unable to forecast which strains of virus will move out of East Asia to other countries, or the geographic range of viruses that do travel over long distances.

The improvement in laboratory and epidemiological capacity in countries affected by AI over the past 20 years has been a major effect of the investment by donors and national governments into veterinary services. The information that has been generated is highly valuable for these studies. This review highlights that there is still a major need, particularly in low- to middle-income countries, to establish timely and detailed information on the characteristics of viruses, control and preventive programmes in place, and the nature of surveillance programmes including any biases. The collection of high-quality epidemiological data from surveillance systems and outbreak investigations remains crucial to be able to produce models and risk assessments that are meaningful for policy development. 360

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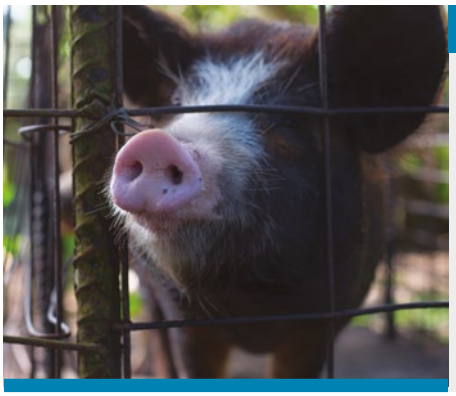

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PERSPECTIVE

FAO approaches to curb African swine fever spread

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INTRODUCTION

African swine fever (ASF) is a highly contagious and often fatal disease of pigs of all ages. ASF's progressive spread and possibility of becoming endemic is undoubtedly a true global threat, not only to the health of swine but also to the millions of people who are dependent upon pork production for their livelihoods and food security. ASF virus can be transmitted through pork and pork products (raw/frozen/dried/undercooked) in which the virus can survive for a long time. During 2020/21, despite the reduced mobility of people due to COVID-19 restrictions, ASF spread to new countries. It persists in many countries of Asia, Eastern Europe, the Pacific and sub-Saharan Africa, and was recently introduced to Hispaniola Island (the Dominican Republic and Haiti) in the Caribbean, and poses a real threat to countries currently free from the disease.

ASF IN THE WORLD

ASF was first recognized in Kenya in 1909 (Montgomery, 1921). As pig farming increased in the region, more ASF outbreaks occurred. In East Africa, Southern Africa and likely in Central Africa, the virus is maintained in a sylvatic cycle between warthogs and the *Ornithodoros* ticks living in their burrows. In Africa, wild suids are asymptomatic carriers of ASF and act as the reservoir. These include warthogs (*Phacochoerus africanus* and *Phacochoerus aethiopicus*), bushpigs (*Potamochoerus porcus* and *Potamochoerus larvatus*) and giant forest hogs (*Hylochoerus meinertzhageni*) (Beltran-Alcrudo *et al.*, 2017). Still, current dynamics of the disease in Africa are mostly due to pig-to-pig transmission, i.e. the domestic cycle (Penrith *et al.*, 2019). In Central Africa, ASF has been detected since the 1980s. In West Africa, the disease remained limited in southern Senegal and its neighbours until 1995. However, after the first outbreak in Côte d'Ivoire (1996), the disease rapidly spread to other countries within the region (Brown *et al.*, 2018). In Southern Africa, the dynamics of ASF has increased in recent years. Recent introductions or reintroductions of ASF include outbreaks in Madagascar (1997), Mauritius (2007), the southern part of South Africa (2012) outside the control zone, and Zimbabwe (2015). Since 2019, ASF-affected provinces were outside of the ASF control zone in South Africa, with Western Cape reported the disease for the first time in March 2021. ASF has also been reported in the United Republic of Tanzania and Zambia. Despite an increasing demand for pork, the scaling up of pig production has been challenging due to many intra- and interdistrict and transborder ASF outbreaks. The lack of biosecurity, and anthropogenic activities along the value chain, have been risk factors for spread in many countries.

Europe has experienced two distinct ASF epizootics. The first epizootic started in Portugal in 1957 (Cwynar, Stojkov and Wlazlak, 2019) and spread through most of Western Europe (Portugal, Spain, Italy, France, Malta, Belgium and the Netherlands), as well as to Brazil and the Caribbean (Cuba, the Dominican Republic and Haiti). The disease was eradicated from both continents by the early 1990s, except for the Italian island of Sardinia, where it has remained endemic. The second epizootic started in Georgia in 2007 (FAO, 2007) and progressively spread among domestic and wild boar through the Caucasus, the Russian Federation and westwards into multiple eastern, northern and southern European countries, where the disease is still actively spreading. The virus was also detected in Western Europe, in wild boars in Belgium (2018) which has regained its freedom from ASF (World Organisation for Animal Health [WOAH], 2020), and in wild boars (2020) and domestic pigs (2021) in Germany and in Italy in both wild boars and domestic pigs (2022). In both epizootics, contaminated food waste from airports and seaports was suspected as the route of introduction (Costard *et al.*, 2009; Beltran-Alcrudo *et al.*, 2019).

After several outbreaks progressively reported eastward in the Russian Federation, the first ASF outbreak in Asia was confirmed in China in 2018. The disease spread throughout China and into other countries in East Asia (2019) and the Greater Mekong subregion (2019), and jumping across the sea to Pacific Island countries (2019/20).

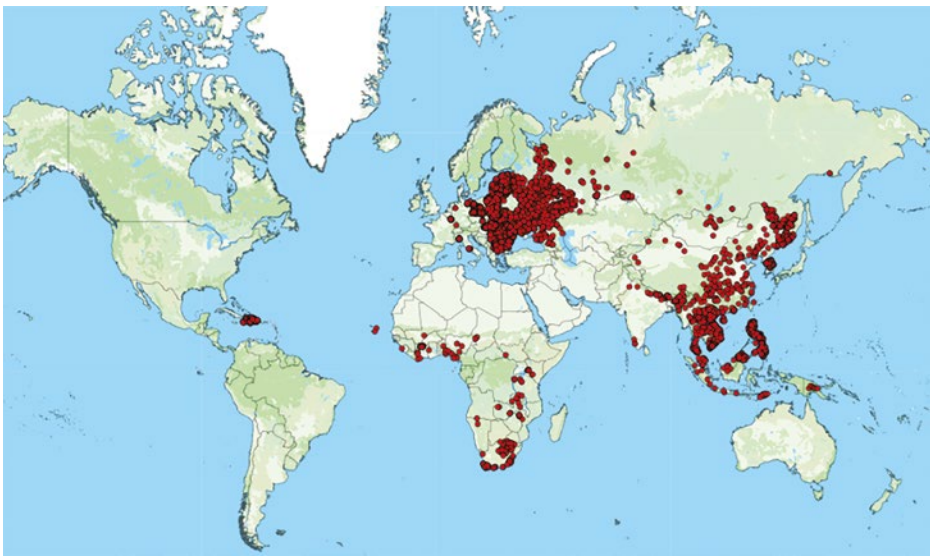

Figure 1. ASF outbreaks reported in the past 10 years
Source: FAO. 2022. Cited 16 October 2022. https://data.apps.fao.org/

[1] FAO.

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A farmer feeds with milk her pigs at a farm in Kiambu, Kenya.

In the Americas, ASF was detected in Cuba in 1971, in the Dominican Republic and Haiti in 1978, outbreaks which were controlled by massive destruction of pigs to eradicate the disease. However, after 40 years of freedom from the disease, ASF was again confirmed in the Caribbean region, in the Dominican Republic and Haiti, notified to WOAH on 29 July 2021 and 20 September 2021, respectively.

Although the wild suids in Africa are asymptomatic, ASF may also pose a threat to biodiversity in other wild Suidae found in Asia.

ECONOMIC IMPACT

In Asia, the economic consequences of ASF have been devastating, given the ASF's high lethality rate in native populations and its spread across the region, but also due to the restrictive measures and trade bans implemented by countries in response. Between 2017 and 2019, China's pig herd contracted by 41 percent, from 447 million to 316 million heads (FAO, 2021a), reducing global pork production by 9–34 percent (Mason-D'Croz *et al*., 2020). The impact of ASF on pig prices was not homogeneous among provinces: when comparing the provinces with the highest and lowest pig prices, the differential increased by more than 500 percent (2 CNY/kg in August 2018; 12.42 CNY/kg in December 2019) due to demand-supply imbalances generated by ASF and associated control measures. At the retail node, China's average pork price went from 25 CNY/kg in January 2018 to 51 CNY/kg in December 2019, making pork prohibitively expensive for many people. Considering that China alone concentrated 45.7 percent of the pig population in 2017 (FAO, 2021a), the introduction and spread of ASF in Asia affected global markets. China's efforts to fill the pork supply gap drove their imports to record levels (~2.1 million metric ton [MMT] in 2019 and ~4.3 MMT in 2020), creating imbalances that resulted in an increase in pork prices globally between 17 and 85 percent depending on the region. Such changes are associated with knock-on effects in other commodities, with implications for food energy availability and food security (Mason-D'Croz *et al*., 2020).

In Africa, despite an increasing demand for pigs and pork, the scaling up of pig production has been challenging. Africa had a total of 42.7 million pigs in 2019, up from 36.3 million in 2015 (FAO, 2021a). Annual growth varies between 2 to 7 percent. About 77 percent of the pigs are found in East Africa (41 percent) and West Africa (36 percent). On aggregate level, the socioeconomic impacts of ASF attributable to its rapid spread, high morbidity, high case fatality rates and the consequent trade bans would be expected to be highest in East and West Africa. Impacts differ across production systems. For example, in Uganda, low-input, low-output farming systems that involve only a small monetary investment could be impacted less compared to commercial smallholder or large-scale farms. In such systems, pigs are mostly kept as passive investments, and ASF incidence of 19 percent at household level has been reported (Chenais, *et al*., 2017). Similar to what happens in some other regions, during outbreaks farmers sell off animals at lower prices to avoid mortality losses, or slaughter for sale or local consumption. In commercial systems, identified ASF-related losses include: wasted inputs (feeds, veterinary costs, drugs, vaccines, transportation, bills and utilities), clean-up costs, pay-off to staff, facility rental costs and some maintenance costs, in addition to forgone revenues expected from the farm. A commercial system keeping 122 sows can generate a profit of approximately USD 109 637 per annum, and an outbreak of ASF has the potential to cause losses of up to USD 910 836 in a single year (Fasina *et al.,* 2011).

ASF has spread to multiple regions with a substantial economic impact that goes beyond farmers, and can even affect markets of other animal products. In newly infected countries, ASF causes shortage of pork products, and has pushed up retail prices of other meats as consumers looked for cheaper protein sources. In addition to the difficulties in eradicating the disease, countries have faced challenges in rebuilding their pig population to meet their demand for pork, as the disease also wiped out their sow herds and replacement animals became scarce. ASF has affected global meat prices due to an unprecedented increase in pork imports by ASF-affected countries. Such impact could extend to global feed markets, as feed-importing countries may reduce imports of soybean or maize for feed purposes (FAO, 2019). As a result, ASF has been pointed out as a major inflationary driver in countries such as China and the Philippines, where pork represents a key product in the average consumer basket (Philippine News Agency, 2021).

ASF CONTROL

ASF control programmes should be based on evidence-based actions adapted to the local context, including the epidemiological situation, biosecurity practices in pig production and the whole value chain, government capacities, and farmers, with a participatory community engagement and holistic value chain approach. In the absence of a licensed or authorized ASF vaccine to prevent ASF infection, good biosecurity practices are the most important measures to ensure protection from ASF. This includes the application of strict biosecurity measures specific to the different swine-producing sectors, including the frequent cleaning and disinfection of farms and transport vehicles; improved husbandry practices and production systems; cooking swill before feeding, or refraining from swill feeding where feasible; and strengthening the proper disposal of food waste (in food services, airports and seaports) which may contain uncooked pork products. Understanding pig and pork value chains within the country and with neighbouring countries is essential for improved risk management. Around 40 percent of all pigs are raised in low-input, small-scale pig raising and related value chain systems, which provide food and livelihood for millions of rural families across the globe. These farmers face enormous challenges in compliance with biosecurity practices required for ASF prevention. Collective action at community level is key to overcoming biosecurity issues by involving and engaging the different actors, from production to trading and marketing.

In addition, many countries experience problems with the practical application of risk-based surveillance and control interventions based on stamping out ASF. The sale of sick and dead animals poses a high risk for disease spread. Interventions, including motivational factors and incentives coupled with regulations, must targ*et all* stakeholders in the marketing chain, including farmers, traders, slaughterers and transporters, as well as the

relevant authorities. A community- and market chain-driven approach with the collaboration of the private and public sectors is required to change behaviours.

FAO ACTIONS

Since 1978, FAO has been providing technical assistance to its Member Nations in ASF prevention and control through more than 50 national, subregional, regional or global FAO Technical Cooperation Programme (TCP) projects funded by development partners. Currently, FAO implements or plans to launch projects in the different regions to assist affected countries contain the spread of ASF. Recent examples include a regional project to strengthen ASF surveillance and control in West and Central Africa, supported by the Government of Ireland; assistance to ASF control in Nigeria as a part of the project "Strengthening Global Coordination of Animal Health Emergencies of International Concern" funded by the United States Agency for International Development; and FAO-funded regional TCP projects in East and Southeast Asia, the Balkans, Latin America and the Caribbean, and the Pacific, as well as national TCP projects for Papua New Guinea and Togo. The aim is to address ASF in a strategic and coordinated manner, to tackle the challenges or mitigate the risk posed by ASF. An Incident Coordination Group on ASF has been established under the FAO Emergency Management Centre for Animal Health (EMC-AH) to manage the responses to epidemiological events and country requests for guidance and support on prevention and control strategies. Also, worldwide disease events are monitored by the EMPRES-i+ system. To enhance preparedness and provide technical support for ASF control, EMPRES has provided knowledge products and technical guidance on various emerging needs, and continued coordination with various global and regional partners. Together with the European Union and WOAH, a technical paper focusing on ecology and biosecurity in situations where wild boar play the key role in spreading ASF virus was developed. FAO and WOAH jointly coordinate risk communication campaigns, as high awareness should be maintained across national, regional and global levels.

In **Africa**, a regional strategy for ASF control was developed in 2017 and is currently in the process of revision. In **East Africa**, where there are many important pig-producing hubs with outbreaks of ASF, there is still a strong need for further coordination between countries. For example, even though ASF is endemic in the Southern Highlands zone of the United Republic of Tanzania since 2020, an increased number of ASF outbreaks has been reported in several areas where demand-driven domestic pig production has been increased. FAO together with Tanzanian veterinary services convened a regional community-led consultation meeting to discuss the strategies to reduce the burden of ASF, conducted participatory epidemiology disease search, developed the national ASF control strategy, mapped the high-risk locations along value chains, developed awareness materials and continues to engage with all stakeholders along the pig value chain. These activities, if also conducted in other countries in East Africa, will improve understanding of ASF patterns for risk management in the region.

In **Southern Africa**, FAO organized a South-South and Triangular Cooperation (SSTC) study tour for four Member Countries of the Southern African Development Community in October 2019, to observe the latest development of ASF control measures developed by South Africa. This SSTC study tour, organized in June 2019 in Zimbabwe, was a follow-up activity of the Harare workshop, where the pressing issue of the control of high-impact transboundary animal diseases such as ASF in Southern Africa were discussed. A project on the control of transboundary animal diseases including ASF, aimed at improving food security and nutrition of smallholder farmers in Southern Africa, has been prepared.

> "Countries faced challenges in rebuilding their pig population to meet their demand for pork, as the disease also wiped out their sow herds"

In **West Africa,** ASF is endemic in several countries, with recurrent outbreaks causing high losses to pig producers. From January 2020 to October 2021 three countries, namely Côte d'Ivoire, Nigeria and Sierra Leone reported ASF outbreaks. FAO has provided support to these countries, such as capacity building in animal health emergency management, training on biosecurity measures for pig value chain operators, and good hygiene and biosecurity practices for value chain stakeholders. In 2020, FAO developed good practice guides for different actors in the pork industry, including backyard farmers. Technical assistance was provided for ASF risk mapping, the development of an ASF emergency intervention plan with standard operating procedures (SOPs) for ASF outbreak management and veterinary inspection at national veterinary control/border posts, and an ASF risk communication plan along with awareness materials. FAO also provided support to countries' efforts in pig value chain reconstruction. To strengthen capacity in outbreak detection, trainings on ASF prevention, control and biosecurity/biosafety were conducted, and a virtual regional quality assurance programme was implemented. In some cases, joint ASF outbreak investigation was conducted in collaboration with government veterinary services.

In **the Americas**, technical assistance has been provided to the countries of the region for strengthening preparedness against a potential ASF incursion under the FAO TCP regional project. In response to the recent ASF emergence in the Caribbean, FAO in cooperation with WOAH, Organismo Internacional Regional de Sanidad Agropecuaria and the Inter-American Institute for Cooperation on Agriculture deployed an EMC-AH mission to the Dominican Republic (11–18 August 2021) and to Haiti (19 August–2 September). The following immediate needs were identified:

- to enhance emergency coordination units at central, regional and local level;
- to reinforce laboratory diagnostic capacity;
- to strengthen epidemiological risk-based surveillance capacity;
- to enhance outbreak control capacity to implement a contingency plan; and
- to enhance biosecurity at small, medium and large production units.

Efforts were made to set up coordination mechanisms to put in place a bilateral programme for ASF control and eradication between the Dominican Republic and Haiti, using the One Island approach. An emergency TCP project was developed based on the findings of the EMC-AH missions, and launched at the beginning of 2022. The Latin America and the Caribbean Region developed the "Regional Framework for the containment and prevention of ASF spread in the Americas", working on the design and implementation of a regional strategy for the control and eradication of ASF under the FAO-WOAH Global Framework for Progressive Control of Transboundary Animal Diseases (GF-TADs) umbrella and in collaboration with countries in the regions.

In **Asia**, FAO convened an emergency consultation meeting in September 2018, right after China reported its outbreak of ASF, to discuss regional direction to prevent the spread and mitigate the impact of ASF, and to assess the risk of introduction to other

countries in Asia. This resulted in a regional collaborative framework, based on which FAO has been providing technical and operational assistance to Member Nations to strengthen capacities to detect, control and prevent ASF through:

- Providing support to countries to develop, review or update strategies and guidelines for ASF.
- Holding trainings on ASF detection and emergency response. The four-week tutored course on ASF preparedness developed for Europe was adapted to the Asian context. Regional training of trainers and in-country-level trainings were also held; to overcome COVID-19 travel restrictions, FAO has set the format of a fully virtual regional level of activities, combined with hybrid or face-to-face in-country-level activities.
- Providing laboratory support (FAO, 2020e) to train laboratory personnel, and to procure diagnostic reagents and consumables including a regular regional proficiency testing programme, in collaboration with the Australian Centre for Disease Preparedness.
- Creating awareness and risk communication materials (FAO, 2020f).
- Continued coordination efforts with other partners under the GF-TADs umbrella.

In **Europe**, FAO has been providing technical assistance to countries ever since the incursion of ASF through the port of Poti, Georgia in 2007. Efforts have targeted all aspects of preparedness, detection, prevention and control, including:

- Awareness-raising, with the development of numerous awareness materials (FAO, 2021b) and formats for a variety of audiences.
- Face-to-face training efforts on laboratory diagnosis (FAO, 2020a), epidemiology, wild boar management (FAO, 2019a), risk communication and stamping out (FAO, 2019b), and training of trainers that cascades down to field veterinarians or hunters, as ad hoc events. More recently, training has occurred in an online format, with a week-long tutored course on ASF preparedness for Europe in English and in Serbian (FAO, 2020b; United Nations in Serbia, 2020) that has allowed the training of 1 013 participants from 37 countries during the COVID-19 pandemic. The course has been later adapted, translated and delivered in other regions, through FAO Virtual Learning Centers, for the Southern African subregion (in English language, 15 countries, September 2021), Canada (in English and French languages, three countries, September 2021), the Pacific Islands subregion (in English language, 11 countries, October 2021), the Americas (in Spanish language, 11 countries, November 2021), and Europe and Central Asia (in Russian language, 12 countries, November 2021).
- A series of tools, including a survey tool to better understand pig value chains and biosecurity with a particular focus on the less-known backyard systems (Kukielka *et al.*, 2017; Beltran-Alcrudo *et al.*, 2018); a wild boar distribution and density map (Pittiglio *et al.*, 2018); a tool (OutCosT) to estimate the cost of an ASF endemic and its control in a country; a tool to assess the risk and biosecurity of hunting grounds; and a mobile app (FAO, 2020c) for the reporting of wild boar carcasses.
- Assessment missions and simulation exercises (FAO, 2021c) to identify gaps and test preparedness, regional meetings (also online to overcome COVID-19 restrictions) to exchange information between countries and coordinate (FAO, 2019c, 2020d), including those under the Global Framework for the Progressive Control of Transboundary Animal Diseases (GF-TADs) and Standing Group of Experts on ASF.

GLOBAL AND REGIONAL COORDINATION OF ASF CONTROL

Transboundary animal diseases are most effectively addressed under international frameworks that can coordinate the activities of relevant stakeholders and provide a platform for knowledge exchange leading to the development of common approaches towards sustainable control. Examples which highlight the benefits to the international community include the successes of the Global Rinderpest Eradication Programme, the European Commission for the Control of Foot-and-Mouth Disease, and the Peste des Petits Ruminants Global Control and Eradication Programme. The GF-TADs represents the existing umbrella to harmonize the overall TADs management of FAO with that of WOAH and other pertinent partners. In July 2020, FAO and WOAH established a joint working group on ASF under GF-TADs to coordinate, monitor and evaluate the implementation of the Global Initiative for the Control of ASF, and to contribute to the development and support of ASF control strategies at global and regional levels. This GF-TADs initiative aims to tackle strategic challenges, promote partnerships, strengthen prevention and preparedness measures, and minimize the adverse impacts of ASF. The Global Initiative provides the structure to work towards the global control of ASF (FAO and WOAH, 2020).

FAO and WOAH organized a GF-TADs global virtual event, a call for action entitled "African Swine Fever: An Unprecedented Global Threat – A Challenge to Livelihoods, Food Security and Biodiversity", in October 2020. The event brought together around 600 international experts from national veterinary services, industry and academia, as well as regional and international partners. During the event, the participants discussed the GF-TADs Global Initiative, and existing tools, mechanisms and practices to effectively control the disease. As a follow-up of the call for action, WOAH and FAO organized the virtual event "Stop ASF: Public and Private Partnering for Success" from 14 to 28 June 2021, to highlight the importance and role of public-private partnerships and to promote the engagement and collaboration of the public and private sectors in the Global Initiative. Over the course of the two-week event, around 1 350 representatives from state veterinary services, academia and the private sector benefited from prerecorded videos, a live question and answer session, and a live panel discussion. The prerecorded videos and recordings of the two sessions, as well as the responses to questions raised by the participants, are available online (FAO and WOAH, 2021).

At a regional level, FAO and WOAH supported establishment of the Regional Standing Groups of Experts on ASF in Europe, Asia and the Americas to foster closer cooperation and coordination among countries affected by ASF or at high risk of introduction. The Standing Groups of Experts ensure regular exchange of information on the ASF situation and control measures; regular review of national and regional control strategies or emergency preparedness; and collaboration on laboratory diagnostics, awareness-raising, and risk communication and border control measures between countries in the region. FAO has also developed OUTCOST, an Excel-based tool to estimate the cost of a pig disease outbreak in a country (or at subnational level). OUTCOST has been validated through its piloting in very different settings in four countries in three continents, demonstrating its power to rapidly and accurately assess (or simulate) direct disease costs for both ASF and classical swine fever at subnational and national levels, and in affected and at-risk countries. In order to address challenges, FAO has been developing a practical and feasible guidance/decision support system for ASF surveillance, diagnosis, control interventions and biosecurity management for different epidemiological aspects, again focused on resource-poor settings.

WAY FORWARD

The communication campaign on ASF risk mitigation should be on a continuous basis and contribute to a high level of awareness and behaviour change of all stakeholders involved, from farmers and butchers to border inspectors and international travellers.

The further research and development of technologies for the prevention and early detection of, and response to, the disease are required. For example, pigs and pig herd identification and traceability, cleaning and disinfection of pens, quick and bloodless culling and the safe disposal of carcasses with the production of biogas and manure, should be piloted for feasibility and acceptance by farming communities, and verified and promoted by local authorities and communities. Fair compensation must be paid if it is necessary to cull pigs when an outbreak occurs. Without guaranteed fair compensation and trust in authorities to pay compensation, there is a high probability that farmers will sell their pigs at the first sign of an outbreak without reporting the appearance of the disease, which may compromise all prevention and control efforts.

Considering the complexity and enormous challenges for ASF control and the global threat to food security and livelihoods of millions of people, including trade restrictions, economic losses and the threat to biodiversity, there is a need to foster multisectoral and public-private engagement for concerted and joint ASF risk mitigation actions to safeguard the industrial commercial sector, as well as the backyard and subsistence pig sector. [360]

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ADVANCES

African swine fever in Cameroon: 40 years of lessons learned

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INTRODUCTION

Cameroon has the largest pig population in Central Africa, estimated at over 3 000 000 heads of animals in 2014. In terms of animal production, pig farming ranks third in the country. More than 217 000 families rely on pig production or other related activities to supplement their income, most of whom live in rural areas and are among the low-income strata of the population (Cameroon, Ministry of Livestock, Fisheries and Animal Industries [MINEPIA], 2013).

For four decades, Cameroon has been facing African swine fever (ASF) epizootics (Cameroon, MINEPIA, FAO and World Trade Organization [WTO], 2015), a viral swine disease for which no effective vaccine or treatment available (FAO, World Organisation for Animal Health [WOAH] and World Bank, 2011). ASF has been epidemic in the country since it was first reported (Cameroon, MINEPIA, FAO and WTO, 2015).

Before the incursion of ASF in 1982, pig was the second most important animal species reared in the country, which had a population of over 1 400 000 pigs. The predominant production system was extensive production system, mostly in the Northwest, West, Southwest and Central Provinces (Ekue, 2009).

ASF was first reported in Cameroon in February 1982, in intensive pig farms in high-pig-producing regions in Mungo Division (Ekue and Tanya, 1985). The virus was introduced most probably through imported swill for animal feeding. Several actions were taken by the Government to control the spread of the disease, including a significant mobilization of resources, stamping-out efforts and compensation. However, due to the lack of adequate preparedness, poor coordination and communication to the public, the virus spread to neighbouring regions and settled across the southern part of the country (Cameroon, MINEPIA and Direction des Services Vétérinaires [DSV], 2005). The three northern regions (Far North, North and Adamaoua) remained free from ASF until 2010 when the disease became endemic in the entire country (WOAH, 2021).

Risks associated with wildlife and vectors are not yet well known. A 1989 study found the absence of soft ticks. However, this study dates back 30 years and must be updated in light of the relevant observations made by Wade *et al.* (2019) about the strong transboundary trade and wildlife movements between Cameroon and neighbouring countries.

> “Well targeted, coordinated and supportive actions along the value chain will lead to more efficient disease control and sustainable development”

CONTROL STRATEGIES AND MEASURES

To support ASF diagnosis and control, a Technical Cooperation Programme (TCP) project was initiated between FAO and Cameroon in 2000. The seroprevalence of ASF was determined to be 11 percent. Based on these data, a more holistic and efficient approach towards the control of ASF was initiated, based on stakeholder involvement in decision-making and the implementation of control measures.

One of the outcomes of the TCP was the development of the five-year Swine Production Development Programme, including a national ASF control strategy. Under this programme, and through the Highly Indebted Poor Country Initiative, the Government mobilized about XOF 6.5 billion, equivalent to USD 13 million (Cameroon, MINEPIA and DSV, 2013)) to improve the swine production sector and reduce the effects of ASF.

RECORDED SUCCESSES

As a result, from 2005 to 2011, the swine sector recorded a holistic development through the capacity building of stakeholders, restructuring of the sector, establishment of stakeholder organizations, multifaceted support for the development of competitive production and implementation of a participatory control plan.

During this time, more than 3 000 pig farmer organizations were set up and over 29 000 pig farmers received various forms of support including training, and the effective participation of stakeholders in control actions was promoted. An appreciable reduction of the incidence of ASF was recorded, from 11 percent in 2002 to 1 percent in 2006 (Cameroon, MINEPIA and DSV, 2007), 7 percent in 2007 (Cameroon, MINEPIA and DSV, 2008) and 0.2 percent in 2008 (Cameroon, MINEPIA and DSV, 2009).

THE MAJOR FAILURE

Despite the endemic nature of ASF, the economy of the pig industry in southern regions soared and prompted the desire of producers in northern regions, who were still free from the disease, to increase resulted in the uncontrolled movement of pigs from the ASF-endemic south to the ASF-free north. Subsequently the first outbreaks of ASF were reported in northern regions in January 2010 (WOAH, 2021), and finally the virus was transported across

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the northern border into Chad (Cameroon, MINEPIA and DSV, 2013) (Figure 1).

In response to this unexpected development, stringent sanitary measures were implemented, including the creation of 11 road checkpoints with a total restriction of the pig movement from all the newly infected regions. Heightened surveillance measures were implemented, leading to a return to serenity. By December 2010, the situation in northern Cameroon was under control, but unfortunately a lack of vigilance at the border with neighbouring Chad subsequently led to the reintroduction of the disease from southern Chad to the north of the country.

THE ASF SITUATION IN THE PERIOD FROM 2011 TO 2015

After the 2010 outbreaks, a series of measures were taken, namely: the formal suspension of pig trade and movement of pigs from north to south and vice versa (Douffissa, 2007); the destruction and incineration of infected pig houses and material that could not be disinfected and decontaminated; the organization of the value chain and training of pig traders on compliance with biosecurity measures in the transportation of pigs; compulsory disinfection and the control of all vehicles to be used in pig transport; and the systematic stamping out of all pigs from infected towns and villages (Cameroon, MINEPIA and DSV, 2013).

Following the implementation of the aforementioned measures, the situation returned to normal, and in 2011 only four outbreaks were reported. The incidence of the disease was estimated at less than 1 percent, the lowest result since 1982.

In March 2012, another wave of outbreaks was reported, indicating flaws in the pig movement control measures (Figure 2).

Four new ASF outbreaks were reported in 2013 (Figure 3) with 2 981 pig deaths recorded. An epidemiological survey carried out within the framework of a TCP project (Cameroon, MINEPIA, FAO and WTO, 2015) reported an incidence of 0.2 percent. Another meaningful finding of this survey was the high awareness and ASF knowledge of pig value chain stakeholders: 86.2 percent of breeders had already heard about ASF, and 47 percent had experienced it in their herds; 100 percent of stakeholders involved in the slaughter of pigs and 81.8 percent of pig roasters and traders knew about ASF; and 33.7 percent of breeders suspected traders of being the source of contamination of their animals.

In terms of biosecurity, the survey revealed a high density of pig farms in the production basins, with an average of ten pigsties within a radius of 500 m in some areas, and a very low level of biosecurity, characterized by free visits and access to farms by strangers,

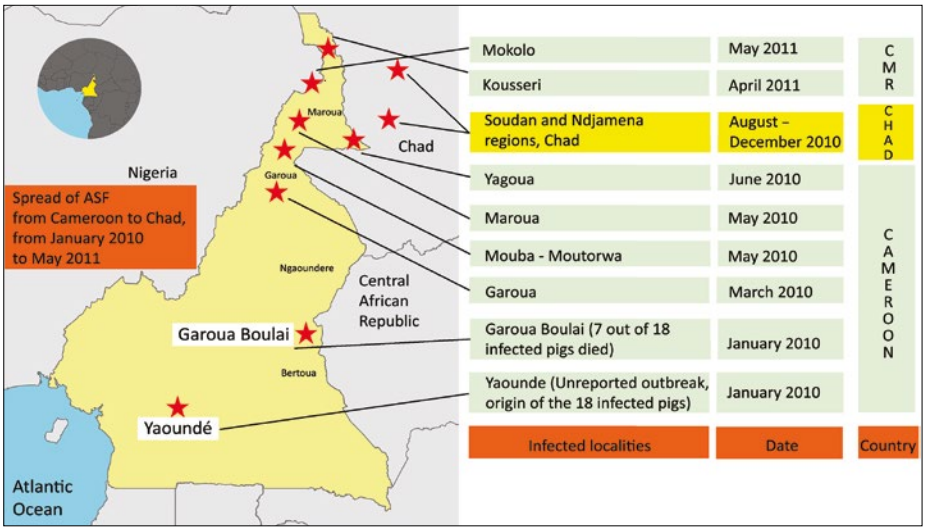

Figure 1. Spread of ASF from southern to northern Cameroon and then Chad, 2010/11
Source: Cameroon, MINEPIA & DSV. 2013a. *Rapport annuel 2012 des activités de lutte et de contrôle de la peste porcine africaine au Cameroun*. Yaoundé, DSV & MINEPIA.

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The culling of infected animals and destruction of carcasses.

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Veterinary control post.

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Destruction of infected animals.

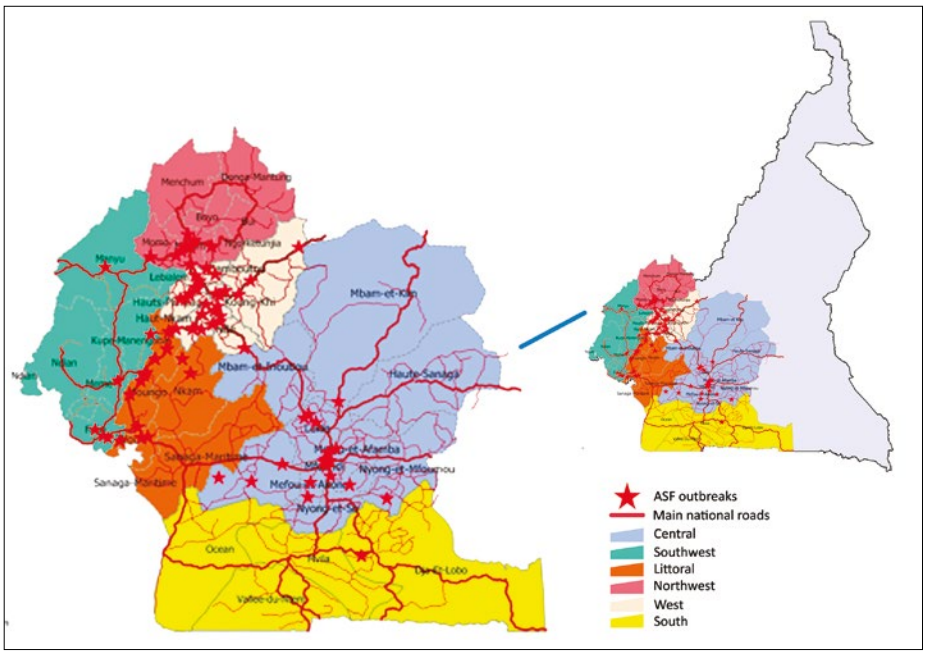

Figure 2. ASF outbreaks in western Cameroon in 2012
Source: Cameroon, MINEPIA & DSV. 2013a. *Rapport annuel 2012 des activités de lutte et de contrôle de la peste porcine africaine au Cameroun.* Yaoundé, DSV & MINEPIA.

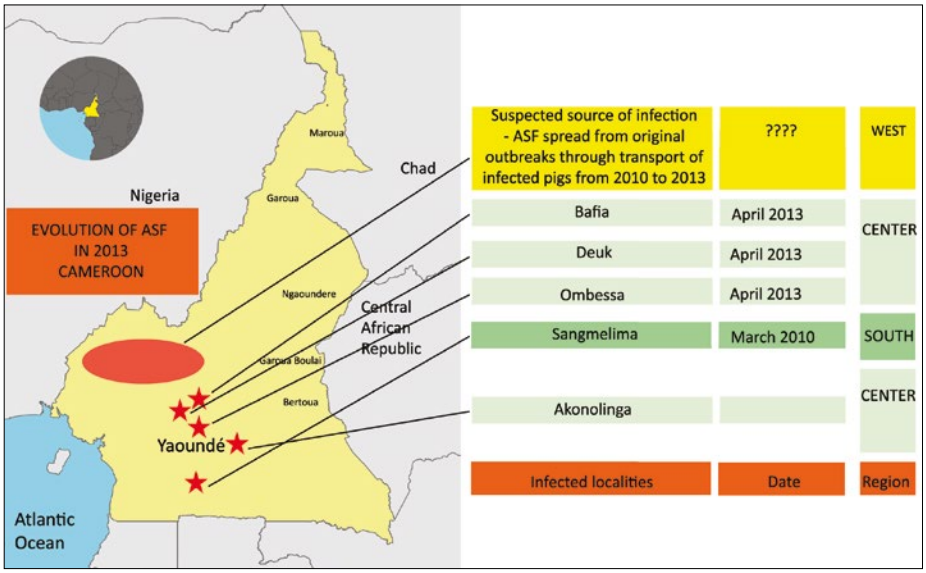

Figure 3. Summary of ASF outbreaks in 2013
Source: Cameroon, MINEPIA & DSV. 2013a. *Rapport annuel 2012 des activités de lutte et de contrôle de la peste porcine africaine au Cameroun.* Yaoundé, DSV & MINEPIA.

the non-compliance with biosegregation principles and low external biosecurity in the majority of production units, as well as lack of knowledge with regard to safe renewal of the stock.

PREVAILING SEROTYPES AND THE REGIONAL DIMENSION

Genetic characterization of ASF viruses showed that three different variants of ASF genotype I were involved in the 2010–2018 outbreaks in Cameroon. Of these, only variant ASF virus genotype I variable 19 transcription regulatory sequence was identical to the Cameroon/82 isolate found in the country during the first outbreaks in 1981/82. The study demonstrated that the three variants involved in these outbreaks were similar to those in neighbouring countries, suggesting movement of the virus across borders (Wade *et al.*, 2019). This is evidence that successful and sustainable ASF control measures in Cameroon can only be achieved by the appropriate implementation of subregional cooperation actions among the Economic Community of Central African States and Economic Community of West African States Member Countries. The 2010/11 events are in line with this assertion (Ndongo, 2013).

DISEASE SITUATION (2018–2020)

A strategic ASF control plan was developed in 2015 (Cameroon, MINEPIA, FAO and WTO, 2015) and accompanied by an operational plan (action plan) in 2019. At present, large-scale public actions are no longer being taken. Nevertheless, the incidence of the disease is at the lowest level (0.04 percent). Thus, "living with the disease" has become the option taken by the public authorities (Cameroon, MINEPIA and DSV, 2013).

The clinical signs and lesions resulting from ASF which are observed today are no longer the same as those observed in the past, ranging most often from clinical signs limited to anorexia, stunted growth and a cough, as well as cases of abortion which often give the alarm signal in most of the outbreaks. The progressive increase in the mortality rate can last for up to two weeks, and so gives farmers room for destocking and selling off to butchers and traders, thereby increasing the risk of spread of the virus. At necropsy, haemorrhagic lesions are very discreet and especially localized in the kidneys and gastrointestinal nodes (Cameroon, MINEPIA, 2013), unlike during the earlier outbreaks of the 1980s, where hyperacute to acute forms were most common, with a sudden rise in the mortality rate (80 percent in 1982) within a few days, with clear typical ASF-generalized haemorrhagic lesions (Ekue and Tanya, 1985).

The results predict a better future for pig farming in the affected regions if measures advocated by the strategic plan are properly implemented (Sali, 2014). Such measures include biosecurity improvement along the value chain and stakeholders' involvement in surveillance for rapid detection and effective outbreak management.

Table 1. Evolution of the number of ASF suspicions and confirmed outbreaks by laboratory analysis in Cameroon from 2018 to 2020

Year	ASF suspicions (not confirmed)	Confirmed ASF outbreaks by laboratory analysis	Total of reported outbreaks
2018	19	17	36
2019	15	8	23
2020	12	3	15

Source: Cameroon, MINEPIA & DSV. 2021. *Rapport annuel 2020 des activités de lutte et de contrôle de la peste porcine africaine au Cameroun.* Yaoundé, DSV & MINEPIA.

Note: data available in 2021.

The epidemiological analysis from 2018 to 2020 shows a constant decrease in notifications and epizootic outbreaks with highly variable peaks, especially in the southern part of the country (Table 1).

CONCLUSION

Cameroon recorded significant results in ASF control from 2005 to 2011, thanks to the mobilization of resources and the setting up of a specific institutional framework (Cameroon, MINEPIA and DSV, 2005, 2007, 2008, 2009). Cameroon's livestock development authorities have also recognized the importance of farm registration for disease control, and continue to promote registration to improve traceability and to support risk management.

The involvement of all actors along the value chain is critical. Thus, the most effective government approach would be to support stakeholders, and guiding or channelling their efforts while ensuring appropriate supervision of control initiatives.

The decrease in the number of reported outbreaks and laboratory confirmations might not be accurate due to under-reporting. Improving reporting, efficient surveillance system and laboratory capacities for rapid detection are required. In addition, compensation mechanisms are necessary to avoid under-reporting by actors in the pork value chains and thus to avoid the continued spread and the maintenance of the disease.

In the Cameroon context, biosecurity appears more than ever to be the unique means for the effective control of ASF and for enhancing the development of pig production. This observation is underpinned by the existence of some highly performing pig production units in the country. For instance, the Kounden pig breeding station, a state-owned unit located in the West Region, has never experienced an ASF outbreak even though it is located in the heart of the most ASF-affected region, thanks to high-level biosecurity measures. Many other commercial farms follow the highest biosecurity measures, and have become the main producers of piglets or the major high-performance swine breeding stock providers in the country. These commercial units emerged about 15 years ago with the implementation of the Swine Production Development Programme and have never recorded any outbreak.

Raising awareness for improving biosecurity should remain an ongoing activity. Improving value chain organization and promoting the participation of all actors, which have shown valuable results in the past, should remain a priority core of the government strategy for the effective control of ASF in Cameroon. In this context, incentives such as improving access to genetically more profitable breeds bound to better biosecurity have been shown to be effective. Support and training of farmers on biosecurity measures may be profitable to the sector.

In the most successful ASF outbreak control actions, collaboration with producers and the involvement of producers' organizations have been the key factors for efficient risk management. Based on its experience with the different aspects of ASF risk management, Cameroon has recognized that well targeted, coordinated and supportive actions along the value chain will lead to more efficient disease control and sustainable development of the pig industry. 360

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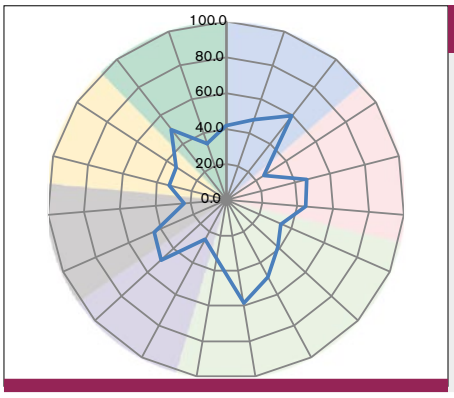

ADVANCES

How the FAO Surveillance Evaluation Tool and its Biothreat Detection Module accelerate countries' capacities

Contributors: Gael Lamielle, Ihab ElMasry, Gisela Gioia and Sophie VonDobschuetz [1]

INTRODUCTION

It has been estimated that 60 percent of all infectious diseases and 75 percent of emerging diseases affecting humans originate in animals (also known as zoonotic diseases) (Taylor, Latham and Woolhouse, 2001; Woolhouse and Gowtage-Sequeria, 2005), very much like COVID-19 which continues to spread around the world. While the impact of zoonoses on human health is evident, non-zoonotic and transboundary animal diseases also affect people's well-being by threatening livestock production systems and thus the communities depending on them for livelihood and nutrition. Such is the case for ASF's spread throughout Asia (FAO, 2018) and other regions, as well as other animal diseases such as Newcastle disease or *peste des petits ruminants*. Lastly, it is important to consider that a number of terrorist events against animals have occurred in the twentieth century using both zoonotic and non-zoonotic agents to push political or social agendas (Keremedis *et al*. 2013). Strong surveillance systems are therefore essential to rapidly detect and identify high-impact animal diseases for immediate response before further spread, to ensure a safe and plentiful food supply and assess the likelihood of bioterrorism events.

To support countries' veterinary services in strengthening their surveillance capacities, FAO launched the Surveillance Evaluation Tool (SET) in 2017 (FAO, 2019). This was developed for the FAO component of the Global Health Security Agenda, for the African countries which requested a methodology to comprehensively assess animal disease surveillance systems and facilitate the development of specific recommendations to address the gaps in their systems. SET was adapted from the original Outil d'Analyse des Systèmes de Surveillance (OASIS) tool developed by the French Agency for Food, Environmental and Occupational Health and Safety (Hendrikx *et al*., 2011), to meet countries' requests, and which was streamlined with other existing FAO tools. The final SET tool has been used in 14 African countries as part of FAO's Global Health Security Agenda-related activities with support from the United States Agency for International Development. Successes from SET's initial implementation have generated much interest from other projects and countries, and the tool has been used in additional countries in Africa, Central Asia and Southeast Asia as a baseline assessment prior to the implementation of various activities to strengthen surveillance under differed FAO projects.[2]

> "The successes of SET comes from the fact that significant attention is placed on developing recommendations together with national veterinary services"

SET METHODOLOGY

Several evaluation methodologies are available from international organizations to support countries in the development of their national capacities. The World Health Organization (WHO) developed the Joint External Evaluation to provide countries with a broad assessment of their One Health capacities including the public health and animal health sectors (WHO, 2022a). Likewise, the World Organisation for Animal Health (WOAH) uses the Performance of Veterinary Services tool to further evaluate the strengths and gaps of veterinary services (WOAH, 2020). SET was designed to help complement these evaluations by providing more depth on countries' capacities to conduct animal disease surveillance.

SET achieves this level of such details through its 96 indicators, divided into seven areas and 19 categories specific to surveillance, as listed in Table 1. Following a phase of data collection, each indicator is scored from 1 to 4, reflecting the country's capacity. Graphics depicting a system's strengths and weaknesses are then automatically generated (Figure 1).

The tool itself is only one aspect of the evaluation methodology, however. The preparatory phase requires at least one month prior to the start of the assessment mission in the country. During this time, the evaluation team (assessors) is identified, the areas to visit and stakeholders to interview are selected, and a request for information questionnaire is sent to the veterinary services to provide assessors with background knowledge and documents to review before their arrival. Focal points from the veterinary services are an integral part of the evaluation team, and they participate in all aspects of the assessment to ensure that the outputs are useful to the country. The team is led by an expert who has been formally trained in, or has previous experience of, using SET.

The information used to score the surveillance system comes from interviews conducted with stakeholders at all levels of the surveillance system, along with a thorough review of relevant documentation including surveillance plans, protocols, legislation and more. While it is virtually impossible to meet every person involved in surveillance in a country, it is important to ensure representation of all major stakeholders of the surveillance system. These can vary according to the national

[1] FAO.

[2] The countries which have used SET to date are Azerbaijan, Burkina Faso, Cameroon, Côte d'Ivoire, Democratic Republic of the Congo, Ethiopia, Ghana, Guinea, Indonesia, Iraq, Jordan, Kenya, Kazakhstan, Kyrgyzstan, Liberia, Mali, Mozambique, Niger, Senegal, Sierra Leone, Sudan, Tajikistan, Tunisia, Uganda, United Republic of Tanzania and Uzbekistan.

Table 1. Areas and categories evaluated by SET

Areas	Categories	Indicators per category
Institutional organization	Central institutional organization	7
	Field institutional organization	8
	Intersectoral collaborations	5
Laboratory	Operational aspects	2
	Technical aspects	10
	Analytical aspects	3
Surveillance activities	Objectives and context of surveillance	3
	Surveillance data collection	15
	Surveillance methods	10
	Active surveillance	4
	Risk assessment	2
Surveillance workforce	Workforce management	5
	Training	4
Data management	Information system	2
	Data processing and exploitation	4
Communication	Internal communication	4
	External communication	4
Evaluation	Monitoring and evaluation	2
	External evaluation	2

Source: Authors' elaboration.

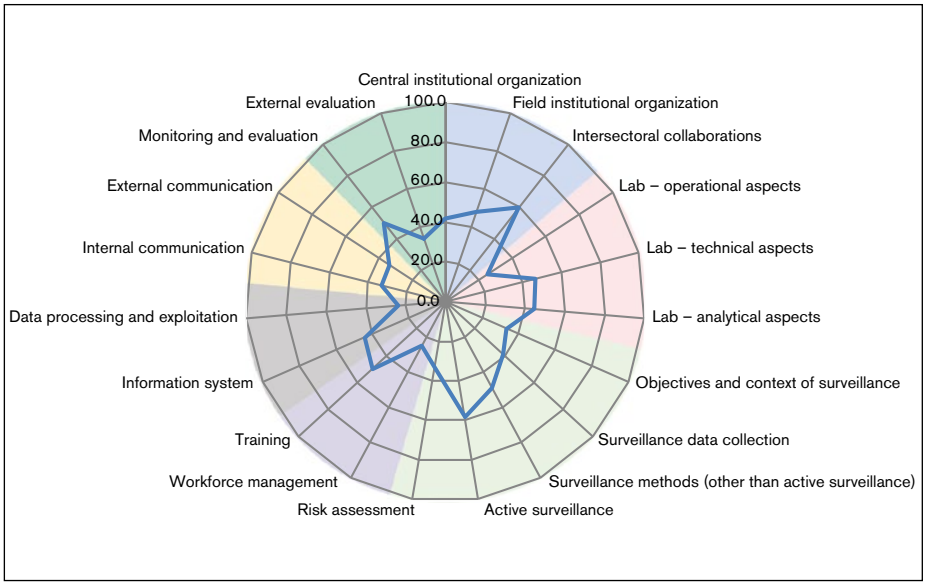

Figure 1. Spider graph depicting a surveillance system's strengths and weaknesses
Source: Authors' elaboration.

context; however, the stakeholders are usually (but not exclusively) representatives from veterinary services (particularly the epidemiology unit), veterinary laboratories at all levels, livestock or veterinary officers in the field, veterinary paraprofessionals or community animal health workers, intersectoral partners (e.g. ministries of health or of the environment/wildlife, administrators of One Health platforms), the private sector, border posts, slaughterhouses and markets.

Typical SET missions last 12 days, where the first week is dedicated to interviews and information-gathering. The team then scores all 96 indicators of the system, a process which takes two days. The evaluators must remain objective during scoring, and for each score a detailed justification is entered based on the information gathered and the realities observed during the previous week. The spider graphs produced allow the team to conduct an in-depth strengths, weaknesses, opportunities and threats analysis for the system, which helps develop country-specific recommendations. Once again, the team members from the veterinary services are invaluable to support the development of recommendations that are locally relevant, achievable, measurable and have realistic timelines.

At the end of the mission, all evaluation outputs are presented to decision-makers for their feedback. After the mission, evaluation outputs are shared in a report with veterinary services for feedback and posted online once endorsement is obtained.

EXPANDING BEYOND CLASSICAL ANIMAL HEALTH SURVEILLANCE: THE NEW SET BIOTHREAT DETECTION MODULE

There are examples throughout history of countries and non-state actors using or threatening to use biological agents against animals. When non-state actors take such action for financial or personal gain, it is classified as an agrocrime; if done to coerce sociopolitical objectives, these acts are classified as agroterrorism, a subset of bioterrorism specifically targeting livestock and crop production (Keremedis *et al.*, 2013; WOAH, 2020). Well-functioning surveillance systems are essential for effective preparedness and response against bioterrorism events. They allow rapid detection and containment of diseases, identification of perpetrators through case tracing, and monitoring of the population to prevent accidental and deliberate disease outbreaks (Bravata *et al.*, 2004; Chalk, 2004; Wheelis, Casagrande and Madden, 2020).

SET's comprehensive assessment of all aspects related to animal disease surveillance generated interest for a project on agroterrorism and agrocrime funded by Global Affairs Canada. The project's goal is to build resilience against agroterrorism and agrocrime attacks on livestock that can have potentially devastating economic, social and public health effects. The project was launched in 2019 and is being implemented by a consortium including FAO, WOAH and the International Criminal Police Organization (INTERPOL). The project has been assessing baseline capacities in the target region using SET, FAO's Laboratory Mapping Tool (LMT), WOAH's Performance of Veterinary Services and WHO's Joint External Evaluation. Within this framework, FAO has developed biothreat modules for SET and LMT. In combination, outputs from these modules will inform the subsequent development of national preparedness and response capacities to agroterrorism and agrocrimes.

The SET biothreat detection module includes specific indicators related to the detection and investigation of potential terrorist and criminal animal health events. These focus on collaboration between law enforcement and veterinary services, mechanisms to suspect terrorist and criminal events, mechanisms for joint epidemiologic and criminal investigations, and more. The first draft of the module was developed and reviewed by biothreat reduction experts

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Interviewing slaughterhouse workers outside Monrovia during the Surveillance Evaluation Tool (SET) mission in Liberia.

with a range of technical and geographic backgrounds in 2020. In 2021, the module was piloted in Tunisia, and in 2022, Jordan.

WAY FORWARD

SET has generated much interest from various countries and projects because it fills a niche for a specific tool to evaluate and guide the development of animal disease surveillance systems. A review of SET indicators has recently been conducted, in order to streamline the tool and better integrate it with other existing assessments, ensuring that it will remain useful for the beneficiary countries. In the next phase of the project, FAO will integrate SET outputs into a progressive pathway for surveillance capacity development to further help countries prioritize their capacity-building activities.

CONCLUSION

The successes of SET comes from the fact that significant attention is placed on developing recommendations together with national veterinary services, in a way that is actionable and realistic. Thus far, the approach has guided the development of animal disease surveillance capacities in two ways:

- in the context of specific projects, where SET provides a baseline assessment which can then be used to develop projects' subsequent activities; and
- directly by ministries, incorporating outputs and recommendations into their strategic documents.

The new SET biothreat detection module expands SET to specific attributes for the surveillance and investigation of deliberate animal disease outbreaks. Moreover, the updated SET 2.0 has been made more relevant and comprehensive based on lessons learned in the past 24 missions and on expert input. [360]

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FAO IN ACTION

Lumpy skin disease introduction and spread in South, East and Southeast Asia

Contributors: Xavier Roche, Damian Tago Pacheco, Andriy Rozstalnyy and Madhur Dhingra[1]

Lumpy skin disease (LSD) is a transboundary animal disease (TAD) with significant consequences on rural livelihoods. In 2019, LSD spread into Asia for the first time, reported in Bangladesh, China and India, and spread to other parts of Asia. In 2020, FAO published a qualitative risk assessment on the likelihood of introduction and/or spread of LSD in South, East and Southeast Asia for the period of October to December 2020, and estimated the preliminary impacts of the disease in the region (Roche *et al.*, 2020). This note briefly presents the risk assessment, and how the disease has evolved since the risk assessment was conducted.

BACKGROUND

LSD is a vector-borne viral disease of cattle and Asian water buffalo that causes substantial economic losses. Cattle and buffalo in South, East and Southeast Asia account for more than 30 percent and 97 percent of the global population, respectively (Figure 1); 31 percent and 98 percent of global cow and buffalo milk production; and 29 percent of the cattle slaughtered globally for meat production (FAO, 2021). These animals play an important role in Asia's socioeconomic fabric. Asian exports of live cattle and buffalo meat and meat products, dairy products and hides accounted for USD 5.5 billion in 2017.

The detection of an exotic disease may have severe trade implications for infected countries. The presence of LSD virus in South, East and Southeast Asia poses a high risk to LSD-free countries in the region, with high number and significant formal and informal movements of susceptible cattle and buffalo within and between countries (Figure 2), trade of their products, poor biosecurity in cattle/buffalo production systems and along the value chain, where competent vectors are present.

RISK ASSESSMENT

A risk assessment was carried out in order to assess the likelihood of introduction and/or spread of LSD in targeted countries in Asia based on the major risk pathways such as formal and informal trade of live cattle and buffalo and their products, and vector-borne spread, as outlined in Figure 3. For countries that had already reported LSD at the time of analysis, the assessment only considered the likelihood of spread. Five levels, from negligible to high, were used to qualitatively determine the likelihood of introduction and/or spread. The assessment also considered the level of uncertainty related to data availability, quality and quantity. Among the countries listed as high risk in the risk assessment, Viet Nam and Myanmar had already reported the disease in November 2020. LSD also started to occur in Sri Lanka from September and was confirmed in December 2020 (World Organisation for Animal Health [WOAH], 2021).

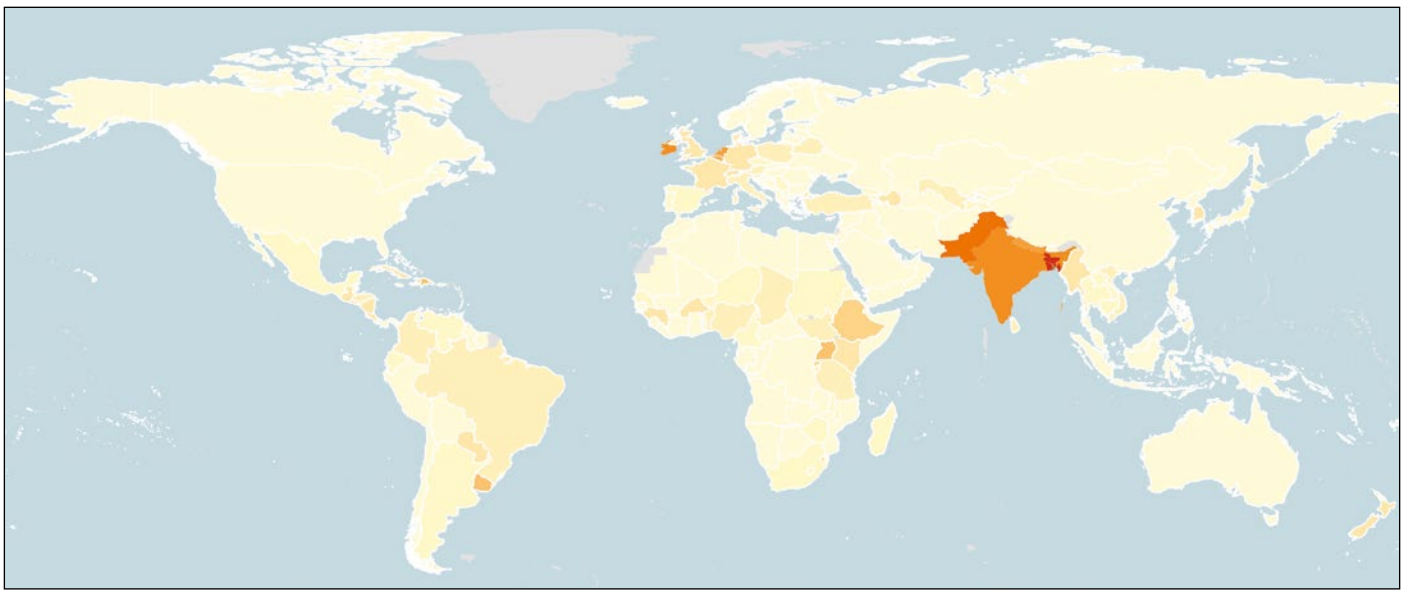

Figure 1. Density of LSD-susceptible animals by country
Source: FAO. 2021. FAOSTAT. In: *Statistics Division*. Rome. Cited 15 August 2020. www.fao.org/faostat/en/#home

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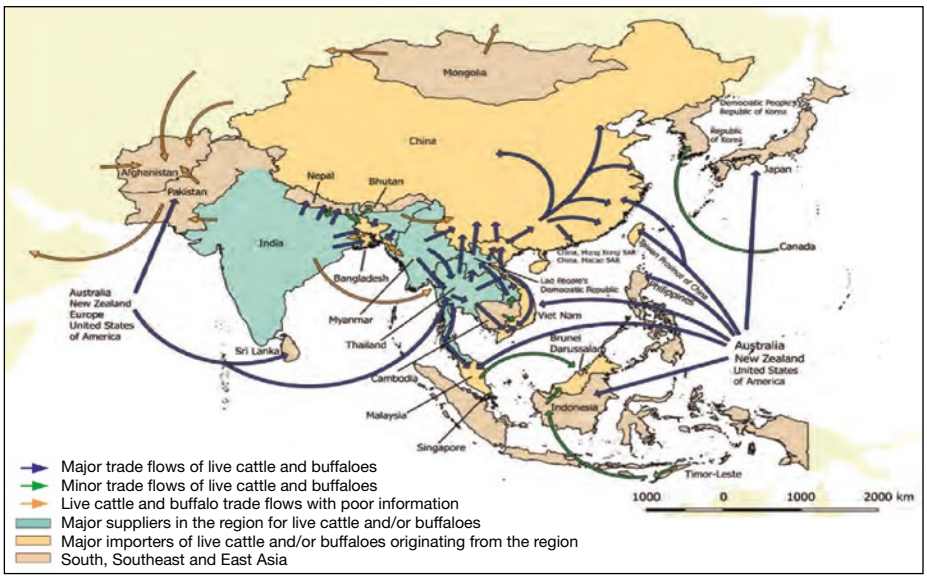

Figure 2. Formal and informal trade flows of live cattle and buffalo across South, East and Southeast Asia

Source: Roche *et al.* 2020. *Introduction and spread of lumpy skin disease in South, East and Southeast Asia: qualitative risk assessment and management.* FAO Animal Production and Health Paper 183. Rome, FAO. https://doi.org/10.4060/cb1892en

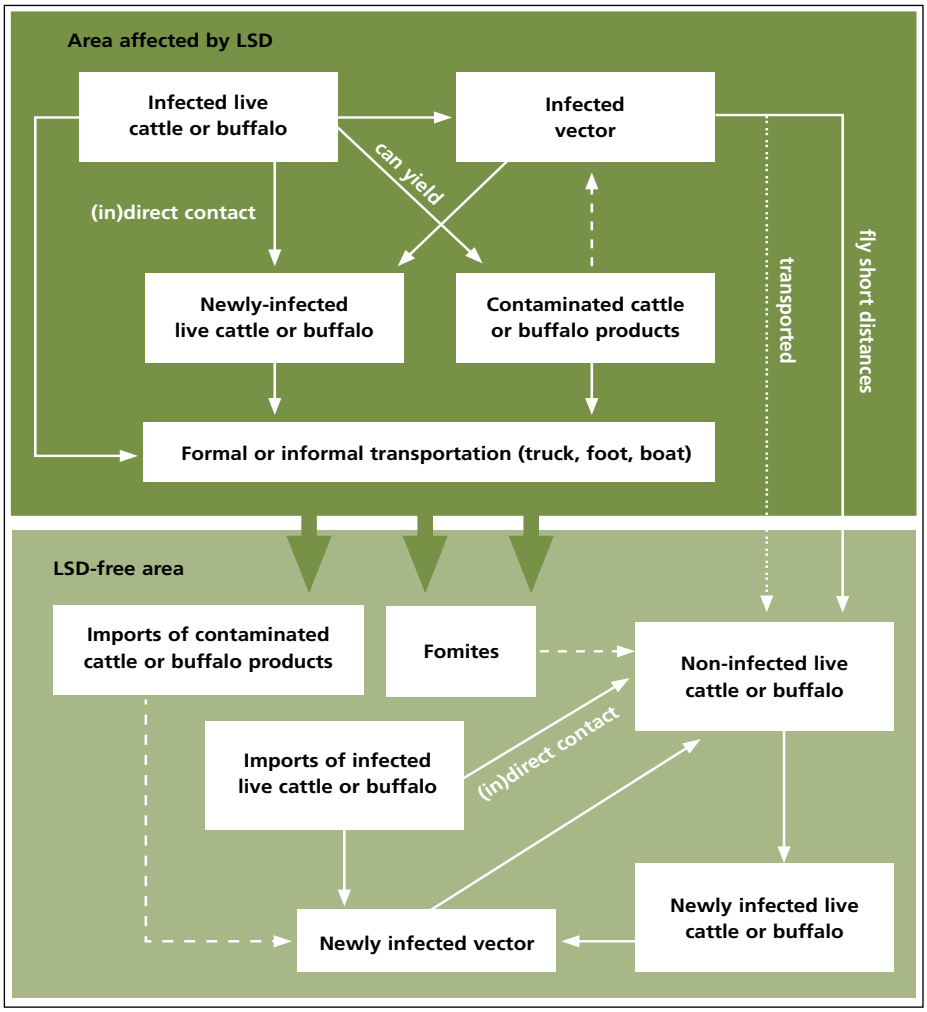

Figure 3. Risk pathways for LSD introduction and spread

Note: Figure 3 depicts major risk pathways for LSD introduction from an affected to an unaffected area. Long lines of dashes reflect potential but likely minor pathways of LSD spread or transmission. The lines of short dashes represent the transport of infected vectors. Cattle or buffalo products include carcasses, meat, milk, hides, skins and offal.

Vectors include all competent blood-sucking arthropods for LSD spread which vary by region.

Source: Roche *et al.* 2020. *Introduction and spread of lumpy skin disease in South, East and Southeast Asia: qualitative risk assessment and management.* FAO Animal Production and Health Paper 183. Rome, FAO. https://doi.org/10.4060/cb1892en

ESTIMATION OF THE ECONOMIC IMPACT

LSD can inflict substantial direct losses through mortality, reduced milk production, damaged hides, poor growth, reduced draught power capacity, reproductive problems associated with abortions, infertility and lack of semen for artificial insemination. Vaccination costs, trade and other indirect revenue losses are directly proportional to the extent of LSD spread.

DIRECT LOSSES

To estimate preliminary economic impact, we built two scenarios based on the experience from Near East countries, where severe LSD outbreaks were reported from 2012 to 2016. The first scenario assumed that the LSD spread affects 3.42 percent of Asia's cattle population; the second scenario included further spread of LSD, putting 10.52 percent of Asia's cattle population at risk. Each scenario estimated losses assumed at high and medium impact (Table 1).

The estimated economic impact of LSD as direct losses of livestock and production in targeted countries in Asia was as high as USD 1.45 billion.

VACCINE COST

LSD prevention/control approaches may primarily include: (i) vaccination of susceptible herds with >80 percent coverage; (ii) movement control of cattle and buffalo and quarantine; and (iii) slaughter campaigns where feasible, to prevent spread. For LSD, homologous vaccines based on the Neethling strain of LSD virus, and heterologous vaccines based on goat pox virus are commercially available. The direct vaccination costs are already lower than estimated direct losses, even before considering additional indirect losses (Table 2).

DISEASE CONTROL OPTIONS

Countries need to decide realistic and feasible policy goals to devise national prevention and control strategies. **In countries where LSD virus is already confirmed**, strategic vaccination aiming to stop the spread, such as vaccination buffer zones/belts or ring vaccination, may need to be considered, along with movement control, active surveillance and biosecurity.

In countries at high risk of LSD introduction, there is an urgent need to implement a contingency plan for early detection and removal of the initial cases; pre-emptive vaccination of all susceptible animals in wide-enough strips along high-risk zones bordering infected neighbouring countries; and an LSD control plan to address the situation in which LSD is detected in several districts/provinces.

Table 1. LSD-related direct losses estimated for different scenarios (unit: USD 1 000)

	Scenario 2		Scenario 1	
	Medium	High	Medium	High
Mortality loss	181 971	319 543	559 748	982 922
Milk loss	43 581	108 206	134 055	332 845
Weight loss	8 951	24 670	27 532	75 885
Hides loss	15 957	15 957	49 085	49 085
Draft power loss	5 977	5 977	18 385	18 385
Total	**256 437**	**474 354**	**788 805**	**1 459 123**

Note: For scenario 1, LSD spread affects 3.42 percent and for scenario 2, further spread of LSD puts at risk 10.52 percent of Asia's cattle population.

Source: Roche et al. 2020. *Introduction and spread of lumpy skin disease in South, East and Southeast Asia: qualitative risk assessment and management.* FAO Animal Production and Health Paper 183. Rome, FAO. https://doi.org/10.4060/cb1892en

Table 2. Estimated costs in US dollars of LSD vaccination (vaccine costs) in affected countries of Asia (Bangladesh, Bhutan, China, India and Nepal)

	Infected provinces	Infected + neighbouring
No. of vaccines needed	129 675 795	331 612 731
Cost of vaccines	142 875 668	356 014 502

Source: Roche et al. 2020. *Introduction and spread of lumpy skin disease in South, East and Southeast Asia: qualitative risk assessment and management.* FAO Animal Production and Health Paper 183. Rome, FAO. https://doi.org/10.4060/cb1892en

Countries at moderate risk should monitor the situation, with a high level of contingency planning, to rapidly address any changes in risk level. That timely and accurate provision of information on how to prevent or address LSD should be provided to village farmers in a form they understand is also an important element of LSD control.

Detailed LSD prevention and control options are available in the risk assessment. When planning vaccination, it is important to note that when scabs are found on animals, the LSD virus has been circulating in the area/herds for at least three to four weeks, and that maximum protection is achieved approximately three weeks post-vaccination. Details of different types of commercially available vaccines and their advantages and disadvantages are also discussed in the risk assessment (Roche *et al.*, 2020).

KNOWLEDGE GAPS

Despite knowledge gained from recent studies following the emergence of LSD in Europe and the Near East, there are still many gaps. Among the most urgent priorities are:

- challenge trials to test the efficacy of locally available vaccines against LSD;
- establishing the rate of onset, duration of immunity and protection provided by vaccination;
- clarifying the epidemiological significance of animals with subclinical infection (due to innate or acquired immunity or a low infection rate, including in small ruminants) in the spread or maintenance of LSD virus;
- informed vector control programmes on vector ecology in different regions, as well as vector species involved in LSD virus transmission, and the distance and timespan over which they can transmit infection;
- understanding of virus survival in interepizootic periods;
- exploration of the possibility of simultaneous administration of LSD vaccine with other obligatory vaccines (such as foot-and-mouth or Brucellosis) and any adverse effect of this on seroconversion or protective immunity; and
- inclusion of attenuated LSD vaccination into cattle testing regimes, such as intradermal tuberculin testing.

CONCLUSION OF THE RISK ASSESSMENT

The risk assessment demonstrated a strong economic justification for vaccination under any scenario. There is a high risk of LSD endemicity in targeted countries in Asia, which would be accompanied by disastrous socioeconomic consequences. While countries are responsible for individual national policy goals, transparency and timely information-sharing are highly important for tackling LSD, as the virus spreads via vectors and has a relatively long incubation period. A regional approach to ensure the harmonization of control measures would be of benefit for all countries in the region and would mitigate impacts on rural livelihoods. This includes exploring approaches to harmonize vaccination strategies in the region. Collaboration between infected and at-risk countries sharing borders is paramount for the exchange of information on disease prevalence, applied control measures and vaccines being used, and for post-vaccination seromonitoring. FAO encourages and supports countries in urgent need to be included in regional coordination to control LSD in Asia and prevent its further spread.

SITUATION OF THE DISEASE AFTER THE RISK ASSESSMENT

By the end of 2020, LSD was already in Bangladesh, Bhutan, China, India, Myanmar, Nepal, Sri Lanka and Viet Nam, among the countries evaluated by the risk assessment. As predicted by the risk assessment, in 2021 LSD spread into Thailand in March, Cambodia, Lao People's Democratic Republic and Malaysia in May, and Mongolia in August (WOAH, 2021).

Given the complexity of the cattle and buffalo value chain and the rapidity of LSD spread in Asia, countries currently free of LSD in the region should stay alert as a significant risk of disease introduction exists, particularly for those involved in formal or informal transboundary trade of live cattle and buffaloes. Although Australia, New Zealand and Pacific countries were not included in the risk assessment in 2020, considering the endemic situation in many Southeast Asian countries, the features of the virus and the risk factors described in the risk assessment, a risk of introduction is present. These countries need to revise their emergency preparedness plans including provisions and arrangements for emergency and/or mass vaccination, border control inspections, surge capacities for surveillance and lab diagnostic testing, quick and safe culling and disposal of affected animals (as per cultural norms), and movement control and zoning, and must enhance their awareness campaigns among international travellers, farmers and value chain actors. 360

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FAO IN ACTION

Outbreak investigation in Mongolia: cascade training promotes evidence-based disease control

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INTRODUCTION

With just 3 million inhabitants, Mongolia's sparsely distributed human population is dwarfed by that of its livestock, with over 57 million small ruminants and 4.3 million cattle (National Statistical Office of Mongolia, 2017). Traditionally agriculture forms the core of Mongolia's economy, and 80 percent of agricultural production consists of livestock rearing, predominantly of ruminants and equines. The livestock industry engages two thirds of Mongolia's rural population, and agriculture accounts for 14 percent of gross domestic product (FAO, European Union and CIRAD 2022). Due to recent population expansion and Mongolia's extremely harsh climate, the livestock industry is prone to threats including those posed by climate change or incursions of TADs.

Mongolia has unfortunately experienced a high number of incursions of TADs in the last 20 years. A 2016 report for FAO commented:

Disease incursions into Mongolia are considerably more frequent in relation to the level of risk than any other country in the world that I can identify. Mongolia sees as a high national priority the need to expand export of animal products, but these efforts have been thwarted over the last decade by repeated introductions of a range of undesirable organisms. (Morris and Bolortuya, Report for FAO, 2016)

In the period 2000–2017, there have been at least 30 separate incursions of major diseases into Mongolia, including 14 incursions of foot-and-mouth disease (FMD), four of sheep and goat pox, (including large outbreaks from 2013 to 2016), and the first incursion of *peste des petits ruminants* in 2016.

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Traditional herding of cattle in Mongolia.

A thorough understanding of risk factors for the introduction, transmission and spread of TADs, and the economic and social impacts of outbreaks on affected herders, is crucial in improving disease control strategies and measures. Such information can only be gained from thorough and systematic disease outbreak investigations carried out at the local level in affected areas. On the central level, the data collected must be collated and interpreted effectively, and then used in a policy development environment that engenders an evidence-based approach to disease control.

The FAO and the Government of Mongolia have identified such disease outbreak investigation as an important area where additional capacity is required. Relatively few veterinarians in Mongolia have received specialist postgraduate training in epidemiology, and the focus of the extensive activities carried out in response to disease outbreaks has, to date, been particularly on the implementation of control measures, leaving less room for comprehensive epidemiological information gathering.

Improving disease outbreak investigation capacity in Mongolia is a challenge requiring action in two interconnected areas. The first is to develop a cadre of veterinarians at central level in the government veterinary services who have the expertise to become "outbreak investigation leaders". These leaders are involved in the design of standard operating procedures (SOPs) for outbreak investigation and the collation and interpretation of the data gathered. They are also critical in changing the policy development mindset to one where evidence can be effectively used to alter disease control strategies. However, these "outbreak investigation leaders" cannot act alone. Also critical in improving capacity is equipping the relatively large number of veterinarians working on the ground with the skills needed to conduct disease outbreak investigations effectively.

This article briefly describes the approach of a training programme to strengthen veterinary capacity for disease outbreak investigation both at central and field levels, and to promote evidence-based disease control. This training is implemented with the support of FAO under its resilience programme to support country priorities and build capacity for the control of TADs.

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APPROACH: A TRAINING CASCADE

The training programme was designed with two phases (Figure 1), recognizing the need to train some veterinarians at central level with in-depth expertise, but extend training in routine outbreak investigation to a wide audience of front-line veterinarians. In the first phase, a group of outbreak investigation leaders were trained in both routine and advanced aspects of outbreak investigation in two workshops led by international experts. These outbreak investigation leaders were then asked to adapt what they had learned, in order to develop new SOPs for outbreak investigation in the Mongolian context. Alongside this, they were asked to develop a training course and materials that could be used to train field veterinarians on the proper application of these SOPs.

In the second phase, some of the trained outbreak investigation leaders became trainers, and delivered the newly developed regional training courses on routine outbreak investigation, with support provided by the international trainers who also acted as observers. Going forward, the intention is that further regional outbreak investigation workshops will be conducted by the Mongolian veterinary services without the need for support from international experts.

TRAINING PARTNERS

The training programme was implemented with the support of specialized partners. The **European Commission for the Control of Foot-and-Mouth Disease** (EuFMD), a specialized commission of FAO, has extensive experience in provision of training on emergency preparedness and control of FMD. The training materials and approach used in Mongolia were based on EuFMD's Real-Time Training courses which have now been conducted over 60 times. These unique courses involve participants investigating an outbreak in "real time", visiting affected premises, designing and using questionnaires for interviewing livestock owners, examining animals, taking samples for laboratory diagnostics, and collating, analysing and interpreting the results of these investigations. The use of appropriate biosecurity measures is also emphasized, ensuring that those responsible for investigating a disease do not become themselves responsible for its onward spread. This real-life training approach has been highly valued, ensuring that the focus of the training remains practical and applied. In particular, visiting affected herders and spending time discussing their perceptions of the disease and its control are important in ensuring that disease investigations and subsequent control measures remain centred on the needs of the livestock keepers themselves.

The second workshop in phase one, and the regional training courses, was delivered in partnership with **Agronomes et Vétérinaires Sans Frontières** (AVSF), an international non-governmental organization that has been conducting activities in support of the development of Mongolia's livestock sector since 2004. AVSF's extensive experience of training delivery and understanding of livestock industry stakeholders brought significant logistical expertise to the team.

In addition, the newly established Mongolian Veterinary Epidemiology Association (MVEA) and Mercy Corps provided their support for the distribution of communication materials for disease recognition to all veterinarians in the country.

PHASE ONE: NEW SKILLS FOR OUTBREAK INVESTIGATION LEADERS

The first workshop took place in September 2017 and was based in Ulaanbaatar. Participants were trained on topics considered essential to routine outbreak investigation, including confirmation of the causative disease agent, appropriate collection of diagnostic samples, collection of routine data including herd structure, onset and signs of disease, Global Positioning System location, vaccination history, dangerous contacts during incubation period, and period of onwards spread. A veterinarian visiting a disease outbreak must not only collect information; they must also take steps to respond to the situation they encounter. For this reason, the training also covered initial outbreak response, including provision of advice to herders, application of immediate local control measures, and communication with local veterinary and governmental authorities. A field visit to an area where there had recently been an outbreak of FMD was conducted, and this practical and applied training was highly appreciated. Techniques for adult training were also included, since some of the outbreak investigation leaders were expected to become trainers

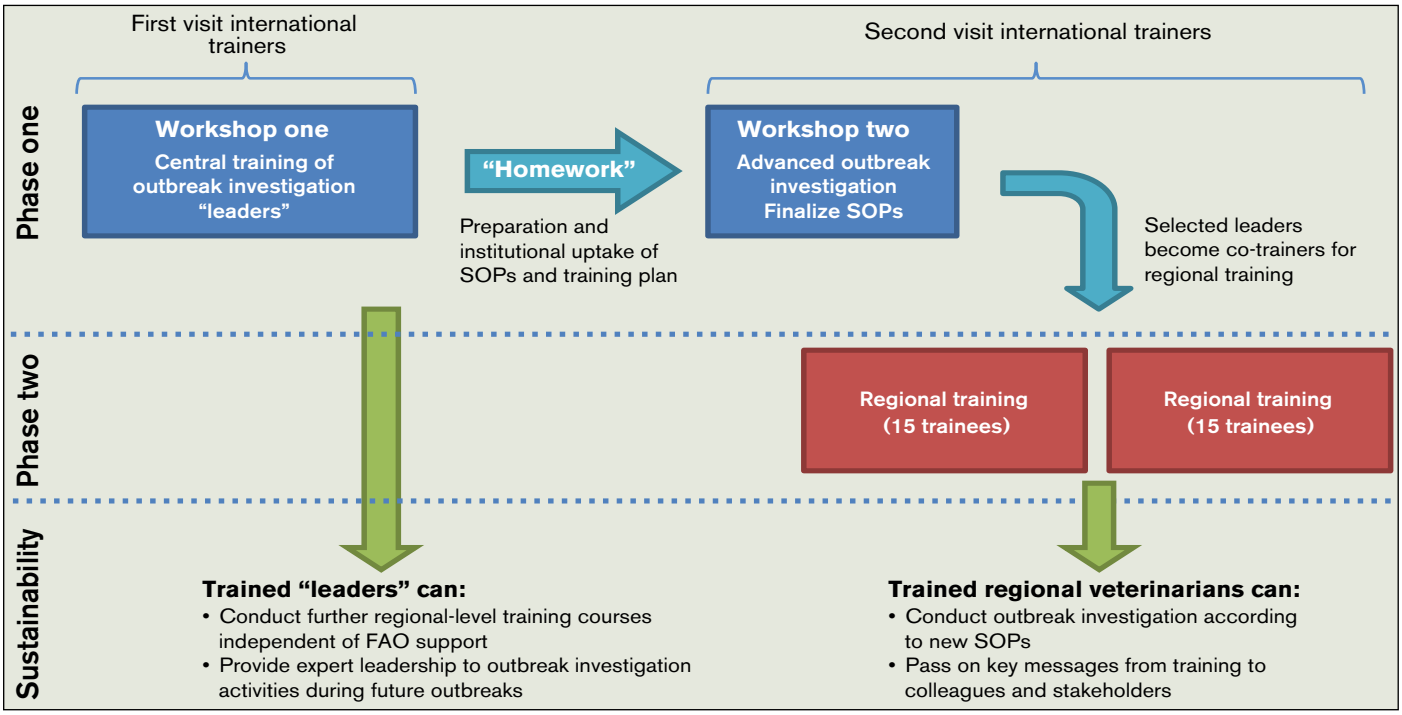

Figure 1. Outline of the training programme

Source: Authors' elaboration.

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Interviewing herders affected by an FMD outbreak.

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Examining and sampling animals

themselves in the second phase. The participants were diverse, consisting of central and regional staff of the Department of Veterinary and Animal Breeding (DVAB) alongside representatives of the university and non-governmental organizations, including MVEA. They were active and dedicated to learning and, as a result, the training was intensive and rewarding. A feedback survey was conducted at the end of the training course; 75 percent of the participants rated the course as "excellent", with the remainder describing it as "good". All participants reported an improvement in self-assessed competency at completing the stated learning objectives after the course.

The second workshop was again conducted with the group of "outbreak investigation leaders" and took place in December 2017, with field visits requiring suitable clothing to cope with the harsh winter conditions. Advanced outbreak investigation involves the collation of the results from multiple routine outbreak investigations, and combines these with further studies which typically take place after the end of an outbreak. It aims to answer questions on issues such as the main risk factors for transmission of the disease, the social and economic impacts of the disease on the affected herders, and the effectivity of the control measures employed.

Participants were taken through the process of defining a research question, study design, questionnaire development, conducting the study in the field, data management, analysis, interpretation and presentation of the results to their peers of the veterinary services. At this workshop, the SOPs and training materials that had been developed after the first workshop were also reviewed and improved. The findings of this workshop highlighted the high impact of both the disease and the applied control measures on affected herders, and how an epidemiological approach to disease control might be used to identify the control measures most likely to reduce disease risks, balanced against reducing the impacts on the livelihoods of those affected.

PHASE TWO: CASCADING TRAINING TO VETERINARIANS ON THE FRONT LINE

The second phase of training took place in April 2018. Two of the trained outbreak investigation leaders (Chimedtseren B. and Erdenebat B.) were the trainers for these courses, supported by national and international FAO experts. The training was conducted in Orkhon in Central Region and Khentii in Eastern Region, both regions identified as being at high risk of disease outbreaks. The training was centred around developing the necessary skills to correctly implement the SOPs for outbreak investigation and biosecurity. Additional focus was given to the methods of training delivery, emphasizing application of adult learning techniques, practical and applied training, and participatory exercises, rather than following a lecture-based format. Participants highly appreciated the practical, field-based element of the training, and their input meant that further improvements were made to both the SOPs and the format of the training course itself.

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Preparing for field studies as part of the advanced outbreak investigation training.

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Interviewing herders during phase two of the regional training.

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Participants using training materials translated into Mongolian during phase two of the regional training.

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Trained outbreak investigation leaders deliver regional training.

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Regional outbreak investigation training in Khentii.

EQUIPPING TRAINEES: NOT ONLY NEW MATERIALS, BUT NEW MINDSETS

The final result of the regional training workshops is a well-developed training approach and materials in Mongolian language, suitable for wider dissemination by DVAB. In addition, a concerted action by the MVEA and Mercy Corps has resulted in a total of 1 750 sets of posters on lesion ageing and diagnostic sampling, distributed to veterinarians in all areas of Mongolia. The project partners are developing a number of tools to assist with priority challenges identified through the training. These include the adaptation and development of mobile applications for outbreak investigation and serosurveillance, and short video messages to inform herders and local veterinarians about disease prevention and biosecurity practices. On the central level, MVEA and DVAB intend to further develop the SOPs related to outbreak investigation, which will help to safeguard a more uniform approach to epidemiological disease investigation.

SUSTAINING MOMENTUM FOR EVIDENCE-BASED DISEASE CONTROL

Alongside these tangible outputs, the training programme has also resulted in a growing appreciation of the value of epidemiological evidence as a basis for the design and evaluation of disease control strategies. To stay motivated, outbreak investigators need to see their findings applied in local as well as national decisions; equally, national decision-makers need to make investigations an integral part of every outbreak response. While TADs such as FMD and *peste des petits ruminants* are an ongoing and severe threat to Mongolia's herders and livestock industry, continuing to nurture this changed mindset towards risk-based disease control is an important future continuous activity for all partners involved.

ACKNOWLEDGEMENTS

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FAO IN ACTION

Impacts of African swine fever on the meat market in Viet Nam

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BACKGROUND

African swine fever (ASF) is an emerging viral disease of pig, characterized by the sudden death of pigs regardless of age and gender. ASF affects both domestic pigs and wild boars. The main transmission of ASF virus is through direct contact, via the oral-nasal route, through ingestion of pork or other contaminated products containing the virus (e.g. swill, waste, carcasses), excretions from infected pigs, or indirect contact with the virus through fomites such as shoes, clothes and utensils. Vector-borne transmission occurs through bites from infected Ornithodoros soft ticks, where present (Beltran-Alcrudo *et al.*, 2017). There is no vaccine or cure available to prevent this disease.

ASF virus was first detected in Kenya in 1909 (Montgomery, 1921). In 2007, the virus entered Georgia and spread into Eastern Europe and Russian Federation. The first ASF in Asia was reported in August 2018, in Shenyang, Liaoning Province, China (Li and Tian, 2018). The disease spread throughout China and into neighbouring countries including countries in Greater Mekong Subregion (2019) and jumped to island countries in the Pacific (2019/20). In February 2019, the Ministry of Agriculture and Rural Development of Viet Nam (MARD) confirmed the first ASF case (World Organisation for Animal Health [WOAH], 2019a), seven months after the virus entered China. It was first observed in a family-owned backyard pig farm in Hung Yen Province in the Red River Delta of northern Viet Nam at the end of January 2019 (Le *et al.*, 2019), and spread to all 63 provinces and municipalities in the country by August 2019 (WOAH, 2019b).

Viet Nam is one of the top pork producers in the world (OECD and FAO, 2021) with annual production of pork more than 30 kg/capita on average (Figure 1). Considering that ASF has a high mortality rate while no vaccines and cures are available, the Vietnamese Government and livestock sector have recognized the potential impacts of ASF outbreaks, and made efforts to control the disease. MARD has issued many ASF-related policies, interventions and other measures to control the spread of ASF and reduce its impacts. These have included culling of infected animals, the cleaning and disinfection of affected farms, imposing movement restrictions on pigs, and compensation for farmers to encourage outbreak reports. Later, financial support was also provided to help repopulation (Viet Nam, MARD, 2019a; Viet Nam, 2019, 2020a).

Although the control measures were effective in controlling outbreak numbers, they posed potential threats to the meat market in the country, and subsequently caused economic losses to different stakeholders in the value chain such as producers and consumers. Understanding the economic effects of the disease can support decision-makers to create better management strategies and eventually mitigate the impacts of the disease. However, to the best of knowledge, limited research regarding ASF in Viet Nam has been conducted, and most studies have focused more on epidemiology (Lee *et al.*, 2021; Tran *et al.*, 2021a, 2021b). Therefore, the objective of this report is to assess how ASF has affected pig production and the import and prices of pork, as well as of the other main meat types in Viet Nam.

ECONOMIC IMPACTS

PRODUCTION

From 2010 to 2018, the total pig population in Viet Nam was always more than 25 million, dominated by pigs in smallholder farms, with more than 80 percent of farms having less than ten pigs (Chăn nuôi Việt Nam, 2021).

Since ASF entered Viet Nam, it has been reported that almost all outbreaks were detected at small- and medium-sized farms with low biosecurity (Lee *et al.*, 2021). Thus, most of the pigs in small- and medium-sized farms were infected and died or were destroyed in stamping-out efforts. According to Viet Nam's General Statistics Office (GSO), ASF caused the loss of 6 million pigs through death and depopulation in 2019 (Viet Nam, GSO, 2021). Since the disease spread extensively during 2019, there was little success in the repopulation process; some repopulation efforts resulted in a bimodal loss curve (Figure 2).

As the result, the total pig population dropped to less than 20 million, a sharp decrease of almost 30 percent compared to the pre-ASF figure, marking the lowest figure in over a decade (Figure 3).

Due to ASF, the number of breeding pigs (sows) also declined. In 2020, with great effort in disease management, the recorded pig

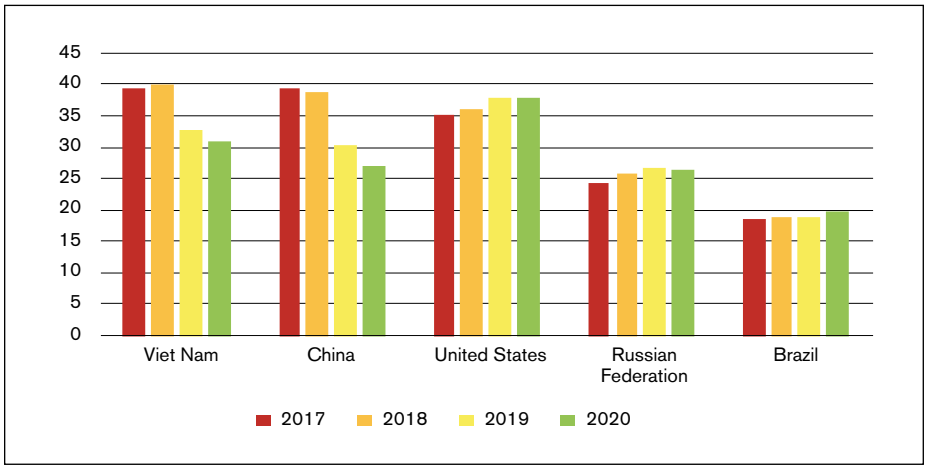

Figure 1. Annual production of global top pork producers (unit: kg/capita)

Source: OECD & FAO. 2021. OECD-FAO agricultural outlook 2021–2030. In: *OECD.Stat*. Paris. Cited 29 September 2021. https://stats.oecd.org/#

[1] FAO, Rome.

[2] FAO Regional Office for Asia and Pacific, Bangkok.

[3] FAO Viet Nam.

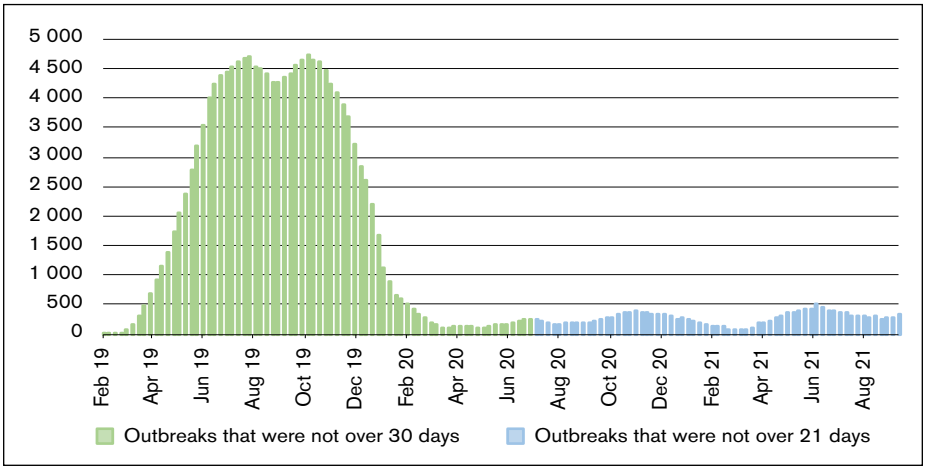

Figure 2. Cumulative number of affected communes in Viet Nam

Sources: FAO. 2022. Animal health. In: *FAO.org*. Rome. Cited 5 August 2022. www.fao.org/animal-health/situation-updates/asf-in-asia-pacific/en. Map 1. ASF situation in Asia (for the past 10 weeks). FAO. 2018–2022. African swine fever situation in Asia & Pacific updates: 1 January 2018–4 August 2022. Rome. Internal document.

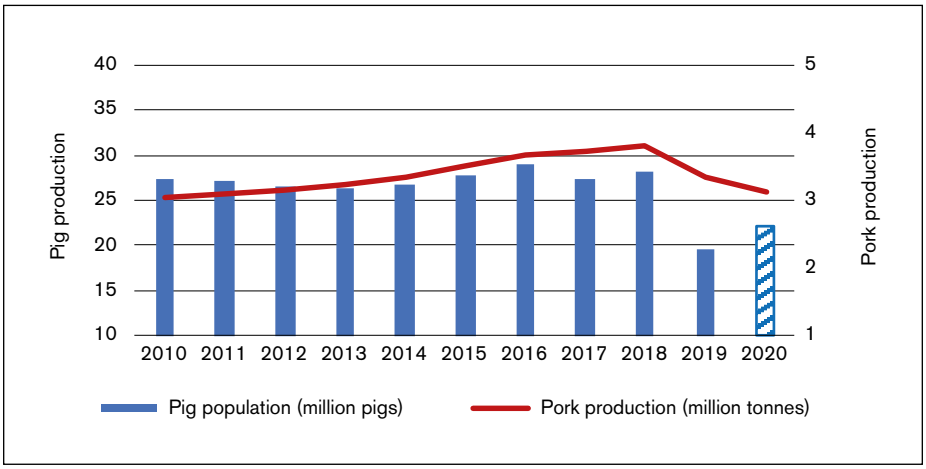

Figure 3. Annual pig population and pork production

Note: data in 2020 for pig population was preliminarily estimated

Source: Viet Nam, GSO. 2020. General Statistics Office. In: *General Statistics Office*. Hanoi. Cited 19 May 2020. www.gso.gov.vn/en/px-web/?pxid=E0638&theme=Agriculture%2C%20Forestry%20and%20Fishing; OECD and FAO. 2021. OECD-FAO agricultural outlook 2021–2030. In: *OECD. Stat*. Paris. Cited 29 September 2021. https://stats.oecd.org/#

deaths and numbers culled due to ASF reduced to only 1.5 percent (about 90 000 pigs) of the figure in 2019 (Viet Nam, GSO, 2021). The preliminary data shows that the pig population gradually recovered in 2020, with about 22 million pigs in the country by the end of the year (Viet Nam, GSO, 2020). Nevertheless, the repopulation rate was low due to limited capital resources, the high price of breeding pigs, the risk of ASF reoccurrence and the unavailability of effective vaccines. Noticeably, while the pig production increased in 2020, the pork production kept decreasing due to the time lag in the production process (a 25 percent reduction compared to the pre-ASF level).

PRICES

The loss in pigs and pork production led to a pork price crisis. In Viet Nam, more than 50 percent of pigs are distributed in the northern parts of the country (Que *et al*., 2020); with the higher supply, the pig price in the northern part is usually lower compared to the south.

After the first confirmation of ASF in February 2019, many pig farmers slaughtered their pigs before they were infected. This action temporarily increased the pork supply in the market; as a result, with the imbalance of supply and demand, the price of pork went down.

In May 2019, ASF was reported from the southern part of Viet Nam for the first time, specifically in the province with the largest number of pig herds in Viet Nam, Dong Nai (Phuoc Tuan, 2019). This lowered the price of live pigs in the south, and the gap in live pig prices between the two regions narrowed.

From May to October 2019 was the peak of ASF outbreaks across the whole country (Figures 2 and 3), and thus many pigs were culled. The lack of pig supply caused an increase of live pig prices in the fourth quarter of 2019 (Figure 4). The highest recorded price was around 90 000–100 000 VND/kg (USD 3.92–4.35) live weight in May/June 2020, doubling the pre-ASF prices.[1]

During the second half of 2020, Viet Nam started to import live pigs (including breeding pigs) from Thailand to stabilize prices and recover the pig population (Anh Minh, 2020). As the supply increased, live pig prices decreased towards the end of the year, but were still 50 percent higher than the pre-ASF level.

Apart from other factors affecting the market (seasons, holidays etc.), it is noticeable that the COVID-19 pandemic has strongly affected live pig prices. In April 2020, the Government applied social distancing measures, including lockdown, for the first time in Viet Nam, asking people to stay home for two weeks to prevent the spread of the virus (Viet Nam, Ministry of Health, 2020). This measure temporarily increased pork demand, since panic led to attempts to stockpile foods during the lockdown period, rocketing the live pig price to a historic level.

From June 2021, the Government again implemented a lockdown which lasted for more than three months. During this time, serious disruptions in logistics occurred, which did not happen during the lockdown in 2020. As the result, live pig prices reduced to the pre-ASF price of 40 000–50 000 VND/kg (USD 1.74–2.18). Prices are expected to continue to decrease. Noticeably, although the live pig price was continuously decreasing, the retail price of pork remained very high because of the increase in logistical costs caused by movement restrictions. For example, the retail price for pork ribs in the market reached approximately 190 000 VND/kg (USD 8.27) in October 2021, almost four times higher than the live pig prices (VietnamBiz, 2021a, 2021b)

IMPORT VOLUME

To stabilize the high pork prices and to meet the domestic demand, MARD enhanced pig and pork import to Viet Nam. In June 2020, Viet Nam started importing live pigs from Thailand for the first time to slaughter for food; as of December 2020, over 300 000 live pigs were imported, providing more than 20 000 tonnes of meat to the local market (Anh Minh, 2020; Viet Nam, MARD, 2020). Viet Nam also reduced the pork import tariff rates for its most-favoured-nation exporters from 15 percent to 10 percent, effective from July to December 2020 (Viet Nam, 2020b). With these efforts, the imported volume of pork increased 200 percent in 2020 compared to the pre-ASF level, with a total of 237 670 tonnes (OECD and FAO, 2021).

From June 2021, Viet Nam suspended the importation of live pigs from Thailand. Although the pork imported tariff rates returned to

[1] USD 1 = VND 23 420.

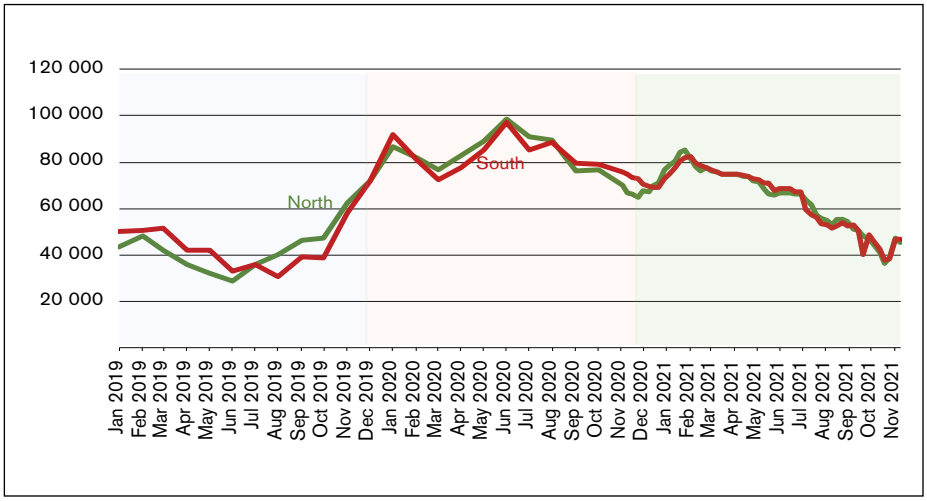

Figure 4. Live pig prices from 2019–2021 (unit: VND/kg)
Source: Authors' elaboration (data provided by VietnamBiz).

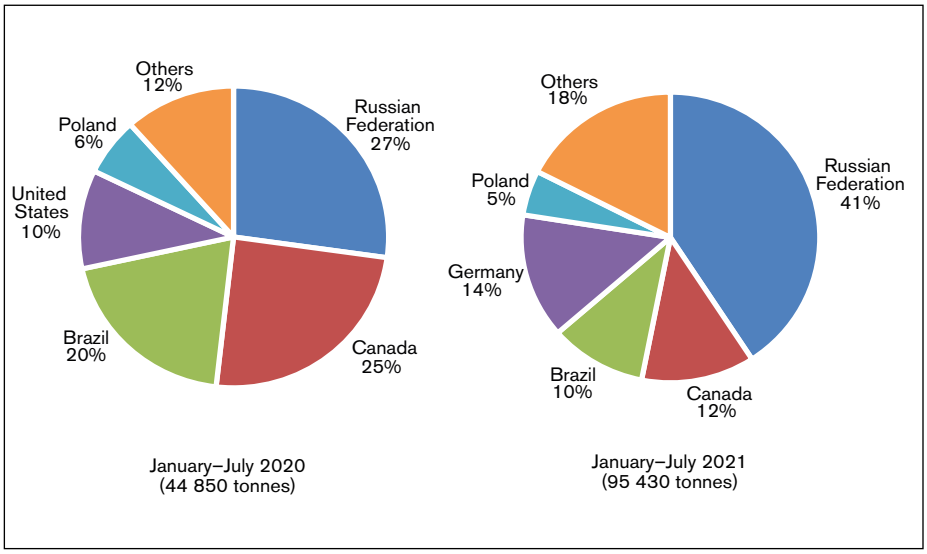

Figure 5. Pork imports to Viet Nam from January to July, in 2020 and 2021, percentage share
Source: Authors' elaboration, based on Viet Nam, MOIT. 2021. Bản tin thị trường Nông, Lâm, Thủy sản. In: *Ministry of Industry and Trade*. Hanoi. Cited 10 October 2021.

15 percent, the import volume of pork remained at a high level. According to the Ministry of Industry and Trade, from the beginning of 2021 to July, Viet Nam imported 95 430 tonnes of frozen pork, a year-on-year increase of 112.8 percent compared to 2020. While the import volume shares in 2020 were split almost equally between Brazil, Canada and the Russian Federation, in 2021 over 40 percent of pork was imported from the Russian Federation (Viet Nam, Ministry of Industry and Trade, 2021) (Figure 5).

OTHER MEAT MARKETS

Higher prices and low production of pork encouraged consumers to substitute alternative protein sources in their diets. Although pork is the dominant protein source in Viet Nam over other types of meat (Nguyen and Ngo, 2016) (Figure 6), pork consumption in Viet Nam started to decline as early as 2018, which could be because of the fear of ASF occurrence in the neighbouring country China.

That downward trend continued until 2020. From 2018 to 2020, to substitute other sources of protein, other meat types were considered by consumers. Poultry meat consumption showed an upward trend due to its affordability and producers' capacity to respond quickly to the rising demand. It is predicted that for the next four years, all meat types will undergo greater consumption by consumers, especially pork (OECD and FAO, 2021).

COST OF ASF

Since ASF was confirmed in China in 2018, its introduction into Viet Nam became an imminent threat. Therefore, as soon as ASF was confirmed in the country in February 2019, the Government actively took measures to prevent disease spread and mitigate the long-term impacts (Viet Nam, MARD, 2019b), by supporting farmers in the affected area (Viet Nam, MARD, 2019c) and sharing information for an increase in awareness. Compensation was paid for pigs which died or were depopulated (Viet Nam, MARD, 2019d). Research on an ASF vaccine was also developed. Police were deployed to detect Illegal transport and sales of infected pigs or meat. Although the number of ASF outbreaks significantly reduced after 2019 (Figure 2), according to an analysis ASF increased pig production cost in Viet Nam by 30 percent (Asian-Agribiz, 2021). According to Nguyen-Thi *et al.*, (2021), ASF outbreaks caused severe economic losses among farmers and thus affected their livelihood. The outbreaks also had adverse impacts on the supply and demand in the traditional small- and medium-sized pig production sector, while the modernized large-scale sector was less affected or even benefited from the outbreaks due to its high level of biosecurity, resulting in a more consistent supply and customer preference for a product seen as more safe.

CONCLUSION

In general, ASF affects different aspects of the meat market, including pig supply, price, international trade, and short- and long-term consumption trends. The reduction in production would change the pig inventory in the short term; however, this temporary lack of pig supply could be improved over time by importing pigs or pork, developing better biosecurity management strategies, and improving disease monitoring and surveillance activities.

The effects of ASF on market prices are complex, since prices also depend on other external factors such as the adverse influence of consumers' concerns and demands. Thus, monitoring the epidemiological situation and pig/pork movement, and promoting improved and more flexible supply chain and market channels, may boost repopulation, avoid logistical disruptions and finally mitigate the long-term impacts of ASF on the pig industry. Although we only compared pork with beef, veal and poultry meat in this report due to data limitations, it may be that ASF has changed consumers' current preferences for food choices towards other meat types in the short term.

Considering that pork is the preferred animal protein in Viet Nam, the industry will likely recover, and production will return to pre-ASF levels in the middle or long term. However, as ASF is established as an endemic disease, the pork industry will need to restructure, with a trend towards a more integrated system. For example, integrated pig-fish farming would lower the risks of production failure in case an ASF epidemic occurs, since it diversifies the production activities and income sources of the farms. 360

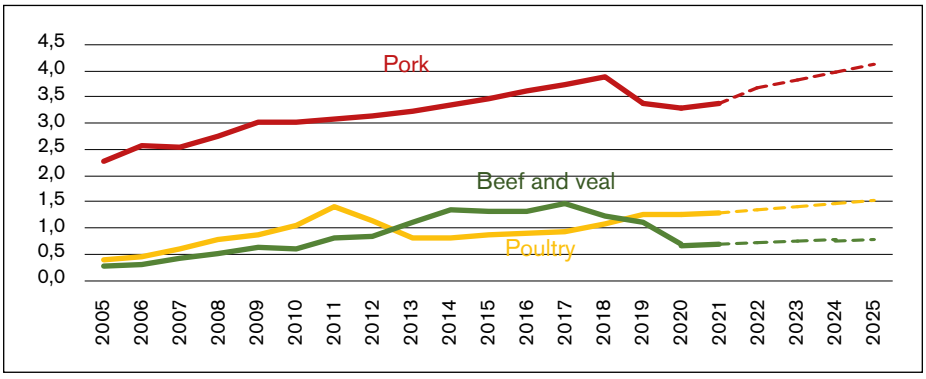

Figure 6. Meat consumption in Viet Nam from 2005 to 2022 (unit: million tonnes)

Source: OECD and FAO. 2021. OECD-FAO agricultural outlook 2021–2030. In: *OECD.Stat*. Paris. Cited 29 September 2021. https://stats.oecd.org/#

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NEWS

EMPRES-i+: strengthening disease intelligence and early warning

Contributors: Andrea Capobianco Dondona, Asma Saidouni, Elisa Palamara, Mirko Bruni, Fairouz Larfaoui and Madhur Dhingra[1]

Timely and reliable disease information enhances early warning and response to transboundary animal diseases (TADs) and emerging zoonoses. It supports early action, prevention and improved response. To address these challenges and support national veterinary services through regional and global disease information and analysis, the Emergency Prevention System for Animal Health (EMPRES) designed and developed a web-based secure information system: EMPRES-i. First released in 2004 in response to the growing demand from users for global animal health information, and using a systematic approach to disease information-gathering and sharing, after active use for 18 years it was completely modernized and upgraded to EMPRES-i+ in 2021. Launched on 22 October 2021, EMPRES-i+ encompasses several new features, including improved data quality for evidence-based decision-making; advanced analytics and visualization to allow country users access to real-time data visualization; forecasting and early warning for early reaction to health threats; and a new cloud-based platform with interoperability with other data platforms from the public health, animal health and environmental sectors. EMPRES-i+ serves also as the data platform for EMA-i, a mobile app for timely animal disease reporting from the field to enhance country-level surveillance, all EMA-i user countries will automatically benefit from the advanced analytics and visualization features at their end.

EMPRES-i+ also uses some functionalities recently developed under the FAO Hand-in-Hand Geospatial Platform that integrate data from across FAO on soil, land, water, climate, fisheries, livestock, crops, forestry, trade and socioeconomics, among others.

A webcast on EMPRES-i+ is available at www.fao.org/webcast/home/en/item/5660/icode/. 360

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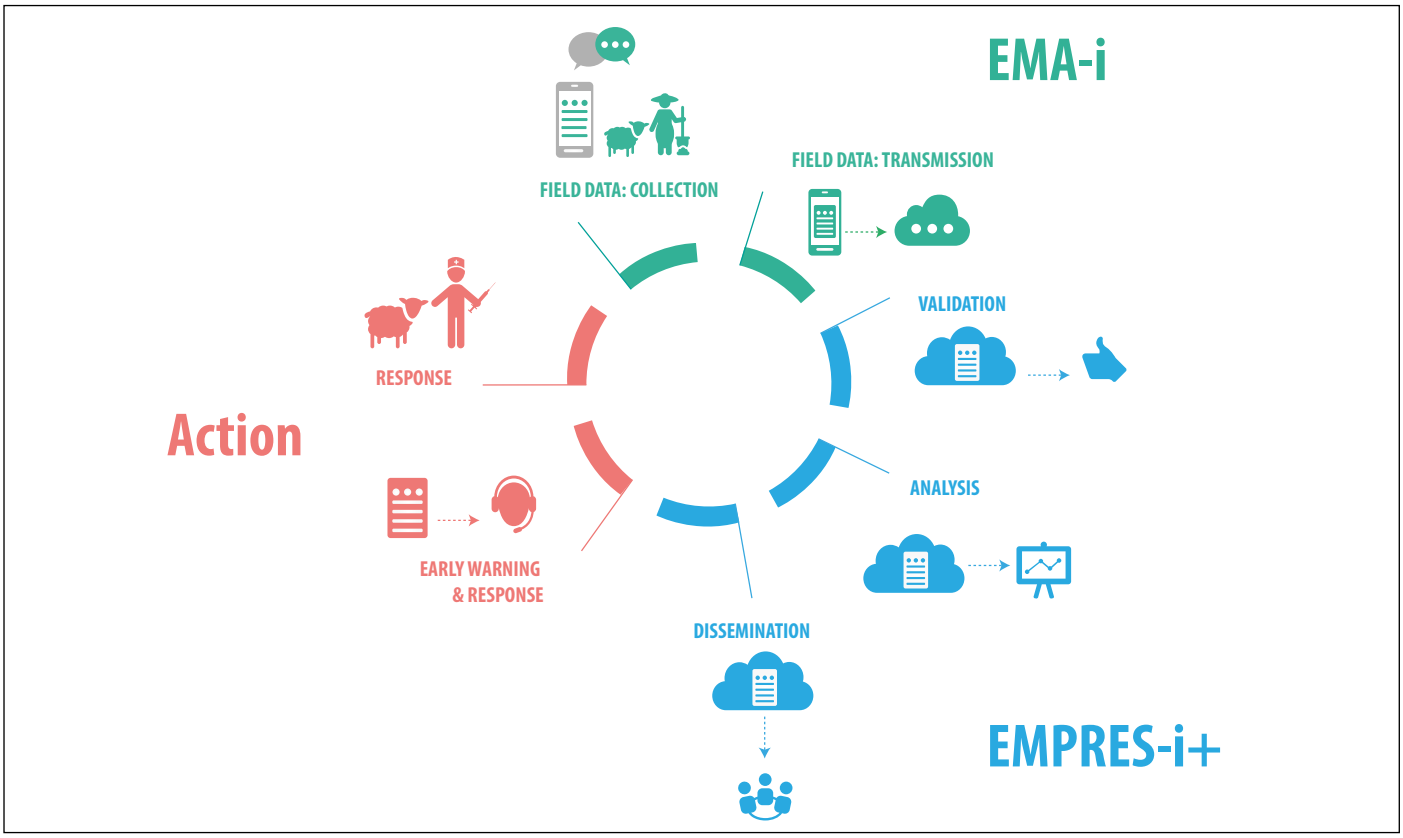

Figure 1. Tools and processes for data reporting from the field for analysis, early warning and response

[1] FAO, Rome, Italy.

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NEWS

FAO Virtual Learning Centers established

Contributors: Madhur Dhingra, Alessandra Alviti, Sam Mulligan and Maria De La Puente Arevalo[1]

Virtual Learning Centers (VLCs) are virtual hubs based in the Food and Agriculture Organization of the United Nations (FAO) regional and subregional offices, with the objective of developing and delivering online training and ensuring the courses offered are in line with the needs of FAO target regions and tailored to the local languages and contexts.

At present, FAO has six VLCs, in Asia and the Pacific (Bangkok and Apia), East Africa (Nairobi), Europe and Central Asia (Budapest), Latin America and the Caribbean (Santiago), the Near East and North Africa (Cairo) and Southern Africa (Harare). A VLC for West Africa is under discussion.

VIRTUAL LEARNING AS A COMPETITIVE ADVANTAGE

The VLC courses aim to build and further develop the capacities of national stakeholders within interdisciplinary areas, including animal health, animal production, food and feed safety and quality, aquaculture, and environment and natural resources. Any FAO content which relates to the 2030 Agenda for Sustainable Development can be developed into a VLC course, in support of the strategic objectives of FAO and the Sustainable Development Goals. By using information and communication technology to deliver courses, the VLCs allow ample and geographically disparate audiences to be trained at low cost and in an environmentally friendly manner.

COURSE DESIGN AND DIGITAL ENGAGEMENT

Some factors that make VLC online courses particularly effective include the following:

- The VLCs use a virtual platform, which provides trainees with access to a wide range of training resources. This platform also allows monitoring and evaluation of our courses by collecting relevant data such, as completion rates and grades.
- VLC courses are mostly tutored courses. This means that expert trainers guide and accompany the learners throughout the course, making sure that all questions are answered and additional information according to the needs or curiosity of the learners is provided.
- Lessons are scalable and highly customizable, and vary depending on the needs of the country and learners' strengths and weaknesses in a subject.
- Lessons always involve interactive content to highlight concepts and ideas. The combination of self-learning materials, live training sessions and online tutored discussion fora foster the creation of a network among students and teachers.
- VLCs adopt a mobile-first solution, in which courses are designed to be used efficiently through mobile devices. Whichever device trainees choose, they will be presented with consistent content across different touchpoints, also accessible with low bandwidth input.

VLCs also support regional networking through their role in the organization of virtual meetings, by providing technical and operational assistance.

SOME EXAMPLES OF VLC COURSES

The VLCs have delivered multiple courses to respond to training priorities at regional level. Several courses on African swine fever (ASF) in English, French, Russian and Spanish were delivered to more than 1 000 veterinarians worldwide, to increase their knowledge of ASF and other related transboundary animal diseases and raise awareness of their huge economic impact on farmers' livelihoods and food security.

The VLCs have also supported the delivery of courses that, due to COVID-19, moved from face-to-face to online formats. One particularly notable success was the poultry farmer field school refresher course for facilitators and master trainers. Over six weeks, 45 participants from Zambia and Zimbabwe – many connecting online from remote areas – were trained in preparing and implementing farmer field schools on family poultry production, particularly of broilers. The course contributed to raising awareness of good animal husbandry practices, antimicrobial resistance and best practices to reduce antimicrobial use. Another success story is the pilot course on avian influenza. The course, funded by FAO and developed by the Organization's Emergency Prevention System for Animal Health and VLC, involved over 400 participants from 98 countries around the world, contributing to the sharing of a variety of experiences from the field and from international actors, with the aim of building knowledge and skills on the detection and prevention of, and response to, avian influenza outbreaks.

To learn more about the VLCs, visit our website at https://virtual-learning-center.fao.org or read the VLCs brochure: https://www.fao.org/documents/card/en/c/cc2708en. 360

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Cattle on display at a livestock market in Narok, Kenya.

[1] FAO, Rome, Italy.

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NEWS

Introducing Madhur Dhingra, Head of EMPRES-AH

In June 2020, Dr Madhur Dhingra joined FAO as Head of the Emergency Prevention System for Animal Health (EMPRES-AH). She took her responsibilities amid the COVID-19 pandemic.

Madhur is a national of India. She graduated as a Doctor of Veterinary Medicine in India and holds a PhD in the spatial epidemiology of highly pathogenic avian influenza from the Université Libre de Bruxelles, Belgium, in addition to a Master of Science degree in international animal health from the University of Edinburgh, United Kingdom of Great Britain and Northern Ireland, and a Master of Science in veterinary sciences (virology) from Haryana Agricultural University, India. She started her career in veterinary services in India, working at national and state level, implementing livestock development and disease control programmes. Madhur first joined FAO in 2011 as a national epidemiologist in FAO-India, working on HPAI surveillance and control. Thereafter, she moved to FAO headquarters where she focused on risk assessments for priority zoonoses and the conceptualization and planning of the in-service training programme on applied veterinary epidemiology for 15 countries in Africa. Prior to taking up the post of Head of EMPRES-AH, she worked at the FAO Regional Office for Asia and the Pacific, leading a multistakeholder regional project on reducing the risk of zoonotic disease emergence and transmission along the livestock production and value chains in Southeast Asia.

For the past two years, Madhur has led a number of activities to support and improve the EMPRES-AH programme. Recognizing the value of disease intelligence and early warning, the global animal disease information system EMPRES-i+ was upgraded and launched by the FAO Director-General in October 2021. Risk assessment is a fundamental component of EMPRES-AH, as testified by increasing activities including risk assessments to introductions of lumpy skin disease in Asia, ASF in the Americas and the emergence of SARS-CoV-2 in fur farming animals with evidence-based recommendations to Members. Guidance to countries on COVID-19 risk mitigation and conducting epidemiological investigations in exposed animals has also been published.

> “EMPRES-AH will enhance early warning and biosecurity management across the value chain via unified One Health approaches, building producer and national resilience to food security, livelihoods and global health threats”

To enhance the global and regional coordination for the control of transboundary animal diseases (TADs), the FAO-World Organisation for Animal Health Global Framework for Progressive Control of Transboundary Animal Diseases (GF-TADs) Strategy 2021–25 has been developed, which is supporting Member Nations' priorities, capacities and partnerships for the control of TADs. A partnerships and financing panel to advise on the partnerships and investments needed for the control of TADs has also been established. Looking at the transcontinental spread of HPAI, a consensus on the adding of HPAI as a global priority disease of GF-TADs was reached at the GF-TADs Global Steering Committee meeting in December 2021, for improved global and regional coordination for control.

The progress on the control of foot-and-mouth disease in countries has been enhanced through regional road map meetings, including epidemiology and laboratory networks in Southern Africa, West Africa and the Near East. A Global Coordination Committee for Foot-and-Mouth Disease has been established to reinforce information exchange and coordination for the implementation of the Progressive Control Pathway for Foot-and-Mouth Disease (PCP-FMD) in countries. The Global Initiative for the Control of ASF was launched in 2020. A call for action, with a public-private partnership webinar to promote the engagement of the private sector in ASF control, was organized thereafter.

EMPRES-AH continued to support the Emergency Centre for Transboundary Animal Disease (ECTAD). Following the alarming spread of H5N1 HPAI 2.3.4.4b, shipments of samples to FAO reference centres for confirmatory diagnosis or further sequencing, especially of new introductions to West Africa have been facilitated.

The establishment of Virtual Learning Centers (VLCs) in five additional FAO regions/subregions (in addition to the two already operational in Southern Africa and Asia and the Pacific) has significantly expanded the use of digital communication technologies for cascading capacity development to risk managers in Member Nations. The VLCs have allowed the delivery of trainings even during the constraints of COVID-19, including to countries in remote areas with limited internet connection.

Going forward, EMPRES-AH will enhance early warning through integrated One Health approaches, building producer and national resilience through progressive management of biosecurity at all levels of the value chain pursuing multistakeholder partnerships for the control of high-impact transboundary and emerging diseases. 360

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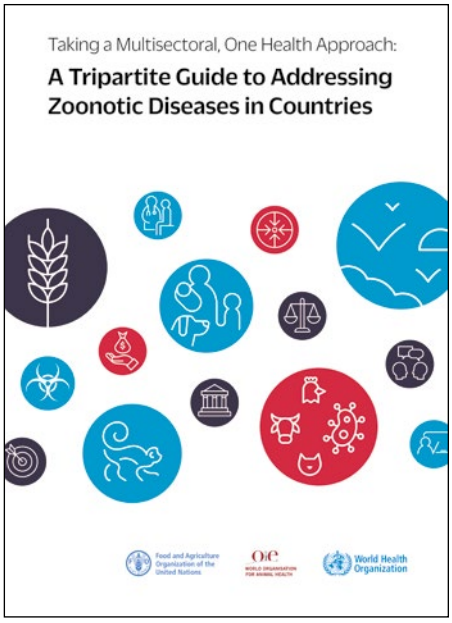
FAO. 2021. *Recommendations for the epidemiological investigation of SARS-CoV-2 in exposed animals: SARS-CoV-2 detection in farmed and companion animals*. Animal Health Risk Analysis, Management No. 2. Rome. https://doi.org/10.4060/cb7140en

FAO. 2022. Virtual Learning Center. In: *FAO.org*. Rome. Cited 1 August 2022. https://virtual-learning-center.fao.org

NEWS

Publications

In addition to the publications introduced in the articles of this edition of empres360, a number of publications were recently published on transboundary animal and zoonotic diseases, One Health and other EMPRES-related topics.

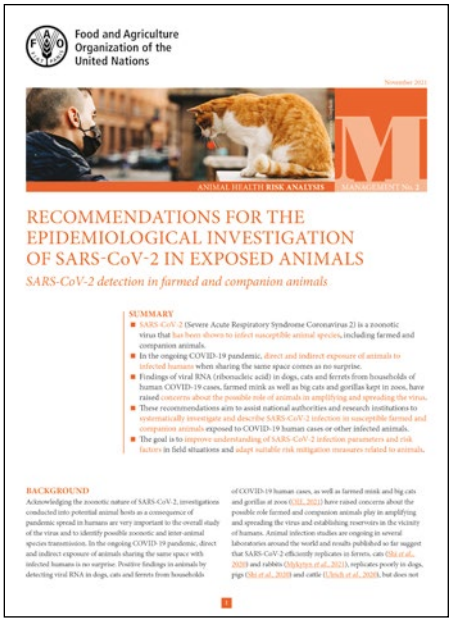


Taking a multisectoral, One Health approach: a tripartite guide to addressing zoonotic diseases in countries (TZG) was published jointly by FAO, the World Organisation for Animal Health (WOAH) and the World Health Organization (WHO) in 2019. The TZG provides lessons learned and good practices identified from country-level experiences in taking One Health approaches for preparedness for, detection and prevention of, and response to zoonotic disease threats. It provides guidance on multisectoral communication, coordination and collaboration to minimize their impacts on health, livelihoods and economies. The TZG also presents information on regional and country-level One Health activities and relevant unisectoral and multisectoral tools available for countries to use, and additionally supports country efforts to implement the WHO International Health Regulations (2005) and WOAH international standards, to address gaps identified through external and internal health system evaluations, and to achieve the targets of the Sustainable Development Goals.

FAO, WOAH & WHO. 2019. *Taking a multisectoral, One Health approach: a tripartite guide to addressing zoonotic diseases in countries.* Rome. www.fao.org/documents/card/en/c/CA2942EN. Available in: Arabic, Chinese, English, French, Russian and Spanish.

The Joint Risk Assessment Operational Tool (JRA OT) is part of the TZG and provides decision-makers with scientifically sound advice that can be used to inform risk management and communication policies for an effective response to a zoonotic disease threat. It supports international regulations, such as the International Health Regulations and the WOAH standards, by providing a mechanism to effectively address management decisions and communications. The JRA OT provides guidance on how to set up a joint qualitative risk assessment and describes step-by-step how to conduct each component of the process, with model documents and templates to support implementation in the annexes.

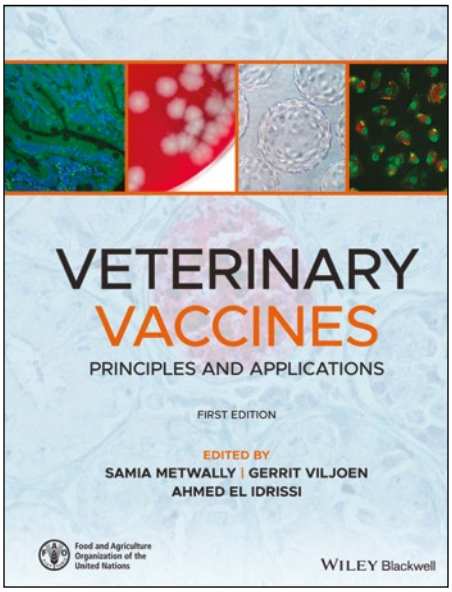
FAO, WOAH & WHO. 2020. *Joint Risk Assessment Operational Tool (JRA OT): an operational tool of the tripartite zoonoses guide.* Geneva, Switzerland. www.fao.org/documents/card/en/c/cb1520en/. Available in: Arabic, Chinese, English, French, Russian and Spanish.



COVID-19 and animals: information on risk mitigation measures for livestock and agricultural professionals and ***Recommendations for the epidemiological investigation of SARS-CoV-2 in exposed animals*** were also published. The former provides practical guidance on how to prevent occupational health problems, and the latter addresses investigations about potential animal hosts, which are of great importance to improve understanding of COVID-19 epidemiology and identify susceptible animal species, as well as possible transmission between humans and animals.

FAO. 2021. *COVID-19 and animals: information on risk mitigation measures for livestock and agricultural professionals.* Rome. https://doi.org/10.4060/cb2549en

FAO. 2021. *Recommendations for the epidemiological investigation of SARS-CoV-2 in exposed animals: SARS-CoV-2 detection in farmed and companion animals.* Animal Health Risk Analysis, Management No. 2. Rome. https://doi.org/10.4060/cb7140en



Veterinary vaccines: principles and applications was published with contributions from leading experts worldwide. The book includes the current state of vaccines and vaccination against selected transboundary animal diseases, advice and recommendations for vaccine production, quality control and effective vaccination schemes including vaccine selection, specifications, vaccination programmes, vaccine handling in the field, application, failures and assessment of herd protection. It also discusses the latest in vaccinology and vaccine immune response to animal disease pathogens of major economic impact to livestock, as well as possible future developments.

Samia Metwally, Gerrit Viljoen & Ahmed El Idrissi. 2021. *Veterinary vaccines: principles and applications.* Rome, FAO, and Hoboken, United States of America, Wiley-Blackwell. www.fao.org/3/cc2031en/cc2031en.pdf

The Multisectoral Coordination Mechanism Operational Tool (MCM OT) provides a standard stepwise approach for countries to establish or strengthen a mechanism for multisectoral, One Health coordination to manage zoonotic diseases for better health outcomes with references to principles and best practices described in the TZG. The MCM OT allows countries to coordinate in addressing zoonotic diseases and other shared health concerns at the human-animal-environment interface.

WHO, FAO & WOAH. 2022. *Multisectoral Coordination Mechanisms Operational Tool: an operational tool of the Tripartite Zoonoses Guide.* Geneva. www.fao.org/3/cc0483en/cc0483en.pdf

The Surveillance and Information Sharing Operational tool (SIS OT) supports national authorities to establish or strengthen their coordinated, multisectoral surveillance and information sharing for zoonotic diseases. Based on the principles presented in the TZG, the SIS OT is intended for use by a working group or in a workshop setting, in particular on "Surveillance for zoonotic diseases and information sharing" with its Excel-based tool (SIS OT workbook).

WHO, FAO & WOAH. 2022. *An operational tool of the Tripartite Zoonoses Guide, Taking a Multisectoral, One Health Approach: Tripartite Guide to Addressing Zoonotic Diseases in Countries.* Geneva, Rome and Paris. www.fao.org/documents/card/en/c/cc0716en

Obituary

Several colleagues who contributed to EMPRES have sadly left us forever in the past four years. Dr Abdelali Benkirane, Animal Health Officer (EMPRES), 1993–2000 – 13 November 2018. Dr Jacques Diouf, FAO Director-General who created EMPRES as a Special Programme in 1994 – 7 August 2019. Dr William A. Gealing (EMPRES consultant) – 12 February 2018. Dr Tim U. Obi (EMPRES consultant) – 17 June 2022. Dr Patrick Otto, Veterinary Public Health Officer in headquarters and then Regional Livestock Officer in the Subregional Office for Southern Africa (Head, Livestock Development) – 19 February 2018. May the departed souls rest in peace.

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The Emergency Prevention System (EMPRES) is an FAO programme, founded in 1994, with the goal of enhancing world food security, fighting transboundary animal and plant pests and diseases and reducing the adverse impact of food safety threats. EMPRES-Animal Health is the component dealing with the prevention and control of transboundary animal diseases (TADs).

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